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Case report

Biochemical and Hematological Changes Following the 120-Km Open-Water Marathon Swim

Wojciech Drygas [1,2], Ewa Rębowska [1] Ewa Stępień [3], Jacek Golański [4] and Magdalena Kwaśniewska [1]✉
[1] Department of Social and Preventive Medicine Medical University of Lodz, Lodz, Poland; [2] Department of Epidemiology, Cardiovascular Prevention and Health Promotion, National Institute of Cardiology, Warsaw, Poland; [3] Department of Clinical Biochemistry, Jagiellonian University Medical College Krakow, Poland; [4] Department of Haemostasis and Haemostatic Disorders, Medical University of Lodz, Poland

Abstract
Data on physiological effects and potential risks of a ultraendurance swimming are scarce. This report presents the unique case of a 61-year old athlete who completed a non-stop open-water 120-km ultramarathon swim on the Warta River, Poland. Pre-swimming examinations revealed favorable conditions (blood pressure, 110/70 mmHg; rest heart rate, 54 beats/minute, ejection fraction, 60%, 20.2 metabolic equivalents in a maximal exercise test). The swimming time and distance covered were 27 h 33 min and 120 km, respectively. Blood samples for hematological and biochemical parameters were collected 30 min, 4 hrs, 10 hrs and 8 days after the swim. The body temperature of the swimmer was 36.7˚C before and 35.1˚C after the swim. The hematological parameters remained within the reference range in the postexercise period except for leucocytes (17.5 and 10.6 x G/l noted 30 minutes and 4 hours after the swim, respectively). Serum urea, aspartate aminotransferase and C-reactive protein increased above the reference range reaching 11.3 mmol/l, 1054 nmol/l/s and 25.9 mg/l, respectively. Symptomatic hyponatremia was not observed. Although the results demonstrate that an experienced athlete is able to complete an ultra-marathon swim without negative health consequences, further studies addressing the potential risks of marathon swimming are required.

Key words: Marathon swim, ultraendurance exercise, biochemical, men.

Introduction

While regular physical activity exerts a range of beneficial physiological effects, a very long-duration ultra-endurance exercise might produce substantial changes in biochemical parameters (Fallon el al., 1999; Kim et al., 2007; Rama et al., 1994; Spiropoulos and Trakada, 2003; Waśkiewicz et al., 2012). Regarding the potential risk of hyponatraemia, skeletal muscle breakdown, hepatic damage, and the gastrointestinal complaints associated with an ultraendurance sport, athletes participating in strenuous training and events should be carefully monitored. Whereas a significant amount of clinical data has been gathered from marathon runners, data on biochemical changes due to long-distance swimming are rather scarce. The few available studies have documented effects of long-distance swimming in courses shorter than 30 km (Castro et al., 2009; Kabasakalis et al. 2011; Knechtle et al. 2007; 2009; Haralambie and Senser, 1980; Wagner et al. 2012).

The growing popularity of marathon swimming is an intriguing phenomenon. Ultra-long-distance swimming traces its origins to the latter part of the 19th century. One of the earliest marathon swims was accomplished in 1875 by Captain Matthew Webb, the first person to swim across the English Channel in 21 hours and 45 minutes covering a distance of about 34 kilometers. Since then open-water swimming has become a rapidly growing discipline within organized aquatic sports, attracting thousands of participants all over the world. More than 500 swimmers have successfully swum the English Channel in the last 10 years. In 2008, the marathon open-water competition over 10 km appeared for the first time as an official Olympic event. Importantly, over the last decades, the participation in marathon events has increased also among master athletes aged over 40 years old.

The purpose of the present study was to investigate the biochemical and hematological changes due to prolonged exhaustive exercise in a 61-year old marathon swimmer. This report presents the unique case of a master athlete who completed a non-stop open-water 120-km ultramarathon swim. Considering the age of the subject and potential biochemical impact of such intense exercise, we hypothesized that completing ultramarathon would provide substantial and long-lasting changes in selected biochemical markers.

Methods

Subject

A 61-year-old Caucasian man, married, working as a physical education teacher and a swimming guard, began his exercise training on regular basis in early childhood. Over a long period he was engaged mainly in long distance running. His swimming career began in 1985 and since then, he has participated in hundreds of national and international competitions. In the years 2003-2010 he accomplished 4 ultraendurance swim marathons with distances of 75-110 km. The physical characteristics of the subject during the month proceeding the event was age, 61.1 years; body mass, 65.9 kg; height 1.79 m; body mass index, 20.5 kg·m^{-2}; waist circumference, 87 cm; body fat, 12.4% (by a bioelectrical impedance analysis).

Procedures before and after the marathon swim

During the 12 months preceding the latest event, his daily

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schedule consisted of about 3 hours of swimming (often at night), usually in two non-stop sessions and 2 hours of vigorous jogging, calisthenics and stretching performed in two separate sessions. All trainings were supervised by a coach, specialists in sports medicine and a dietitian. Total exercise-related energy expenditure was approximately 15,960 MET/min/week, including (mean intensity of swimming - 9.0 METs, jogging – 8.0 METs, stretching – 2.5 METs, calisthenics – 3.5 METs).

The subject underwent detailed clinical examinations in the Department of Preventive Medicine and Centre of Sports Medicine, Medical University of Lodz, Poland. Written informed consent was obtained after explanation of the purpose and nature of the study, and the potential risks of all experimental procedures. The protocol was approved by the Ethical Committee of the Volunteer Water Rescue Organization in Poznań. The procedures consisted of the following parts: a questionnaire interview, blood pressure (BP) and anthropometric measurements, spirometry, echocardiography, a cardiopulmonary exercise test, and blood sample collection. Pre-swimming clinical examinations revealed favorable health conditions with no history of any chronic diseases or treatments (blood pressure - 110/70 mmHg; rest heart rate - 54 beats/minute, ejection fraction, - 60%). A maximal treadmill exercise test revealed no abnormalities in the electrocardiography or blood pressure monitoring. Using a definition for the metabolic equivalent (MET) as the ratio of work metabolic rate to a standard resting metabolic rate of $1.0 \cdot kg^{-1} \cdot h^{-1}$ (Ainsworth et al. 2000), the amount of work performed by the subject during the exercise test reached 20.2 METs.

Blood samples (20 ml) withdrawn from the median antebrachial vein were collected after an overnight fast and at least 24 hours without training (T1), 30 minutes after the swim (T2), 4 hours (T3), 10 hours (T4) and 8 days thereafter (T5). Specimens for biochemical analysis were refrigerated and transported to the laboratory within 10 hours after the blood was drawn. The hematological parameters (erythrocytes, hemoglobin, hematocrit, leucocytes, platelets) and basic biochemical parameters including the levels of glucose, electrolytes, urea, creatinine, uric acid, total protein, albumin, alanine aminotransferase (ALT), aspartate aminotrasferase (AST), gamma-glutamyltranspeptidase (GGT) and C-reactive protein (CRP) were analyzed by standard methods using the routine haematology method (Sysmex K-4500) and the Roche COBAS Integra 400 plus analyzer.

The protocol of the marathon

The marathon swim was set to start on the 17th July 2010 at 14:00 on the waters of the Warta River between Żrekie and Śrem (Poznan voivodeship, Poland). The total distance to cover was about 120 km.

Three independent judges (members of the Polish Swimming Federation) and a medical security team were supervising the swimmer throughout the whole marathon. The subject was instructed to abstain from consuming alcohol and caffeine-containing beverages, as well as to avoid taking any vitamins or other supplements for 24 hours before the event. On the day of the marathon, the swimmer was instructed have a light meal about 3 hours before the event. During the marathon, the fluid intake consisted of warm isotonic liquid solutions (500 ml every 60 minutes until reaching 90th km of the swim, next 50-70 ml every 30-60 minutes) and several bananas, dried apricots, figs, rice crackers, cornflakes and biscuits (six meals 3, 6, 9, 12, 15 and 21 hours after the beginning of the marathon). As the subject decided to swim continuously, all snacks and drinks were thrown into the water by the support team.

Statistical analysis

Regression linear analysis has been performed in order to reveal the direction and level of significance of the observed results. The regression coefficient has been inserted into the tables. A p value < 0.05 was considered statistically significant. Statistical analysis was performed with STATISTICA Windows XP version 9.1

Results

The swimming time and distance covered were 27 hrs 33 min and 120 km, respectively. The air temperature range was between 19 °C (night) and 27 °C (day). The temperature of water ranged between 18 ºC (night) and 24 ºC (day). The weather was cloudy, with some rainy periods during the marathon, with the wind range between 1-11 km/h (day) and 12-19 km/h (night). The swimmer completed the marathon without experiencing any adversity requiring medical attention. The body temperature measured on the tympanic membrane was 36.7 ºC before the warm-up and 35.1 ºC immediately after the swim.

Tables 1-2 present marathon-induced changes in the several hematological and biochemical parameters. Most of hematological variables remained within normal limits between T1 and T5 (Table 1). However, a significant increase in the leukocyte count was observed in the postexercise period (p = 0.04).

Table 1. Change of selected hematological parameters of the master athlete after completing the 120 km non-stop marathon swim.

Parameters	Basic condition	After marathon				Regression coefficient	p
	T1	T2 (30 min)	T3 (4 hrs)	T2 (10 hrs)	T2 (8 days)		
Erythrocytes ($T \cdot l^{-1}$)	4.68	5.12	4.46	4.55	4.48	-.18	.24
Hemoglobin ($mmol \cdot l^{-1}$)	9.49	10.2	9.1	9.2	9.1	-.49	.23
Hematocrit ($1 \cdot l^{-1}$)	.43	.46	.40	.41	.41	-1.41	.32
Leukocytes ($G \cdot l^{-1}$)	4.4	17.5	10.6	8.3	6.0	-3.68	.04
Platelets ($G \cdot l^{-1}$)	181	250	209	201	191	-18.5	.07

Table 2. Changes in selected biochemical parameters of the master athlete after completing the120 km non-stop marathon swim.

Parameters	Basic condition	After marathon				Regression coefficient	p
	T1	T2 (30 min)	T3 (4 hrs)	T2 (10 hrs)	T2 (8 days)		
Sodium (mmol·l^{-1})	141	136	134	135	138	.70	.47
Potassium (mmol·l^{-1})	4.2	4.1	4.5	4.2	4.3	.03	.77
Chloride (mmol·l^{-1})	98	95	97	100	101	2.1	.02
Urea (mmol·l^{-1})	5.9	5.3	11.3	10.2	7.1	-4.0	.52
Creatinine (umol·l^{-1})	79.6	70.7	88.4	79.6	70.7	-.01	.86
Uric acid (umol·l^{-1})	334.9	344.9	386.6	398.5	374.7	.17	.43
Total protein (g·l^{-1})	73	73	63	67	67	-1.4	.56
Albumin (g·l^{-1})	47	46	41	43	43	-.07	.56
AST (nmol·l^{-1}·s^{-1})	408	1054	918	867	527	-9.6	.06
ALT (nmol·l^{-1}·s^{-1})	102	459	408	425	476	.4	.71
GGT (U·l^{-1})	10	11	12	11	10	-.4	.36
CRP (mg·l^{-1})	1.3	13.4	17.3	25.9	1.6	-2.7	.65
Glucose (mmol·l^{-1})	4.9	5.2	5.8	6.1	4.7	-2.2	.74

ALT – alanine aminotransferase; AST – aspartate aminotransferase; CRP – C-reactive protein; GGT –gamma-glutamyltranspeptidase.

Of the biochemical parameters, serum potassium, creatinine, uric acid, albumins, ALT and GGT levels remained within the normal range throughout the whole observation. Serum sodium decreased slightly, reaching 133.9 mmol·l^{-1} about 4 hours after the event. An increase occurred in serum urea and AST from the early minutes after the swim, but statistical significance was not reached. Serum CRP remained over the normal range between T2 and T4, reaching the highest value of 25.9 mg·l^{-1} about 10 hours after the swim (Table 2).

Discussion

The purpose of the present study was to investigate the biochemical and hematological changes due to prolonged exhaustive exercise in a marathon swimmer. Regarding the unusual distance of this event, this report not only provides a range of biochemical data, but is a particular attempt to explore the limits of human capabilities. To our knowledge, there is no evidence in the literature about the physiological effects of such a long distance swim. The vast majority of studies investigating the impact of ultraendurance exercise on biochemical parameters have focused mainly on such types of activities as running or cycling.

As open-water swimming is not only very popular, but has also become an official Olympic event, the findings of the present report provide useful knowledge for physiologists as well as coaches and athletes. Many swimmers attempt to break personal, national or world records in ultraendurance swimming.

Importantly, long-distance swimming in the river is an extremely demanding challenge and outdoor swimmers often face more stressful situations than ultraendurance runners or cyclists. Many hours of monotonous exercise in a horizontal position, differences in air and water temperature, darkness and poor visibility, danger of swallowing insects flying above the surface, as well as the difficulties faced in eating and drinking, are among the most important problems.

The results of the present report demonstrate that many of the analyzed parameters remained almost unaffected compared to the pre-marathon values. Significant change during the observed period was noticed only for the leucocytes count and chloride concentration ($p < 0.05$). Increases in leukocyte count during the first hours after participation in this marathon swim, resulting mainly from increased neutrophil and monocyte counts, may reflect postexercise inflammatory response. This finding is consistent with previous reports on marathon runners (Davidson et al., 1987; Kratz et al., 2002; Reid et al., 2004) as well as with the latest study of Kabaskalis et al. (2011) who presented reactive neutrophilia after a marathon swim. Even exertion produced by swimming less than 10 km results in mild leukocytosis due to neutrophil mobilization similar to that observed during a bacterial infection. Additionally, acute severe exercises induce an oxidative state resulting in an acceleration of human neutrophil apoptosis (Syu et al., 2011). Unfortunately, the apoptotic status of circulating blood cells was not analyzed in our study.

While some forms of regular physical activity may be associated with a lower likelihood of inflammatory marker elevation (King et al., 2003), ultra-endurance exercise is usually associated with a significant elevation of such markers as CRP, fibrinogen and leukocytes (Kim et al., 2009; Kratz et al., 2002; Neubauer et al., 2008; Reid et al., 2004). According to the findings of Kim et al (2009) a long-distance run induced an increase in plasma hs-CRP of over 40 fold, which remained elevated on day 6 of recovery. Another ultra-endurance exercise, such as an Ironman triathlon, resulted in a low-grade systemic inflammation which persisted for at least 5 days after the race (King et al., 2003).

The subject did not develop biochemical or symptomatic hyponatremia, which is consistent with some previous reports demonstrating exercise-associated electrolyte changes in marathon athletes (Fallon et al., 1999; Rama et al., 1994; Reid et al., 2004; Spiropoulos et al., 2003; van Rensburg et al., 1986). The latest study of Wagner and al. (2012) showed two cases of asymptomatic hyponatremia among 25 male open-water ultra-marathon swimmers participating in a marathon swim in Lake Zurich. In our study, the lowest concentration of sodium was observed about 4 hours after the swim, reaching almost 134 mmol·l^{-1}. Based on his experience from previous marathon swims, the subject paid particular attention to adequate fluid and solid food intake during the event. This is the most probable explanation of a relatively stable weight and serum sodium concentration during the observation period.

The serum urea concentration of the subject increased importantly above baseline values immediately after the swim and remained over the normal limits until day 8 of the observation. Findings suggesting a long-term increase in serum urea after marathon races have been reported in several previous studies (Rama et al., 1994; Reid et al., 2004; Kratz et al., 2002). However, as serum creatinine remained within normal range, a decrease in renal function of our subject seems unlikely.

Another important observation is associated with changes in serum aminotransferases. Several authors report a substantial elevation of AST and ALT after prolonged ultra-endurance exercise, mainly marathon running (Kratz et al., 2002; Lippi et al. 2011; Waśkiewicz et al., 2012; Wu et al., 2004). To investigate the possibility of liver injury in response to prolonged aerobic exercise, tests were performed for possible changes in GGT, a more specific liver enzyme. The observed relative stability of serum GGT throughout the whole measurement period ruled out a suspicion of liver damage in our subject.

Most of the athletes described in previous studies exceeded the upper reference limits also for other enzymes, especially LDH and CK, indicating possible muscle damage due to strenuous exercise (Kim et al., 2007 and 2009; Waśkiewicz et al., 2012; Wu et al., 2004). In our study, a 3-fold rise in AST occurred immediately after the event with a progressive decrease to the normal value within 8 days. No definite conclusions in the context of muscle injury can be made, as no other muscle biomarkers were evaluated in our subject. However, swimming involves mainly non-weight-bearing activity and concentric contraction, and thus is thought to be a non-muscle-damaging exercise (Federation Internationale de Natation, 2005).

Hypothermia is one of the potential clinical risks of open-water swimming. Body heat loss during water immersion can be many times that incurred during exposure to air of the same temperature (Fregly et al., 1996). According to the rules of the International Swimming Federation, the water temperature for official competitions should be higher than 16ºC checked on the day of the event two hours before the starting time, in the middle of the course at a depth of 40 cm (Mougios 2007). In our study the swimmer did not experience severe hypothermia although the water temperature fell to 18º C at night. Castro et al (2009) observed hypothermia among most of elite marathon swimmers participating in a 10-km marathon swim in relatively warm water (21º C). However, it is complicated to compare our study with the above results, because the swimmers in Castro's investigation were younger (mean age 21± 7 years old) and the distance covered was much shorter. It is probable that the effective thermoregulatory function of our subject may result from modified sensory functions of his hypothalamic centers, which is characteristic for swimmers exercising in warm and cold environments (Keatinge et al., 2001). Rüst et al. (2012) presented a case report describing an experienced open-water ultra-endurance 53-years old athlete swimming in water of 9.9°C for more than 6 h. The lowest body core temperature was 36°C between 35 and 60 min after finishing the swim. This case report showed that it was possible to swim for 6 h in water of 9.9°C and that the athlete did not suffer from hypothermia under these circumstances. The authos suggest that high body mass index, high body fat, previous experience, and specific preparation of the swimmer are among the most probable explanations for these findings (Rüst et al., 2012). The concept that an increased percentage of body fat allows for a better maintenance of body temperature has, however, no confirmation in the present study or those of other authors (Vybiral et al., 2000). Anthropometric measurements of our subject revealed a percentage of fat tissue within the typical range for adult athletes.

Age is another important issue in the context of the presented case report. According to the available literature the endurance performance decreases with the increasing age. Generally, the peak endurance performance is maintained until the age of 35 years, followed by a progressive decline, mostly pronounced after the age 70 years (Donato et al., 2003; Tanaka and Seals, 2008). The subject of our study revealed favorable pre-swimming health conditions with 20.2 METs reached during a maximal treadmill exercise test. The presented above ultra-marathon completed at the age of 61 years was the best result in his whole adult career. This case report shows that it is possible to swim non-stop for above 27 h without experiencing substantial health problems.

This exceptional performance reflects the contribution of several factors, but a unique interest in endurance sports, a high level of motivation and regular improvement of skills since early childhood should be particularly highlighted. Moreover, a favorable family and medical history, professional medical care and strong support of the closest relatives and friends are also noteworthy. His optimistic attitude correlates with good health practices (not smoking, proper daily sleep, nutrition patterns and recreation habits) which is in line with the observation of Lipowski (2012) that high level of optimism promotes good health behavior in athletes.

The major limitations of this study comprise: 1) analyses of the biochemical and hematological changes limited to one subject; 2) lack of specific biomarkers of possible muscle damage.

Conclusion

This case report revealed that continuous open-water 120-km marathon swim triggered mainly inflammatory responses while other markers remained stable or returned shortly to the reference range despite severe physical stress. The obtained results demonstrate that a well-trained, experienced and highly motivated athlete is able to perform a long-term open-water swim without negative health consequences. Nevertheless, regarding the previous reports on sudden deaths of professional swimmers and triathlon athletes (Harris et al., 2010), further studies addressing the potential risks of ultraendurance swimming are required.

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Key points

- Data on biochemical changes due to long-distance swimming are scarce.
- This report presents the unique case of a 61-year old athlete who completed a non-stop open-water 120-km ultramarathon swim.
- An experienced athlete is able to complete an ultra-marathon swim without serious health consequences.
- Regarding the growing popularity of marathon swimming further studies addressing the potential risks of such exhaustive exercise are required.

AUTHORS BIOGRAPHY

Wojciech DRYGAS
Employment
Head of the Department of Social and Preventive Medicine, Medical University of Lodz, Poland
Head of the Department of Epidemiology, Cardiovascular Prevention and Health Promotion, National Institute of Cardiology, Warsaw, Poland
Degree
MD, PhD
Research interests
Prevention of non-communicable diseases, health promotion, public health, sports medicine
E-mail: wojciech.drygas@umed.lodz.pl

Ewa RĘBOWSKA
Employment
Laboratory diagnostician, medical analyst,
public health specialist at the Department of Social and Preventive Medicine, Medical University of Lodz
Degree
MSc
Research interests
Public Health, prevention of cardiovascular diseases
E-mail: ewa.rebowska@umed.lodz.pl

Ewa STĘPIEŃ
Employment
Department of Clinical Biochemistry, Unit of Genetic Diagnostics and Nutrigenomics, Jagiellonian University Medical College, Kraków, Poland
Degree
MSc, PhD
Research interests
endothelial dysfunction, new biomarkers of vascular diseases: including osteopontin, osteoprotegerin and microparticles, circulating miRNA
E-mail: e.stepien@uj.edu.pl

Jacek GOLAŃSKI
Employment
Senior Researcher and Tutor, Department Haemostatic Disorders, Medical University of Lodz
Degree
PhD, Associate Professor.
Research interests
Methods for monitoring of antiplatelet therapy, effects of polyphenols on hemostasis, mechanisms of platelet activation and disorders of fibrinolytic system in ischaemic heart disease and extracorporeal circulation

Magdalena KWAŚNIEWSKA
Employment
Assistant professor at the Department of Social and Preventive Medicine, Medical University of Lodz
Degree
MD, PhD
Research interests
Prevention of non-communicable diseases, sports medicine
E-mail: magdalena.kwasniewska@umed.lodz.pl

✉ **Magdalena Kwaśniewska, MD, PhD**
Department of Social and Preventive Medicine Medical University of Lodz, Żeligowskiego 7/9, 90-647 Lodz, Poland