Uździcki Artur, Małas Malwina, Przybylski Tomasz, Turoń Skrzypińska Agnieszka, Szylińska Aleksandra, Ciosek Żaneta, Ptak Magdalena, Dutkiewicz Grażyna, Rotter Iwona. Selected metabolic changes after extreme endurance physical exercise by the example of marathon and ultra - marathon runners. Journal of Education, Health and Sport. 2018;8(9):662-672 eISNN 2391-8306. DOI
http://dx.doi.org/10.5281/zenodo.1412496
http://ojs.ukw.edu.pl/index.php/johs/article/view/5944

The journal has had 7 points in Ministry of Science and Higher Education parametric evaluation. Part b item 1223 (26/01/2017).
1223 Journal of Education, Health and Sport eissn 2391-8306 7

The authors declare that there is no conflict of interests regarding the publication of this paper.

Received: 02.08.2018. Revised: 18.08.2018. Accepted: 10.09.2018.

Selected metabolic changes after extreme endurance physical exercise by the example of marathon and ultra - marathon runners

Artur Uździcki[1,2], Malwina Małas[1,3], Tomasz Przybylski[1,4], Agnieszka Turoń-Skrzypińska[5], Aleksandra Szylińska[5], Żaneta Ciosek[5], Magdalena Ptak[5], Grażyna Dutkiewicz[6], Iwona Rotter[5]

[1]Student Scientific Society KINEZIS of the Medical Rehabilitation and Clinical Physiotherapy Department of the Pomeranian Medical University

[2]Student Scientific Society of Pharmacogenomics of Physiology Department of Pomeranian Medical University

[3]Student Scientific Society at the Department of Diagnostic Imaging and Interventional Radiology, Pomeranian Medical University

[4]Student, Faculty of Medicine, Pomeranian Medical University

[5]Department of Medical Rehabilitation and Clinical Physiotherapy, Pomeranian Medical University

[6]Department of Nephrology, Transplantology and Internal Medicine, Pomeranian Medical University

Address for correspondence:

mgr Agnieszka Turoń-Skrzypińska, Medical Rehabilitation and Clinical Physiotherapy Department, Pomeranian Medical University, agi.skrzypinska@gmail.com

Abstract

A popularity of marathons and ultramarathons is growing every year. Attending a marathon can cause a variety of biochemical changes. It is crucial to determine which changes in blood tests are of clinical significance, and what recommendations should be given to the patient. Here the most frequent changes are presented, as described in literature.

Keywords: Marathon, Ultramarathon, Troponin, Blood count, Hyponatremia, Endurance, ALT, AST, Creatinine, Serum

Introduction

Nowadays, sport has become very popular. Regular physical effort has been shown to be effective in prevention of obesity, cardiac and lung diseases, diabetes, osteoporosis, cancer and aging [1].

Not only recreational running, but also longer distance runs, such as marathons and ultra-marathons, which require specific training, are gaining more and more interest. Their purpose is to run a distance from 42,195 km in case of marathon, or more (also competitions lasting 6 hours in duration or longer) in ultra-marathons.

According to statistics an average male finisher, is 29 minute faster than average female finisher, and older - mean age is 40 years for man and 36 years for women [2].

An analysis of male and female ultramarathoners found that the fastest running times were achieved at higher age than marathon runners, so ultramarathon seems to be the domain of master athletes [3].

There seems to be a difference in the age and results, between women and men depending upon the length of the run. In the majority in ultra-marathons, women seemed to achieve the best race time later in life compared to men [4]. Ultra-marathoners have a larger weekly training volume, but run slowly during training compared to marathoners [4].

All over [5] the world there are more than 4 thousand different long-races planned for 2018, and according to www.maratonypolskie.pl [6], there are 3111 running events planned, including 134 marathons, and more than 50 ultra-marathons.

In United States and Canada there were more than 518 thousand people who finished marathons in 2017 [7], whereas in Poland, over 37 thousand competitors participated in the largest marathons- 16% of runners were women and 84% were men [8].

In 2017 in United States more than 99 thousand ultrarunners finished their races, 65% of who were male runners, 35% were females [9].

Many physiological variables have been identified as important predictors of distance running performance, such as maximum aerobic capacity, "anaerobic" threshold, blood lactate turn point, body composition, skeletal muscle fiber composition and mitochondrial oxidative capacity [10].

Before attending an endurance run proper training is required. Effective preparation increases the maximum amount of oxygen delivered during exercise, increases VO2max (maximal oxygen consumption) by 10-15%. The level of the anaerobic transformation threshold also is increased. The circuit training causes changes in the functioning of the myocardium. Adaptation causes a reduction in the heart rate during submaximal intensity efforts. During exercises, the maximum ejection volume of the heart increases. There is also an escalation of capillarization of muscles and density of mitochondrions and the elevation of oxidizing enzymes activity [11]. During prolonged exercises many runners experience a “hitting the wall” feeling because of glycogen decrease [12]. On the other hand, an marathon and ultra-marathon, as an extreme duration exercise, leads to an energy deficit, reduction of body fat and skeletal muscle mass [4].

These changes affect both younger and older runners alike, regardless of their running experience and preparation [4].

The aim of the present article is to describe how runner’s body reacts to such a big effort as marathon and ultra-marathon is, on the example of blood, sodium, renal, liver and troponin changes.

Changes in blood count

No considerable differences for the number of red blood cells and haemoglobin concentration (small increases during the run were observed), hematocrit (small decreases) [13] or blood platelets (mean platelet count showed a significant but moderate increase [14]) during the run and/or recovery in the marathon and ultra-marathon runners were found. Despite this changes all values of these indicators persisted within physiological norms.

However, in these runners, mild haemolysis has been reported. Repetitive forceful foot striking can lead to mechanical damage to erythrocytes resulting in blood cell lysis, resulting in intravascular haemolysis [4]. Some researchers reported the concomitant increases in lactate dehydrogenase (LDH), free bilirubin, methemoglobin, and total plasma hemoglobin content after the race. Apart from these findings, ultrarunners presented elevated serum erythropoietin concentration and reticulocyte count, as well as persistent increases in reticulocytes and mean corpuscular hemoglobin after the race. Nevertheless, it has no influence on red cell volume, suggesting that it has no significant physiological role [15].

White blood cells (WBC) has a relatively low resting value, it is probably related to the adaptation to a long-lasting effort. The total number of WBC elevates significantly during distances longer than marathons of and these increases are also shown during the recovery [13]. Mean corpuscular volume (MCV), mean corpuscular hemoglobin concentration (MCHC) and mean corpuscular hemoglobin (MCH) are stable during the run, and slightly increases during the recovery (within 24 h after termination of the run) [13].

Race - related hyponatremia

Exercise induced hyponatremia (EAH) is defined as serum sodium concentration less than 135 mmol/l during or up to 24 h after prolonged physical activity. EAH can be either symptomatic or asymptomatic. Early symptoms include vomiting, nausea and headache, but in more severe cases it can lead to brain oedema and, consequently, to death [16,17]. Severity of EAH is best defined with presence of symptoms, and not by serum sodium levels [18].

Due to the excessive consumption of water and/or less than necessary consumption of sodium during exercise one can develop hyponatremia. In most cases it is asymptomatic, and it is found in up to 13% of marathon participants [19]. In some cases measured serum sodium concentrations were as low as 114 mmol/l [20].

Several risk factors are found: extensive fluid consumption, increase of body mass after race, altered kidney function, female gender and smaller size [21]. The single strongest predictor of hypernatremia is body mass increase after completing a run [20].

Advice given by guidelines is not consistent: According to The American College of Sports Medicine Recommendations, appropriate fluid intake is 400 - 800 ml/h, but International Marathon Medical Directors Association highlights that fixed ranges of fluid intake is not always appropriate, and drinking to thirst may be the best option, while signs of overhydration (increased urination, bloating, weight gain) must be looked for [22,23]. Special beverages containing electrolytes and carbohydrates can provide benefits, but only in certain circumstances [23].

One needs to remember that EAH should be suspected in patients presenting to a hospital after completing a marathon or ultramarathon and sodium levels should be measured - administration of fluids in severe hyponatremia can lead to brain oedema [24].

Troponin level changes

Cardiac troponins are considered a biochemical gold standard in diagnosing acute coronary events. Besides, they can be significantly elevated in other conditions, such as atrial fibrillation, hypertension, impaired renal function, systolic dysfunction or after chemotherapy [25]. Many studies have shown significant increases in serum troponin levels during and after a marathon run [26,27]. Some studies shown that up to 80% of runners after ultra - marathon (60 km) distance exhibited serum levels of hs - TnI (high-sensitive cardiac troponin I) values exceeding the 99th percentile of the reference limit [28]. Also, the hsTnT (high-sensitive cardiac troponin T) serum levels are elevated in majority of marathon runners. The elevation may be high enough to fulfill the reference value for myocardial infarction [29]. Interestingly, there is a strong evidence to support a thesis that troponin elevation after a marathon does not impact negatively on cardiac event risk. It was shown that despite of immediate elevation of hs - TnT the results returned to baseline value after 72 hours of observation. Authors concluded that elevated troponin may originate from altered cardiomyocyte metabolism rather than from necrosis [30]. In magnetic resonance imaging performed after a marathon run no necrosis was observed, despite raised troponin serum levels [31]. Also, observational study performed on marathon runners shown that elevated troponin levels does not impact negatively on cardiac event risk in comparison to age and risk matched controls [32].

Markers of kidney function in serum

Measurements of creatinine and blood urea nitrogen (BUN) concentration in serum may be useful to detect kidney function impairment in marathon and ultramarathon runners [1,4]]. This particulars biochemical parameters undergo substantial changes during extreme endurance sport. In athletes participating in marathons and ultramarathons significant increase of this parameters are observed.

During extreme exercise significant increase of creatinine level is seen (glomerular filtration rate can rise up to 50%) [33]. It is a consequence of increased release of catecholamines, vasopressin and activation of the renin-angiotensin-aldosterone system. This hormonal changes acts on escalating blood flow through the muscle, which cause decrease in kidney perfusion, as a form of compensation to physical effort [33]. Also the muscle breakdown can increase creatinine concentration regardless of kidney function [34]. However, worsening of kidney function was also proven by parallel course of cystatin C concentration (the alternative bioparameter of renal filtration function which is not dependent on muscle mass), which increased instantly after a marathon or ultra-marathon as well [35].

According to KDIGO 2012 AKI (acute kidney injury) can be diagnosed in case of increase of serum creatinine level by ≥0,3 mg/dl (≥26,5 μmol/l) as compared to previous measurement done in less than 48 hours earlier [36]. Many studies have shown that creatinine level in serum increases after a marathon by 0,12- 0,37 mg/dl, which can, in certain cases, fulfill diagnosis criteria for AKI [1,34,35,37]. Some authors concluded that chance to develop AKI is up to 40-82 % during marathon or ultra-marathon, but it needs highlighting that those changes in creatinine levels does not necessarily indicates kidney failure [34,35].

Also BUN increases below upper reference limit after completing a marathon, which could be a result of elongated accumulation of nonprotein nitrogen in the blood during a sport.

Despite significant elevation of creatinine and blood urea nitrogen concentrations in serum during running, it is proven that after 24 hours this parameters decrease to almost baseline value - unfortunately last tests occurred 24 hours after a run, when a slight elevation persisted [1].

Liver function tests changes

Prolonged physical effort, like maraton or ultramaraton can cause impairment in liver function. It can be measured using serum liver test, such as alanine aminotransferase (ALT), aspartate transaminase (AST), gamma-glutamyltransferase (GGTP) and total bilirubin (T-bilirubin) [4]. During the extreme running and 24 hours after, an increase of ALT can be seen, resulting in values as high as 27,3 U/L upper reference limit [1,37,38]. One possible explanation for ALT elevation is hepatic cell membrane injury, which can be caused by release of free radicals and impaired blood supply [1]. AST, as less specific for liver function, was as high as 5 times the upper reference value, which may be due muscle injury or haemolysis [1,38,39]. Despite significant increase of these two parameters due to the marathon, after 72 hours they return to baseline value.

Another hepatic injury marker is gamma-glutamyltransferase (GGTP). Conflicting data was found on GGTP significance in assessing marathon and ultramarathon [1]. Different studies show either an increase (even sixfold) or decrease of GGTP levels after endurance running[1,37,38,40,41].

Also the total bilirubin raised after the marathon by 0,35-0,7 mg/dl which can be result of mild hemolysis described before[1,37,38].

Generally all parameters normalize within a few days after the race. However, in very rare cases an ultra-marathon can lead to severe liver damage, therefore control of elevated parameters should be recommended[4].

Conclusions

Many changes in blood test can be observed in patients directly and after some time after a marathon. It is important to determine if those variations are of clinical significance, and if they require medical attention. Although most changes shortly return to normal, some must not be ignored, as symptomatic hyponatremia, or persisting elevation of liver damage markers. It is worth highlighting that attending a marathon requires specific preparations and proper fluid intake to prevent serious complications.

References:

1. Shin KA, Park KD, Ahn J, Park Y, Kim YJ. Comparison of Changes in Biochemical Markers for Skeletal Muscles, Hepatic Metabolism, and Renal Function after Three Types of Long-distance Running: Observational Study. Medicine. 2016;95(20):e3657.
2. http://marastats.com/marathon Published 2017. Accessed July 23, 2018.
3. Rüst CA, Knechtle B, Eichenberger E, Rosemann T, Lepers R. Finisher and performance trends in female and male mountain ultramarathoners by age group. International Journal of General Medicine. 2013;6:707-718.
4. Knechtle B, Nikolaidis PT. Physiology and Pathophysiology in Ultra-Marathon Running. Frontiers in Physiology. 2018;9:634.
5. https://worldsmarathons.com/ Accessed July 23, 2018.
6. https://www.maratonypolskie.pl/mp_index.php?dzial=3&action=1&grp=13&trgr=1& bieganie Accessed July 23, 2018.
7. http://www.findmymarathon.com/statistics.php Accessed July 23, 2018.
8. Statystyki biegów 2017. Polskie Stowarzyszenie Biegów Web site. http://psb-biegi.com.pl/ Accessed July 23, 2018.
9. Ultrarunning finishes. UltraRunning Magazine Web site. https://calendar.ultrarunning.com/stats/ultrarunning-finishes?distance=&country=USA Accessed July 23, 2018.
10. Scrimgeour A.G, Noakes T.D, Adams B. et al. Europ. J. Appl. Physiol. (1986) 55:202.
11. Adach Z, Naczk A. Wpływ treningu wytrzymałościowego na organizm. In: Górski J, ed. *Fizjologia wysiłku i treningu fizycznego*. Warszawa: Wydawnictwo Lekarskie PZWL; 2011:91
12. Joyner MJ, Limberg JK. Hitting the wall: glycogen, glucose and the carotid bodies. The Journal of Physiology. 2014;592(Pt 20):4413-4414.
13. Jastrzebski Z, Zychowska M, Jastrzebska M, Prusik K, Kortas J, Ratkowski W, et al. . (2016). Changes in blood morphology and chosen biochemical parameters in ultra-marathon runners during a 100-km run in relation to the age and speed of runners. Int. J. Occup. Med. Environ. Health 29, 801–814.
14. Kłapcińska B, Waśkiewicz Z, Chrapusta SJ, Sadowska-Krępa E, Czuba M, Langfort J. Metabolic responses to a 48-h ultra-marathon run in middle-aged male amateur runners. European Journal of Applied Physiology. 2013;113(11):2781-2793.

15. Robach P, Boisson R. C, Vincent L, Lundby C, Moutereau S, Gergelé L, et al. . (2014). Hemolysis induced by an extreme mountain ultra-marathon is not associated with a decrease in total red blood cell volume. Scand. J. Med. Sci. Sports 24, 18–27.

16. Smith S. Marathon runner's death linked to excessive fluid intake. New York Times. August 13, 2002.

17. Kipps C, Sharma S, Tunstall Pedoe D. The incidence of exercise-associated hyponatraemia in the London marathon. Br J Sports Med. 2011;45(1):14–19.

18. Hew-Butler T., Ayus J.C., Kipps C., Maughan R.J., Mettler S., Meeuwisse W.H., Page A.J., Reid S.A., Rehrer N.J., Roberts W.O., et al. Statement of the Second International Exercise-Associated Hyponatremia Consensus Development Conference, New Zealand, 2007. Clin. J. Sport Med. Off. J. Can. Acad. Sport Med. 2008;18:111–121.

19. Costa RJ, Teixeira A, Rama L, et al. Water and sodium intake habits and status of ultra-endurance runners during a multi-stage ultra-marathon conducted in a hot ambient environment: an observational field based study. Nutrition Journal. 2013;12:13.

20. Almond CS, Shin AY, Fortescue EB, Mannix RC, Wypij D, Binstadt BA, Duncan CN, Olson DP, Salerno AE, Newburger JW, Greenes DS. Hyponatremia among runners in the Boston Marathon. N Engl J Med. 2005;352(15):1550–1556.

21. Kipps C, Sharma S, Tunstall Pedoe D. The incidence of exercise-associated hyponatraemia in the London marathon. Br J Sports Med. 2011;45(1):14–19.

22. Hew-Butler, Verbalis JG, Noakes TD. Updated Fluid Recommendation: Position Statement From the International Marathon Medical Directors Association (IMMDA). Clin J Sport Med 2006;16:283–292.

23. Sawka M.N., Burke L.M., Eichner E.R., Maughan R.J., Montain S.J., Stachenfeld N.S. American College of Sports Medicine position stand. Exercise and fluid replacement. Med. Sci. Sports Exerc. 2007;39:377–390.

24. Kratz A, Siegel AJ, Verbalis JG, Adner MM, Shirey T, Lee-Lewandrowski E, et al. Sodium status of collapsed marathon runners. Arch Pathol Lab Med. 2005; 129:227–30.

25. Lippi G, Schena F, Salvagno GL, et al. Comparison of conventional and highly-sensitive troponin I measurement in ultra-marathon runners. J Thromb Thrombolysis 2012;33:338-42.

26. Neilan TG, Yoerger DM, Douglas PS, Marshall JE, Halpern EF, Lawlor D, Picard MH, Wood MJ. Persistent and reversible cardiac dysfunction among amateur marathon runners, Eur Heart J 2006; 27:1079-1084.

27. Whyte G, Stephens N, Senior R, Goerge K, Shave R, Wilson M, Sharma S. Treat the patient not the blood test: the implications of an increase in cardiac troponin after prolonged endurance exercise, Br J Sports Med. 2007;41:613-615.

28. Lippi G, Schena F, Salvagno GL, et al. Comparison of conventional and highly-sensitive troponin I measurement in ultra-marathon runners. J Thromb Thrombolysis 2012;33:338-42.

29. Baker P, Davies SL, Larkin J, et al Changes to the cardiac biomarkers of non-elite athletes completing the 2009 London Marathon Emerg Med J 2014;31:374-379.

30. Scherr J., Braun S., Schuster T., Hartmann C., Moehlenkamp S., Wolfarth B., Pressler A., Halle M. 72-h kinetics of high-sensitive troponin T and inflammatory markers after marathon. Med. Sci. Sports Exerc. 2011;43:1819–1827.

31. Hanssen H, Keithahn A, Hertel G, Drexel V, Stern H, Schuster T, Lorang D, Beer AJ, Schmidt-Trucksäss A, Nickel T, Weis M, Botnar R, Schwaiger M, Halle M. Magnetic resonance imaging of myocardial injury and ventricular torsion after marathon running. Clin Sci. 2011;120:143-152.

32. Mohlenkamp S, Leineweber K, Lehmann N, Braun S, Roggenbuck U, Perrey M, Broecker-Preuss M, Budde T, Halle M, Mann K, Jockel KH, Erbel R, Heusch G. Coronary atherosclerosis burden, but not transient troponin elevation, predicts long-term outcome in recreational marathon runners. Basic Res Cardiol 2014;109:391.

33. Hogens LE, Walter E, Venn RM, Galloway R, Pitsiladis Y, Sardat F, et al. Acute kidney injury associated with endurance events- is it a cause for concern? A systematic review. BMJ Open Sport Exerc Med. 2017;3(1):e000093.

34. Mansour SG, Verma G, Pata RW, Martin TG, Perazella MA, Parikh CR. Kidney Injury and Repair Biomarkers in Marathon Runners. American Journal of Kidney Diseases. 2017;70(8):252-261.

35. McCullough PA, Chinnaiyan KM, Gallagher MJ, Colar JM, Geddes T, Gold JM. et al. Changes in renal markers and acute kidney injury after marathon running. Nephrology. 2011;16(2):194-199.

36. Khwaja A. KDIGO clinical practice guidelines for acute kidney injury. Nephron Clin Pract. 2012;120(4):c179-84.

37. Traiperm N, Gatterer H, Pariwat P, Burtscher M. Energy metabolism, liver and kidney function in adolescent marathon runners European Journal of Clinical Investigation. 2015;46(1):27-33.

38. Kratz A, Lewandrowski KB, Siegel AJ, Chun KY, Flood JG, Van Cott EM. et al. Effect of Marathon Running on Hematologic and Biochemical Laboratory Parameters, Including Cardiac Markers. American Journal of Clinical Pathology. 2002;118(12):856-863 .

39. Oh RC1, Hustead TR. Causes and evaluation of mildly elevated liver transaminase levels. Am Fam Physician. 2011 Nov 1;84(9):1003-8.

40. Nagel D, Seiler D, Franz H, Jung K. Ultra-Long-Distance Running and the Liver. Int J Sports Med 1990; 11(6): 441-445.

41. Skenderi KP, Kavouras AS, Anatasiou CA, Yiannakouris N, Matalas AL. Exertional Rhabdomyolysis during a 246-km Continuous Running Race. Medicine & Science in Sports & Exercise. 38(6):1054-1057.