Miroslav MYDLÍK[1,2]
Katarína DERZSIOVÁ[1]
Branislav BOHUŠ[3]

Renal function abnormalities after marathon run and 16-kilometre long-distance run

Zaburzenia funkcji nerek po biegu maratońskim i długodystansowym na 16 kilometrów

[1]IVth Internal Clinic, University Hospital of L. Pasteur and Medical School of P. J. Šafárik University, Košice, Slovak Republic
Head: Prof. *Ivan Tkáč*, MD, PhD.

[2]Institute of Experimental Medicine, Medical School of P.J. Šafárik University, Košice, Slovak Republic
Head: *Alojz Bomba*, MVDr, DSc.

[3]IIIrd Internal Clinic of University Hospital of L.Pasteur and Medical School of P. J. Šafárik University, Košice, Slovak Republic
Head: Prof. *Daniel Pella*, MD,PhD.

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Renal functions were investigated in 29 marathon runners and in 20 runners in connection with 16-kilometre long-distance run. Body weight in runners decreased after marathon run in average of 1.3 ± 0.5 kg and after 16-kilometre long-distance run in average of 1.4 ±0.4 kg. Blood pressure decreased after both runs. Total proteinuria and albuminuria significantly increased after both runs. The significant non-glomerular erythrocyturia was found in 9 runners after marathon run and in 3 runners after 16-km long-distance run. Total catalytic activity of serum creatine kinase, and its isoenzyme MB significantly increased after both runs. Increase of isoenzyme MB creatine kinase after runs was lower than 6% of total catalytic activity of creatine kinase. These increases were caused by rhabdomyolysis and were connected with myoglobinuria. Serum myoglobin significantly increased after marathon run and after 16-km run. Serum urea, creatinine, phosphorus and osmolality significantly increased after both runs. Calculated GFR significantly decreased after both runs. FE_{Na}, FE_{Ca}, FE_{P}, FE_{OSM} and FE_{H2O} significantly decreased after both runs. FE_{K} significantly increased after marathon run, but after 16-km run non-significantly decreased. Renal function abnormalities were caused by dehydration, microtraumas in extrarenal urinary tract, protein catabolism, decreased urinary excretion of osmotically active substances, rhabdomyolysis, activation of renin-angiotensin-aldosterone system and other factors. Renal function abnormalities in runners were already not present 2-6 days after marathon run and after 16-kilometre long-distance run and investigated parameters were in normal range or they did not significantly differ from the initial values.

Oceniono funkcję nerek u 29 biegaczy maratońskich i u 20 biegaczy długodystansowych na 16 km. Waga ciała biegaczy obniżała się po biegu maratońskim o 1,3 ± 0,5 kg a po biegu długodystansowym na 16 km o 1,4 ± 0,4 kg. Ciśnienie tętnicze obniżyło się po obu biegach a białkomocz i albuminuria istotnie wzrosły. Po zakończeniu biegu u 9 biegaczy maratońskich i 3 długodystansowców stwierdzono istotną erytrocyturią pochodzenia pozakłębuszkowego. Całkowita aktywność katalityczna w surowiczej kinazy kreatyniny i jej izoenzymu MB istotnie wzrastały po obu biegach. Wzrost izoenzymu MB kinazy kreatyniny po obu biegach był o 6% niższy od całkowitej aktywności kinazy kreatyniny. Ten wzrost był wywołany przez rhabdomializę i był połączony z mioglobinurią. Mioglobinuria istotnie wzrosła po biegu maratońskim i długodystansowym na 16 km. Stężenie mocznika, kreatyniny, fosforu w surowicy i osmolarność istotnie wzrosły po obu biegach. Wyliczony GFR istotnie obniżał się po obu biegach. FE_{Na}, FE_{Ca}, FE_{P}, FE_{OSM} i FE_{H2O} istotnie obniżały się również po obu biegach. FE_{K} istotnie wzrosły po biegu maratońskim, natomiast po biegu na 16 km nieistotnie obniżał się. Zaburzenia funkcji nerek były wywołane przez odwodnienie, mikrourazy w pozanerkowym układzie moczowym, katabolizm białka, obniżone wydalanie z moczem aktywnych osmotycznie substancji, rhabdomiolizę, aktywację układu renina-angiotensyna-aldosteron i inne czynniki. Zaburzenia funkcji nerek ustępowały w 2-6 dni po biegu maratońskimi i po biegu na 16 km; badane parametry normowały się i nie różniły się istotnie od wartości wyjściowych.

Adres do korespondencji:
Professor Miroslav Mydlík, MD, DSc.
IVth Internal Clinic
University Hospital of L. Pasteur
Rastislavova 43
041 90 Košice
Slovak Republic
e-mail: k.derzsiova@unlp.sk
Tel: +421 907914206

Introduction

Renal function investigation is a representative non-invasive investigation which is possible to realize repeatedly after short or long-distance runs [16]. With regard to this fact, that in the last decades it is an increasing interest in long-distance runs in healthy population, in middle-aged men and women, it is necessary to investigate renal function parameters in these subjects befo-

Table I
Clinical and laboratory parameters before (B), immediately after (A) and 2 - 6 days (C) after marathon run and 16-kilometre run.
Parametry kliniczne i laboratoryjne przed (B), bezpośrednio po (A) i 2 -6 dni (C) po biegu maratońskim i długodystansowym na 16 kilometrów.

MR-marathon run, 16 km - 16-kilometre run; *p≤0.05, ** p≤0.01 vs before run; [b]p≤0.05, [a]p≤0.01 2-6 days after run (C) vs immediately after run (A)

Run	Body weight (kg)	Blood pressure (kPa)	Haemoglobin (g/L)	Haematocrit
MR-B	73.2 ± 5.7	18.7 ± 2.0/11.7 ± 1.33	150.4 ± 5.5	0.45 ± 0.03
MR-A	71.9 ± 5.2 *	16.4 ± 1.33/9.3 ± 1.07 **	152.1 ± 4.8 *	0.46 ± 0.02
MR-C	75.3 ± 4.8 [b]	17.6 ± 1.5/11.3 ± 1.33	151.1 ± 4.5	0.45 ± 0.04
16 km-B	74.1 ± 2.6	16.2 ± 2.2/9.7 ± 0.9	150.2 ± 9.9	0.44 ± 0.02
16 km-A	72.7 ± 2.5 *	14.7 ± 2.0/9.3 ± 1.4 **	152.3 ± 8.7 *	0.45 ± 0.02
16 km-C	74.1 ± 2.8	16.4 ± 2.2/10.9 ± 1.2 [b]	145.4 ± 11.9 [b]	0.44 ± 0.03

Table II
Urinary chemical investigation before (B), immediately after (A) and 2 - 6 days (C) after marathon run and 16-kilometre run.
Badanie chemiczne moczu przed (B), bezpośrednio po (A) i 2-6 dni (C) po biegu maratońskim i długodystansowym na 16 kilometrów.

Run	pH	Specific weight (g/dm^3)	Proteinuria (n)						Erythrocyturia (n)					Leucocyturia (n)	Glucose in urine (n)
			0	tr.	1+	2+	3+	4+	0	tr.	1+	2+	3+		
MR-B	5.4 ± 0.5	1025 ± 0.010	21	-	-	-	-	-	17	3	1	-	-	0	0
MR-A	5.1 ± 0.2	1028 ± 0.014	8	4	2	6	1	-	8	4	3	2	4	2	2
MR-C	5.3 ± 0.2	1023 ± 0.011	20	1	-	-	-	-	19	2	-	-	-	0	0
16 km-B	6.1 ± 0.4	1028 ± 0.015	18	2	-	-	-	-	19	1	-	-	-	2	0
16 km-A	5.5 ± 0.5*	1028 ± 0.015	3	8	2	2	4	1	14	3	3	-	-	4	2
16 km-C	6.0 ± 0.5[a]	1022 ± 0.010	16	1	-	-	-	-	16	1	-	-	-	1	0

MR-marathon run, 16-km - 16-kilometre run; tr - trace; *p≤0.05, [a]p≤0.01 2-6 days after run (C) vs immediately after run (A)

Table III
Urinary sediment before (B), immediately after (A) and 2 - 6 days (C) after marathon run and 16-kilometre run.
Osad moczu przed (B), bezpośrednio po (A) i 2 - 6 dni (C) po biegu maratońskim i długodystansowym na 16 kilometrów.

Run	Urinary sediment					
	Erythrocyte (x/µl)	Leucocyte (x/µl)	Casts		Crystals	
			Hyaline (n)	Granulated (n)	Oxalate (n)	Urate (n)
MR-B	1-5 NG (n=4)	2-4 (n=4)	-	-	5	5
MR-A	1-60 NG (n=13)	4-45 (n=15)	7	9	10	5
MR-C	1-4 NG (n=2)	1-8 (n=6)	-	-	8	4
16 km-B	2-5 NG (n=11)	3-30 (n=4)	-	-	2	3
16 km-A	2-19 NG (n=17)	2-38 (n=19)	6	1	6	2
16 km-C	2-6 NG (n=2)	1-25 (n=4)	-	-	3	1

MR-marathon run, 16 km - 16-kilometre run

Table IV
Selected laboratory parameters before (B), immediately after (A) and 2 - 6 days (C) after marathon run and 16-kilometre run.
Wybrane parametry laboratoryjne przed (B), bezpośrednio po (A) i 2 - 6 dni (C) po biegu maratońskim i długodystansowym na 16 kilometrów.

Run	Total proteinuria (g/L)	Albuminuria (g/L)	Myoglobinuria (mg/L)	Erythrocyturia	
				G (%)	NG (%)
MR-B	0.250 ± 0.04	0.12 ± 0.09	1.3 ± 0.3	-	-
MR-A	2.787 ± 0.64 **	1.79 ± 0.45 **	3.2 ± 0.8 *	9.6 ± 0.02	90.4 ± 3.0
MR-C	0.241 ± 0.07 [a]	0.08 ± 0.23 [a]	0.5 ± 0.1 [a]	-	-
16 km-B	0.033 ± 0.03	0.014 ± 0,05	-	-	-
16 km-A	1.145 ± 1.50 **	0.751 ± 0.15 **	-	0	100.0
16 km-C	0.068 ± 0.05 [a]	0.041 ± 0.04 [a]	-	0	100.0

MR-marathon run, 16 km - 16-kilometre run; *p≤0.05, ** p≤0.01 vs before run; [a]p≤0.01 2-6 days after run (C) vs immediately after run (A); G-glomerular erythrocyturia, NG-nonglomerular erythrocyturia

re runs and after long-distance runs to eliminate serious chronic and acute diseases and to prevent kidney damage [13].

The purpose of our study was to investigate the essential renal functions in runners before and immediately after the marathon run and after 16-kilometre long-distance run. The control investigation 2-6 days after the runs was performed. Besides the aim of the study was to compare the obtained results in above mentioned long-distance races [7,9,13,14,17].

Groups of investigated runners and methods

Twenty-nine well trained runners (mean age 33.5 ± 6 yr) among them a 42-year-old woman were investigated before, immediately after and 6 days after standard marathon run (42.195-km). The mean air temperature was 18°C during marathon run.

Besides 20 well trained runners (mean age 44.7 ±10 yr) were investigated. Among them were 2 women, 38 and 43-year-old. All runners in this group were investigated before, immediately after and 2 days after 16-km long-distance run. The mean air temperature was

Table V
Selected laboratory parameters before (B), immediately after (A) and 2 - 6 days (C) after marathon run and 16-kilometre run.
Wybrane parametry laboratoryjne przed (B), bezpośrednio po (A) i 2 - 6 dni (C) po biegu maratońskim i długodystansowym na 16 kilometrów.

Run	Serum CK (µkat/L)	Serum CKisoMB (µkat/L)	Serum Myoglobin (nmol/L)
MR-B	1.2 ± 0.3	0.10 ± 0.03	3.1 ± 0.8
MR-A	4.8 ± 2.2 **	0.26 ± 0.09 **	16.8 ± 2.2 ***
MR-C	2.4 ± 1.2 [a]	0.13 ± 0.07 [a]	3.2 ± 1.1 [a]
16 km-B	2.7 ± 1.7	0.11 ± 0.02	2.7 ± 1.2
16 km-A	5.2 ± 5.0 *	0.23 ± 0.12 **	8.7 ± 3.1 ***
16 km-C	3.2 ± 1.9 [b]	0.15 ± 0.10 [b]	3.5 ± 1.2 [a]

MR-marathon run, 16 km - 16-kilometre run; *p≤0.05, **p≤0.01, ***p≤0.001 vs before run; [b]p≤0.05, [a]p≤0.01 2-6 days after run (C) vs immediately after run (A); CK -creatine kinase. CKisoMB -MB isoenzyme creatine kinase

Table VI
Selected laboratory parameters before (B), immediately after (A) and 2 - 6 days (C) after marathon run and 16-kilometre run.
Wybrane parametry laboratoryjne przed (B), bezpośrednio po (A) i 2 - 6 dni (C) po biegu maratońskim i długodystansowym na 16 kilometrów.

Run	Serum urea (mmol/L)	Serum creatinine (µmol/L)	GFR calculated (ml/s)
MR-B	6.2 ± 1.1	93.4 ± 10	1.71 ± 0.3
MR-A	8.3 ± 2.1 **	111.3 ± 15 **	1.40 ± 0.4 **
MR-C	6.6 ± 0.9 [a]	103.0 ± 11 [a]	1.59 ± 0.3 [b]
16 km-B	5.3 ± 1.2	87.4 ± 7.7	1.65 ± 0.4
16 km-A	5.9 ± 1.3 **	112.1 ± 8.8 **	1.26 ± 0.3**
16 km-C	5.9 ± 1.2	90.3 ± 6.7 [a]	1.60 ± 0.4 [a]

MR-marahon run, 16 km - 16-kilometre run; GFR - glomerular filtration rate; *p≤0.05, ** p≤0.01 vs before run; [b]p≤0.05, [a]p≤0.01 2-6 days after run (C) vs immediately after run (A)

Table VII
Selected laboratory parameters before (B), immediately after (A) and 2 - 6 days (C) after marathon run and 16-kilometre run.
Wybrane parametry laboratoryjne przed (B), bezpośrednio po (A) i 2 - 6 dni (C) po biegu maratońskim i długodystansowym na 16 kilometrów.

Run	Serum Na^+ (mmol/L)	Serum K^+ (mmol/L)	Serum Mg^{2+} (mmol/L)	Serum Cl^- (mmol/L)	Serum osmolality (mmol/kg H_2O)
MR-B	144.4 ± 2.1	4.38 ± 0.30	0.84 ± 0.10	100.6 ± 2.1	287.5 ± 10.1
MR-A	147.6 ± 2.8**	4.10 ± 0.24*	0.72 ± 0.14*	99.4 ± 1.5	300.0 ± 13.0**
MR-C	142.9 ± 3.9	4.14 ± 0.15	0.77 ± 0.15	103.2 ± 1.8 [a]	284.7 ± 8.5 [a]
16 km-B	138.9 ± 1.3	4.31 ± 0.27	0.89 ± 0.07	-	298.1 ± 3.9
16 km-A	140.9 ± 1.6*	4.44 ± 0.38	0.83 ± 0.23	-	307.0 ± 5.7**
16 km-C	140.5 ± 3.0	4.53 ± 0.36	0.86 ± 0.08	-	291.1 ± 5.0 [a]

MR-marathon run, 16-km - 16-kilometre run; *p<0.05, ** p≤0.01 vs before run; [a]p≤0.01 2-6 days after run (C) vs immediately after run (A)

Table VIII
Selected laboratory parameters before (B), immediately after (A) and 2 - 6 days (C) after marathon run and 16-kilometre run.
Wybrane parametry laboratoryjne przed (B), bezpośrednio po (A) i 2- 6 dni (C) po biegu maratońskim i długodystansowym na 16 kilometrów.

MR-marathon run, 16 km - 16-kilometre run; *p≤0.05, ** p≤0.01 vs before run;
[b]p≤0.05, [a]p≤0.01 2-6 days after run (C) vs immediately after run (A)

Run	Serum calcium (mmol/L)	Serum phosphorus (mmol/L)	FE_{Ca} (%)	FE_P (%)
MR-B	2.41 ± 0.14	1.18 ± 0.08	1.58 ± 1.1	15.8 ± 6.5
MR-A	2.41 ± 0.05	1.43 ± 0.10 **	0.59 ± 0.4**	9.9 ± 5.5 **
MR-C	2.31 ± 0.08	1.16 ± 0.08 [a]	1.62 ± 0.9 [a]	18.1 ± 8.3 [a]
16 km-B	2.23 ± 0.09	1.02 ± 0.18	1.12 ± 0.9	16.7 ± 14.3
16 km-A	2.31 ± 0.10	1.52 ± 0.30 **	0.34 ± 0.3 **	14.5 ± 7.8 *
16 km-C	2.27 ± 0.09	0.99 ± 0.12 [a]	1.33 ± 0.7 [a]	11.4 ± 5.6 [b]

Table IX
Selected laboratory parameters before (B), immediately after (A) and 2 - 6 days (C) after marathon run and 16-kilometre run.
Wybrane parametry laboratoryjne przed (B), bezpośrednio po (A) i 2 - 6 dni (C) po biegu maratońskim i długodystansowym na 16 kilometrów.

Run	FE_{Na} (%)	FE_K (%)	FE_{Mg} (%)	FE_{Cl} (%)	FE_{OSM} (%)	FE_{H2O} (%)
MR-B	1.16 ± 0.3	10.6 ± 2.0	3.3 ± 1.3	1.6 ± 0.2	2.5 ± 0.4	0.8 ± 0.2
MR-A	0.34 ± 0.1**	18.9 ± 4.1**	0.7 ± 0.5**	0.7 ± 0.1**	1.6 ± 0.3**	0.6 ± 0.1**
MR-C	1.16 ± 0.2 [a]	13.5 ± 3.2 [b]	3.9 ± 1.2 [a]	1.5 ± 0.2 [a]	2.9 ± 0.6 [a]	0.9 ± 0.3 [a]
16 km-B	1.25 ± 0.6	18.1 ± 9.1	3.5 ± 1.4	-	2.8 ± 0.9	1.7 ± 1.3
16 km-A	0.78 ± 0.5**	15.6 ± 6.5	4.4 ± 3.0	-	2.0 ± 1.0**	1.3 ± 0.8**
16 km-C	1.10 ± 0.6 [a]	14.2 ± 7.4	3.7 ± 1.5	-	2.7 ± 0.8 [a]	1.3 ± 0.9

MR-marathon run, 16km - 16-kilometre run;
*p≤0.05, ** p≤0.01 vs before run;
[b]p≤0.05, [a]p≤0.01 2-6 days after run (C) vs immediately after run (A)

17°C during 16-km long-distance run.

The volunteers were in both groups of runners and we received their verbal consent with internal investigation. All of them were healthy and they participated in many long-distance runs repeatedly. The enviromental conditions were similar in both runs. All runners completed the race. Mean duration time of marathon run was 155±10 min and of 16-kilometre run was 65±5 min in investigated runners. During the races runners drank various fluids: mineral water, juice, coca-cola, etc.

Blood pressure was measured and blood and urinary samples were obtained within 20-30 minutes after the completing races. All samples were transferred immediately in the biochemical or nephrological laboratory.

Standard blood and urinary parameters of renal functions were investigated in all runners using spectrophotometric or enzymatic methods by Roche analyzer Integra 800 and using radioimmunological method. Chemical investigation of urine and urinary sediment were performed using flow cytometry. The morphological examination of urinary erythrocytes was performed by microscope with phase contrast.

Statistical analysis of the obtained results was realized by paired and unpaired t-test at the Institute of Medical Informatics.

Results

The body weight and blood pressure significantly decreased in runners after marathon run and 16-kilometre run, the values of haemoglobin and haematocrit increased, probably as a result of dehydration (Table I) [2]. In urinary chemical investigation, a significant proteinuria in 9 runners after both runs was found, significant haematuria was present in 9 runners after marathon run, but only in 3 runners after 16-kilometre long-distance run. Leucocyturia was observed in 2 runners after marathon run and in 4 runners after 16-kilometre run and transitory glycosuria was found in 2 runners after both races. Transitory glycosuria was not present in control investigation (Table II).

In urinary sediment except of erythocytes and leucocytes were present also hyaline casts (in 7 runners after marathon run and in 6 runners after 16-km run) and granulated casts (in 9 runners after marathon run but only in one runner after 16-km run), calcium oxalate and urate crystals (Table III). Erythrocyturia in urinary sediment after races, investigated by microscope with phase contrast, was non-glomerular. Total proteinuria and albuminuria significantly increased after both runs, they were more significant after the marathon run. In control investigation above mentioned parameters did not significantly differ from the initial values. Myoglobinuria which was investigated only during marathon run significantly increased after the run (Table IV). Catalytic activity of creatine kinase and its isoenzyme MB and serum myoglobin after both races significantly increased (Table V). Concentrations of serum urea and creatinine increased and GFR calculated according to Cockcroft and Gault significantly decreased after both races (Table VI). Serum Na^+ increased after the races and serum K^+ and Mg^{2+} decreased, significantly only after the marathon run (9), but they were in reference range after both runs. Serum osmolality significantly increased after the runs (Table VII). Long-distance races had no significant influence on serum calcium but serum phosphorus significantly increased (Table VIII). Fractional excretions (FE) of osmotically active substances significantly decreased after both runs except FE_K which significantly increased after marathon run and non-significantly decreased after 16-km run (Table IX).

Discussion

Transitory total proteinuria and albuminuria and myoglobinuria significantly increased after both runs, more significantly after the marathon run. In control investigation the values were near the initial findings. The causes of exercise proteinuria after the long-distance runs are: dehydration, capillary vasocontriction in the kidneys, increased permeability of glomerular capillaries, decreased reabsorption of proteins in renal tubules, muscle damage and release of muscle proteins into the blood, one of these proteins - myoglobin, oxidative stress and etc. [3-6].

The exercise proteinuria is both of glomerular and tubular origin and is reversible. The enhanced protein requirements of athletes may in part be due to the recurrent excretion of proteins in the urine after physical effort [6]. Increase of catalytic activity of serum creatine kinase and its isoenzyme MB after both runs was caused by rhabdomyolysis of striated muscles, but not of myocard. That was evident from the increase of serum myoglobin after the runs and myoglobinuria after the marathon run [1,3-7,15,16]. Non-glomerular erythrocyturia after the both runs was caused by microtraumas in extrarenal urinary tract [13]. The transitory decrease of glomerular filtration rate was caused by dehydration and decrease of blood flow following by decrease of effective plasma flow through renal cortex. That was the main cause of serum creatine increase after run and other cause of was the muscle damage [8,10]. According to Mingels et al. serum creatinine increased in 41% after marathon run, while cystatin C only in 21%, because it is less dependent on muscle damage [12]. In our investigated runners we did not find transitory reduction of serum Na^+ after the races, in contrast to some literature data. Main cause of hyponatremia was due to excessive fluid intake during the long-distance run [11]. Fractional excretion of potassium significantly increased after the marathon run [13], probably as a defense mechanism to prevent hyperkalaemia due to rhabdomyolysis.

Above mentioned changes in renal function findings in runners after marathon run and less significant after 16-km run were caused by dehydration, microtraumas in extrarenal urinary tract, protein catabolism, decreased urinary excretion of osmotically active substances, rhabdomyolysis, higher activation of renin-angiotensin-aldosterone system and others. In control investigations renal function abnormalities in runnres 2-6 days after marathon run and after 16-km long-distance run were not present. Investigated parameters were in the normal range or they did not significantly differ from the initial values [13].

Transitory renal functional abnormalities were more significant after the marathon run in comparison with 16-kilometre long-distance run.

Conclusion

It is necessary to realize renal function investigation in runners before long-distance races from the diagnostic, therapeutic and also from prognostic reasons to eliminate definitively pre-existing kidney damage which may be accentuated by various functional disorders during the runs.

Conflict of interest statement: for myself and the second and third authors of the article Renal function abnormalities after marathon run and 16-kilometre long - distance run, which will be published in a „Przegląd Lekarski": NONE DECLARED

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