Impact of physical load on cardiovascular marker´s in outdoor sports: a review

Martin Nosek[1], Štefan Balkó[1], Jan Adamec[1], Dagmar Partlová[2] , Radek Zákon[1], Lukáš Šauer[1], Vanda Hrbková[1]

[1] ***Department of Physical Education and Sport, Jan Evangelista Purkyně University in Ústí nad Labem***

[2] ***Department of Clinical Biochemistry, Masaryk Hospital in Ústí nad Labem***

Abstract

The article is focused on effect of physical load on athletes' health in outdoor sports. The focus of this review is on effect of long-term physical load on heart function. The thought originates from the fact of ambiguous impact of long-term physical load on heart function and inflammatory biomarkers, such as troponin T (cTnT), troponin I (cTnI), creatine kinase (CK) and C-reactive protein. These types of biomarkers are presented in scientific literature as an index of myocardial necrosis. Myocardial necrosis can progress into heart attack. The aim of this review is to describe these issues and find out as many resources as possible with this topic. Through our research, we work with PubMed and Research gate databases. As we found out from scientific literature, there are some certain changes after long-term intensive physical load. The changes are proven on increased of cardiovascular markers in blood. In fact, the level of cardiovascular markers decline after 24-48 hours and the structures of blood are in normal again. In addition, literature say, that appropriately chosen range and intensity of physical load of outdoor sports belong into the most important elements for prevention of getting heart diseases.

Key words:

Sport, physical load, cardiac markers, troponin

Souhrn

Příspěvek se věnuje vlivu zátěže na zdraví sportovců v outdoorových sportech. Zejména se zaměřuje na vliv dlouhotrvající zátěže na činnost srdce. Zamyšlení vychází z faktu ne zcela jednoznačně dokázaného vlivu dlouhotrvající zátěže na srdeční činnost a zánětové biomarkery jako jsou troponin T (cTnT), troponin I (cTnI), kreatinkináza(CK) a kreativní protein (CRP). Tyto biomarkery jsou v odborné literatuře často popisovány jako ukazatele myokardiální nekrózy, která může přerůst v infarkt myokardu. Cílem příspěvku je popsání této problematiky a zmapování dostupných informací o této problematice. K získání informací bylo využito databází PubMed a Research gate. Z rešerše literatury vyplývá, že dlouhodobá intenzivní zátěž zvyšuje podíl srdečních markerů v krvi, ale po 24-48 hodinách se z pravidla tento zvýšený podíl vrací do normálního stavu. Současně literatura konstatuje, že vhodně zvolený výběr a intenzita zatížení outdoorové pohybové aktivity patří mezi nejdůležitějšími faktory pro prevenci vzniku srdečních onemocnění.

Klíčová slova:

Sport, zátěž, srdeční biomarkery, troponin

Introduction

In past few years, there is visible worldwide expansion of outdoor sports such as running, cycling, cross-country skiing, triathlon and more outdoor endurance activities. More and more people are active in these activities as recreational users, but no days, more adults tend to participate in all kinds of outdoor events. As an example, there is more than famous marathon in New York or Boston with up to 50 000 runners (NYCM, 2017). Other running races like 10K run, half marathon or marathon across the whole Czech Republic with more than 100 000 runners (Runczech, 2017; Runtour, 2017). More popular are becoming races on 50K, where

there is more than 30 of them in the Czech Republic with more than 5 000 participants (Behej, 2017). The same popularity is on the races such as cross-country skiing or long-distance triathlons (Bezkuj, 2017; Traitlony, 2017; Skitour, 2017).

This is truly positive news, that people are engaging more in sports activities. From kinatropology or medicine point of view we can state, that physical movement improves many functions and parameters of the human body. For example, increases performance of cardiovascular system, reduces blood pressure, but also helps with too low blood pressure, maintains body weight, increases the amount of active muscle mass, supports and improves the immune system, improves metabolism and breathing functions. At the same time, physical movement is one of the most effective medium for health preventing, the most for cardiovascular diseases. On the other hand, the lack of physical activity can cause many diseases or illnesses, for example of skeletal muscle equipment (Blahutková, Řehulka & Daňhelová, 2005; Sigmund & Sigmundová, 2011).

Questionable and ironical is that there are many cases, where the influence of inaccurate excessive physical load harmed the musculoskeletal system (scoliosis, harm on joint and muscular systems, etc.) or caused illnesses of cardiovascular system (arrhythmia, heart failure, etc.) (Máček & Radvanský, 2011). It is proven, that long-term endurance event such as marathon, ultra marathon, cycle marathon, long-distance cross-country skiing and others is not possible to complete without long-term and systematic work (Engliš, 2012; Mingles, Jacobs & Michielsen, 2009). If the athlete does not spend enough time practicing, the possibility of having issues with cardiovascular system is huge. According to new researches (Middleton, Shave, & George, 2006; Neilan, Januzzi, Lee-Lewandrowski, et al. 2006, La Gerche, Connelly, Mooney, MacIsaac, & Prior, 2008; Mousavi, Czarnecki, Kumar et al. , 2009), there is a significant increase of cardio nonspecific cardiac enzymes called creatine kinase. Some athletes experience also an increased of concentrated cardio specific cardiac troponins (cTn, cTnI, cTnT), which are considered as indexes of problematic heart function - heart attack, inflammation of the heart muscle or heart failure. According to certain researches (for example Middleton, George, Whyte, Gaze, Collinson & Shave, 2008), this phenomenon is happening at the competitors up to 100 % during 60 minutes physical load.

Troponins are proteins of tropomyosin complex of myocytes in skeletal muscles, which are involved in muscle contractility. Troponin C binds calcium ions, troponin I binds actin to restrain interaction between actin and myosin and the third type of troponin, troponin T supports muscle contraction with binding to myosin. All types of troponin are bonded in myofibrils. There are 3-8 % of troponins loosely in cytosol. In cardiology, cardiac isoenzymes (cTn) are used. In case, the cardiac muscle is damaged, troponin I (cTnI) and troponin T (cTnT) are released only from myocardium to blood and both of them provide stratification of another risk of cardiovascular issues. Troponins are visible in blood quickly after the certain damage and stays for few days (Morrow, Cannon, Jesse et al., 2007; Janota, 2011).

The causes of changes of concentration of troponins while exercising are not fully clear. According to certain researches, the cause of changes is consequence of boosted physiological regeneration of cardiomyocytes (Middleton, George, Whyte, Gaze, Collinson & Shave, 2008; Giannoni, Giovannini, & Clerico,2009). The second option of increased concentration of troponins might be reversibility of damaged cardiomyocytes of the cardiac wall (Rafai, Douglas, O'Toole, et al. ,1999). The third cause of increased concentration of troponins while exercising is considered an adaptation response to physical load. It causes an increased concentration of catecholamines, which goes over the capacity of physiological homeostasis (Dünser, Walter, & Hasibeder, 2009). Other studies consider as a cause, an increased pressure and volume of cardiomyocytes, which are connected with myocardial overload Hessel, Atsma, van der Valk, Bax, Schalij & van der Laarse, 2008). The last theory about increased concentration of troponins while exercising is that the increased is caused by ischemia of cardiomyocytes while the body is in extreme muscle anaerobic load (Chaitman, 2011; Middleton, George, Whyte, Gaze, Collinson & Shave, 2008).

There are new findings about cardiac biomarkers thanks to a development of new methods, that increase of troponins (cTn, cTnI, cTnT) already start while exercising, however the most visible changes are happening within 3 hours after race. The increase amount of cardio specific cardiac troponins is getting back in normal level after 24 hours after physical load, exceptionally, the increased level might last longer 48-72 hours after physical load (Lippi, Schena, Dipalo, Montagnana, Salvagno, Aloe & Guidi,2012; Middleton, Shave, & George, 2006; Scherr, Braun, Schuster, Hartmann, Moehlenkamp, Wolfarth, Pressler, & Halle, 2011).

It is important to run many researches on this topic, because our bodies are constantly changing and each outdoor sport has different effect on our body system. Therefore, we are trying to display as many cases as possible about outdoor sports and their influence on cardiac system.

METHODS

To reveal the results, there were used two types of theoretical methods - descriptive and comparative. These methods helped us to work with data from PubMed and Researchgate databases. The data, we worked with, were collected from last 7 years (2010-2017) and were focused on effect of long-term physical load on cardiac markers in outdoor sports. To make this review affected we chose these types of criteria: type of biomarkers, study population, type of load, distance of duration, sampling and outcome. Based on these criteria, there is a discussion about suitability and use of outdoor sports for prevention of getting heart diseases.

RESULTS AND DISCUSSION

In the following part, there are demonstrated available studies about the effect of high intensity physical load on health condition of athletes in outdoor sports.

Table 1. Summary of researches focused on impact of outdoor sports on cardio markers

Biomarker	Study population	Type of load	Distance of duration	Sampling	Outcome	Reference
CK, CRP	20 M (10 M with load – induced hypertension, 10 M normal)	Running	Ultra marathon 100km	Baseline, post load	CRP and CK more significantly increased in the hypertensive group than normal	16
cTnI	17 M	Running	Half marathon	After the run, 3,6 and 24 hour	cTnI were significantly increased in athletes (100%)	23
CK, cTnT	20 M	Running	Ultra marathon 24 hour	1day before, immediately after race	CK increased post-race, 2 runners showed increased cTnT(10%)	34
CRP, cTnT	7 M (amateur runners)	Running	48 hour ultra marathon	48,24,12 before, after race and 12,24,48 h of running	CRP, cTn showed increase after race(86%), Most of the changes dissolved during the 48 h post –race recovery	15
CK,cTnT	15 M (7 elite,8 non elite)	Triathlon	Ironman	Before, immediately, 2 hours and 7 days after finish	cTnT was significantly increased in the elite group after race (100%), not in non elite group, 7 days after recovery in both groups was normal CK	11
cTnT	1 elite African male	Running	Half marathon	Immediately, 3 hour after race, 3 days	cTnT was significantly increased after race (100%)	2

cTnI,	32 M (18 elite 14 amateur)	Rowing	30 min maximal rowing test	Before, after 5min, 1,3,6,12,24 h after test	Peak cTnI exceeded in 9 elite(50%), 3 amateur rowers	22
cTnT	31 M	Running	Ultra marathon 330 km	Before, halfway, immediately the race, 3 days after arrival	Increased significantly to halfway (75%), not permanent structural damage at the myocardium level	19
cTnT	15 M (amateur)	Triathlon	60 min maximal test in swimming, cycling, running,	Before, immediately after 5 min and 1,3,6,12 and24 hour	Increased of cTnT after physical load in all cases (100%), normal values after 24 hours in all cases	21
CK, cTnI	40 M (amateur)	Running	Marathon	Before, immediately after race	Increased of CK and cTnI after a race without a harm on heart of all competitors (100%)	44
cTnT, CK	13 M	Running	Test: long duration running 60 min and two series of 12x30 sec sprints	1, 4 hour after test	Significant increased of cTnT after sprints than after physical load with mild intensity (80%). Significant increased of CK regardless on exercise protocol	43
CK,cTnT	36 M, 29 F (elite athletes)	Dragon Boating	Test 30 min	Pre-training, 1 hour post-training	No increased of cTnT (0%), CK increase is more significant at males than females	3
CK, cTnT	14 M	Road Cycling	Race 177km	Before, immediately, 3 hour after race	Increased values for all competitors (100%). Later, all values reinstated	20
CRP,CK,	18 M (nonprofessional)	Running	Ultra marathon 2 days 130 km	Before, immediately - after first and second days, after1,3,5 days race	No changes after first and second day. After first race day, increased of values (100%), after that reinstated	1
cTnI,	26 M	Running	Ultra marathon 100 km	1 week before race, immediately and 1 day after finish	Increased values of cTn at 19 runners (73%), after 24 hours 8 runners still with increased values	25
cTnT	17 M	Running	Run 5 km	1 day before the race, 1 hour before race, immediately after race, 1,3,5 hour after race	Increased values of cTnT - 12 from 17 competitors (70%)	14

Explanation: M : Male, F: Female, CK: Creatine kinase; CRP: C –reactive protein; TnI – troponin, cTn – high sensitive cardiac troponin

The results presented above (Table no. 1) illustrate, that higher values of cardiac markers were appeared almost in every research focused on issues of physical load in outdoor sports.

Only in two investigations there was no increase in troponin in the blood of athletes. First was the case of German national team when dragon boating before World Cup (Bauer, Zießler, Walscheid, Mooren, & Hillebrecht, 2016). The second is the research of elite rowers (Legaz-Arrese, López-Laval, George, Puente-Lanzarote, Moliner-Urdiales, Ayala-Tajuelo, Mayolas-Pi, & Reverter-Masia (2015). Possibly, the physical load while paddling is not long enough for the release of substance. It is proven in other researches which address, if the physical load is shorter than 60 minutes, the cumulating is less possible (Middleton, George, Whyte, Gaze, Collinson & Shave, 2008). This statement is excluded by Keselman, Vergara, Nyberg, and Nystrom, (2017) who found out that short-distance running races completed with maximum effort, might cause metabolic stress and release of troponin T. The results display 75% increase of troponin at short-distance cross country runners (Keselman, Vergara, Nyberg, & Nystrom, 2017; Weippert, Divchev, Schmidt, Gettel, Neugebauer, Behrens, et al.(2016). Whereas, the half marathon runners prove 100% increase of troponin (Barakat, Pezzilli, & Prestinenza, 2014; Lippi, Schena, Dipalo, Montagnana, Salvagno, Aloe, & Guidi, 2012). This is proven by other researches by Lippi, Cervellin, Banfi and Plebani (2011) or Young-Joo, Jae Ki, Kyung-A., Chul-Hyun, Yoon-Hee and Kyoung-Min (2015), who claim, that up to 94% of athletes, who completed marathon, had increased level of troponin in their blood. The interesting fact is, that ultra marathon runners do not prove that significant increase of troponin in blood, it was found out at 68% of runners (Arakawa, et al.(2016); Klapczinska, Waskiewicz, Chrapusta, Sadowska-Krepa, Czuba, & Langfort, 2013; Le Goff, Kaux, Gergele, Millet, Viallon, Croisille, & Cavalier,2015; Li, How, Kao, Chiu, Meng, Hsu, & Tsay, 2017; Kim et al., 2012; Passaglia et al., 2013).

There are other analyses of outdoor sports, such as triathlon or road cycling, about their effect on cardio markers. The conclusions of these analyses are similar to results of long-distance runs. Athletes‘ biomarkers increased the amount to 100% at long-term high intensity physical load (Chan-Ho, Kwi-Baek, Jin, Jin-Goo, & Yi-Sub, 2014; Legaz-Arrese, López-Laval, George, Puente-Lanzarote, & Castellar-Oti´n, 2015, Le Goff, Kaux, D´Otreppe, Goffaux, Chapelle, & Cavalier, 2016).

The research literature explain, that long-term high intensity physical load increase the amount of cardiac markers in blood. However, all cases prove that increased amount of cardiac markers decline after 24-48 hours, which it is also presented by Le Goff, Laurent, Kaux and Chapelle (2011).

Conclusion

In conclusion, the research proves that intensity and duration of physical load significantly correlates with occurrence of cardiac markers in blood. That means, the shorter duration of physical load and higher intensity of physical activity, the higher probability of increased concentration of biomarkers. Another fact is that long-term high intensity physical load influences an amount of cardiac markers in blood (increase of cardio markers). However, after 24-48 hours, the increased level of cardiac markers decline and go into a normal level. Even though, the researches proves that high intensity physical exercise has an influence on heart function and higher concentration cardiac markers, the regular outdoor sports with right intensity and purpose have preventive effects on cardiovascular diseases and healthy life style.

Acknowledgements

This research was realized with the support of the Structural university research grant (SGS 2017) in the J. E. Purkyne University in Usti nad Labem.

References

1. Arakawa, K., Hosono, A., Shibata, R.G.……& Tokudome, S. (2016). Changes in blood biochemical markers before, during, and after a 2-day ultramarathon. *Open Asses Jour. of Sport Med., 2016*(7), 1-7.
2. Barakat, B., Pezzilli, R., & Prestinenza, P. (2014). Elevated serum high-sensitive cardiac troponin T in adolescent runner: exercise or something else? *Emergency Care Journal, 10*(1744), 1-7.
3. Bauer, P., Zießler, S., Walscheid, R., Mooren, F.C., & Hillebrecht, A. (2016). Changes of biomarkers af

ter high-intensity exercise in male and female elite athletes of dragon boating. *Journal of sport Science, 4*(2016), 1-8.
4. Behej (2017). *Závody.* Retrieved from: https://www.behej.com/rubrika/zavody
5. Bezkuj (2017). *Informace.* Retrived from: https://www.bezkuj.com/clanky
6. Blahutková, M., Řehulka, E.,& Daňhelová, Š.(2005). *Pohyb a duševní zdraví.* Brno: Paido, 2005.
7. Dünser, M.W., Walter, R., & Hasibeder, M.D. (2009). Sympathetic Overstimulation During Critical Illness: Adverse Effects of Adrenergic Stress. *Journal of Intensive Care Medicine, 24*(5), 293-316.
8. Engliš, M. (2012). Srdeční troponiny a maraton. *Labor. Aktuell.,12*(2),28-30.
9. Giannoni, A., Giovannini, S., & Clerico, A. (2009). Measurement of circulating concentrations of cardiac troponin I and T in healthy subjects: a tool for monitoring myocardial tissue renewal?. *Clinical Chemistry and Laboratory Medicine, 47*(10), 1167-1177.
10. Hessel, M.H.M., Atsma, D.E., van der Valk, E.J.M., Bax, W. H., Schalij. M.D., van der Laarse, A.(2008). Release of cardiac troponin I from viable cardiomyocytes is mediated by integrin stimulation. *Pflugers Arch - Eur J Physiol, 455*(16), 979–986.
11. Chaitman, B.R. (2011). Exercise stress testing. In: Bonow R.O., Mann, D.L., Zipes, D.P.,Libby, P., eds. *Braunwald's Heart Disease: A Textbook of Cardiovascular Medicine*. 9th ed. Philadelphia, PA: Saunders Elsevier; 2011, 168–199.
12. Chan-Ho,P., Kwi-Baek, K., Jin, H., Jin-Goo, J., & Yi-Sub, K.(2014). Cardiac damage biomarkers following a triathlon in elite and non-elite triathletes. *Korean J Physiol Pharmacol, 18*(5)419-423.
13. Janota, T. (2011). *Vyšetřování srdečních troponinů a univerzální definice akutního infarktu myokardu.* Retrieved from: https://www.tribune.cz/clanek/23137-vysetrovani-srdecnich-troponinu-a-univerzalni-defi-nice-akutniho-infarktu-myokardu
14. Keselman, B., Vergara, M, Nyberg, S., & Nystrom, F.H.(2017). A randomized cross-over study of acute effects of running 5 km on glucose, insuline, metabolic rate, cortisol and troponin *T. PLoS ONE, 12*(6), 1-14.
15. Klapczinska, B., Waskiewicz, Z., Chrapusta, S., Sadowska-Krepa, E., Czuba, M., & Langfort, J.(2013). Metabolic responses to a 48-h ultra-marathon run in middle-aged male amateur runners. *Eur J Appl Physiol, 2013*(113), 2781-2793.
16. Kim, Y.J., Kim, C.H., Shin, K.A., Kim, A.C., Lee, Y.H., Goh, C.W., & Park, Y. (2012). Cardiac markers of EIH athletes in ultramarathon. *Int J Sport Med, 2012*(33), 171-176.
17. La Gerche, A., Connelly, K.A., Mooney, D.J., MacIsaac, A.I., & Prior, D.L.(2008). Biochemical and functional abnormalities of left and right ventricular function after ultraendurance exercise. *Hearth, 94*(7), 860-866.
18. Le Goff, C. Laurent, T., Kaux, J.F., & Chapelle, J.P.(2012). Intense physical exercise related to zhe emergent generation of cardiovascular markers: a review. *Biology of sport, 29*(1), 11-16.
19. Le Goff, C., Kaux, J.F., Gergele, L., Millet, G., Viallon, M., Croisille, P., & Cavalier, E. (2015). Imact of an ultra-trail of 330 km on plasma levels of cardiac biomarkers. *Eur. Jour. of Sports Med., 3*(1), 77.
20. Le Goff, C., Kaux, J.F., D´Otreppe, S., Goffaux, M.F., Chapelle, J.P., & Cavalier, E.(2016). Relase of cardiac biomarkers during a cycling race. *World of Journal Cardiovascular Diseases, 2016*(6),285-294.
21. Legaz-Arrese, A., López-Laval, I., George, K., Puente-Lanzarote, J.J, & Castellar-Oti´n, C.(2015). Individual variability of high-sensitivity cardiac troponin levels after aerobic exercise is not mediated by exercise mode. *Biomarkers, 20*(4), 219-224.
22. Legaz-Arrese, A., López-Laval, I., George, K., Puente-Lanzarote, J.J, Moliner-Urdiales, D., Ayala-Tajuelo, V.J., Mayolas-Pi, C., & Reverter-Masia, J. (2015). Individual variability in cardiac biomarker release after 30 min high-intensity rowing in elite and amateur athletes. *Appl. Physiol.Nutr.Metab., 40*(2015),951-958.
23. Lippi, G., Schena, F., Dipalo, M., Montagnana, M., Salvagno, G.L., Aloe, R., & Guidi, G.C. (2012). Troponin I measured with a hight sensitivity immunoassay is signifi cantly increased after a hlaf marathon run. *Scand. J.of Clinicale&Laborat. Invest., 72*(2012),467-470.
24. Lippi, G., Cervellin, G., Banfi, G., & Plebani, M. (2011). Cardiac troponins and physical exercise. It´s time to make a point. *Biochemia Medica, 21*(1), 55-62.
25. Li, L.H., How, C.K., Kao, W.F., Chiu, Y.H., Meng, C., Hsu, C.C.,& Tsay, Y.G.(2017). The impact of hep

atities B carrier on cardiac troponin I in 100-km ultramarathon runners. *J.Chin Medd Assoc., 80*(6), 347-352.
26. Máček, M., & Radvanský, J. (2011). F*yziologie a klinické aspekty pohybové aktivity.* Praha: Galén.
27. Middleton, N., Shave, R., & George, K. (2006). Left ventricular function immediately following prolonged exercise: A meta-analysis. *Med Sci Sports Exerc,38*(2006), 681–687.
28. Middleton, N., George, K., Whyte, G., Gaze, D., Collinson, P., & Shave, R. (2008). Cardiac troponin T release is stimulated by endurance exercite in healthy humans. *Journal Am Coll Cardiol, 52*(2008), 1813-1814.
29. Mingles, A., Jacobs, L., & Michielsen, E.(2009). Reference population and marathon runner sera assessed by highly sensitive cardiac troponin T and commercial cardiac troponin T and I assays. *Clin. Chem., 55*(1),101-108.
30. Morrow, D. A., Cannon, C. P., Jesse, R. L., Newby, L. K., Ravkilde, J., Storrow, A. B.:NYCM (2017). *New York city marathon.* Retrived from: https://www.tcsnycmarathon.org/about-the-race
31. Mousavi,N., Czarnecki, A., Kumar, K. et al. (2009). Relation of biomarkers and cardiac magnetic resonance imaging after marathon running. *Am J Cardiol, 103*(2009), 1467–1472.
32. Neilan, T.G., Januzzi, J.L., Lee-Lewandrowski, E. et al. (2006). Myocardial injury and ventricular dysfunction related to training levels among nonelite participants in the Boston marathon. *Circulation, 114*(22),2325-33.
33. Passaglia, D.G., Emed, L.G.M, ….& Faria-Neto, J.R.(2013). Acute effects of prolonged physical exercise : evaluation after a 24-hour ultramarathon. *Arg Bras Cardiol, 100*(1),21-28.
34. Rafai, N., Douglas, P.S., O'Toole, M. et al. (1999). Cardiac troponin T and I, echocardiographic [correction of electrocardiographic] wall motion analyses, and ejection fractions in athletes participating in the Hawaii Ironman Triathlon. *Am J Cardiol, 83*(1999), 1085–1089.
35. Runczech (2017). O nás. Retrieved from: https://www.runczech.com/cs/
36. Runtour (2017). Run tour. Retrieved from: http://www.run-tour.cz/cs/runtour
37. Sigmud, E., & Sigmundová, D. (2011). *Pohybová aktivita pro podporu zdraví dětí a mládeže.* Olomouc: UP.
38. Scherr, J., Braun, S., Schuster, T., Hartmann, C., Moehlenkamp, S., Wolfarth, B., Pressler, A.,& Halle, M. (2011). 72-h kinetics of high-sensitive troponin T and inflammatory markers after marathon. *Med Sci Sports Exerc, 43*(2011), 1819–1827.
39. Skitour (2017). *Výsledky.* Retrieved from: http://www.ski-tour.cz/cs/vysledky/velka-tour
40. Triatlony (2017). *Výsledky.* Retrieved from: https://www.triatlony.com/terminovka/výsledky
41. Tang, W. (2007). National Academy of Clinical Biochemistry and IFCC Committee for Standardization of Markers of Cardiac Damage Laboratory Medicine Practice Guidelines: analytical issues for biochemical markers of acute coronary syndromes. *Clinical Chemistry, 53*(4), 547-551.
42. Weippert, M., Divchev, D., Schmidt, P., Gettel, H., Neugebauer, A., Behrens, K. et al.(2016). Cardiac troponin T and echocardiographic dimensions after repeated sprint vs moderate intensity continuous exercise in healthy young males. *Scientific rep., 6*(246), 1-7.
43. Young-Joo, K., Jae Ki, A., Kyung-A., S., Chul-Hyun, K., Yoon-Hee, L., & Kyoung-Min, P.(2015). Correlation of cardiac markers and biomarkers with blood pressure of middle-aged marathon runners. *J.Clin. Hypertens, 17*(11), 868-873.

Author: Mgr. Martin Nosek, Ph.D.
E-mail: martin.nosek@ujep.cz