KIDNEY FUNCTION DURING AND AFTER A 100 KM RUN

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INTRODUCTION

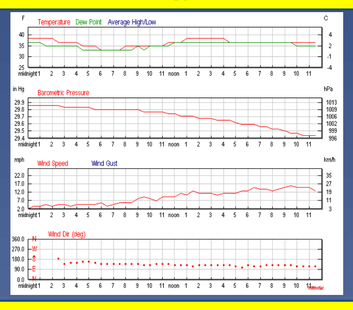
The beneficial effects for human health due to physical exercise are well known and the running is one of the most popular activities.
In many previous studies the acute kidney injury (AKI) was reported as a common complication of marathon and ultramarathon. AKI according to Acute Kidney Injury Network (AKIN) criteria was diagnosed in about 40% of marathon finishers and 30-80% of ultramarathon participants.
It is difficult to accept the fact that according to up-to date medical literature the risk of AKI in healthy persons after marathon is as high as in ailing ones with numerous co-morbidities, receiving well-defined nephrotoxic agents.
The post-exercise albuminuria is thought to be related to the intensity but not a duration of exercise.
In present study we measured creatinine clearance (CrCl) and albuminuria after every 25 km of 100 km run.

METHODS

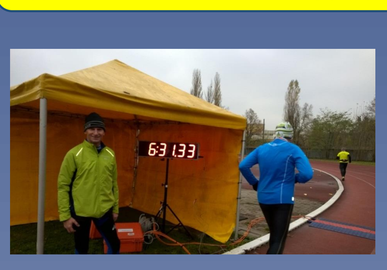
20 healthy, amateur runners (males, mean age 40,75 ± 7,15 years) took part in the 100km run on the track.
The participants were healthy, active adults, without kidney disease, diabetes, metabolic and cardiovascular disorders. All subjects had an actual physical tests and no contraindications against active sport exercises.
Blood and urine were collected before run, after every 25 km and 12 hours after run (a rest). eGFR was calculated according to MDRD and CKD EPI formulas (adjusted and unadjusted for body surface area). eCrCl was calculated using Cockcroft-Gault equation. AKI was defined using AKI Network (AKIN) criteria.
Stage 1 AKI was defied as a 1.5 to 2.0-fold increase or ≥ 0.3 mg/dl increase in serum creatinine level from pre-race creatinine value.
Albuminuria was defined as albumin to creatinine ratio (ACR; mg/g).

The rout was based in the university stadium track (400 m track circumference).

During the race the organizer provided a station offering a food and beverages such as hypotonic sports drinks, caffeinated drinks, water, fruits, chocolate, energy bars and bread.



The temperature during the run rose from 1⁰C (7 am) to 4⁰C (1-4 pm) and then dropped to 3⁰C at the end of the study (4-7 pm).

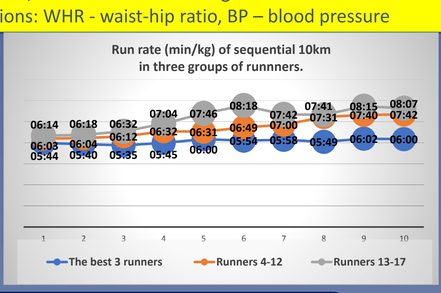


The first runner finished 100km run after 9h 52 min, the last after 13h 34 min.
The mean run rate was 6:47 min/km and decreases from 6:03 min/km during the first 10km to 7:24 min/km during the last 10 km.
The run rate of the best three runners was stable during the whole test but decreased gradually in the group of the slowest runners (right .

General characteristics of all study participants

	All runners	Finishers
Number of subjects	20	17
Age (years)	40,75 ± 7,15	40,18 ± 4,57
Male sex (%)	100%	100%
Height (m)	177,75 ± 6,58	178,59 ± 6,21
Weight (kg)	76,87 ± 8,39	77,47 ± 8,80
Body mass index (kg/m2)	24,31 ± 2,15	24,26 ± 2,28
Body fat percentage (%)	13,76 ± 5,42	13,56 ± 5,80
WHR	0,81 ± 0,06	0,81 ± 0,06
Pre-race systolic BP (mmHg)	137,82 ± 16,93	136,12 ± 10,62
Pre-race diastolic BP (mmHg)	82,4 ± 9,17	82,12 ± 7,92
Pre-race heart rate (bpm)	66,65 ± 7,70	66,41 ± 8,69
Systolic BP (mmHg) 12h after race	129,67 ± 18,12	129,94 ± 11,09
Diastolic BP (mmHg) 12h after race	75,72 ± 9,86	75,56 ± 8,12
Heart rate (bpm) 12h after race	72,61 ± 8,13	71,81±8,29
Duration of regular running (years)	6,11 ±7,19	6,31 ± 7,57
Mean training (days/month)	16,70 ± 6,69	17,11 ± 7,04
Average training km/month	225,38 ± 98,33	228,4 ± 105,22
Marathons finished (n)	43,89 ± 110,11*	48,38 ± 116,39
Ultramarathons races finished (n)	15,06 ± 13,54	15,75 ± 13,99
Marathon personal best time (h:min)	3:24 ± 0:22	03:23 ± 00:23
100km run personal best time (h:min)	12:24 ± 2:50**	12:36 ± 02:41

* one of the runners completed 477marathons. All other runners completed 21,64 marathons on average.
**most of the 100km ultramarathons were mountains trail runs. Abbreviations: WHR - waist-hip ratio, BP – blood pressure



RESULTS

17 runners completed the study. 3 subjects discontinue run and their results were not included to statistical analysis.
The increase of creatinine, urea and uric acid was observed after 100km (p< 0.05).
The mean increase of creatinine was 0,21 mg/dl (24,53%).
The mean increase of urea was 21 mg/dl (62%).
5 runners fulfilled AKIN criteria of AKI stage 1. None of the subjects met criteria for AKIN stage 2. Creatinine level decreased rapidly after the race.
The urea and uric acid levels were still significantly increased 12 h after the race.
The eGFR according to MDRD and CKD EPI formulas and eCrCl according to Cockcroft-Gault formula were significantly decreased after run (p<0.05).
Creatinine clearance calculated from the timed urine collections remains stable.

Changes of electrolytes and conventional biomarkers of AKI

	Before	25km	50km	75km	100km	rest
Creatinine (mg/dl)	0,88 ± 0,11	0,97± 0,11	1,00± 0,14	1,07± 0,167*	1,10 ± 0,20*	0,97± 0,12
Urea (mg/dl)	34,29 ± 7,25	40,12±7,91	45,35± 10,85	51,65± 13,42*	55,94± 15,34*	49,88± 12,02*
Uric acid (mg/dl)	5,15 ± 0,87	5,32± 0,96*	5,62± 1,19*	5,82± 1,37*	5,94± 1,50*	6,09 ± 1,43*
eGFR MDRD (ml/min)	98,53 ± 15,44	87,06±12,40	85± 13,96	78,88 ±15,33*	76,47 ± 14,66*	88,00 ± 14,33
eGFR MDRD BSA (ml/min)	111,24 ± 19,22	98,53 ± 15,17	95,88 ± 16,22	89,18 ± 19,37*	86,65± 18,87*	98,59 ± 18,12
eGFR CKD EPI (ml/min	105,59 ± 10,08	97,12 ± 11,88	94,59 ± 14,06	87,88 ± 15,37*	85,94± 16,82*	97,12 ± 12,34
eGFR CKD EPI BSA (ml/min)	119,59 ± 14,53	109,82 ± 15,55	106,82 ± 16,75	99,41 ± 19,23*	97,35 ± 21,51*	107,29 ± 18,84
eCrCl C-G (ml/min	124,59 ± 23,08	112,00 ± 18,94	109,76 ± 19,75	102,88 ± 22,60	101,00± 23,49*	113,53 ± 22,63
CrCl (ml/min)	141,81 ± 25,08	136,93 ± 47,55	144,04 ± 28,20	120,33 ± 38,83	137,78 ± 41,04	150,50 ± 43,33
Diuresis (ml/min)	1,725 ± 0,72	1,85 ± 1,27	1,20 ± 0,55	1,59 ± 2,01	1,60 ± 1,82	1,07 ± 0,41

*significant differences between pre race value and result in particular phases, p < 0.05
Abbreviations: GFR - glomerular filtration rate; CKD-EPI - Chronic Kidney Disease Epidemiology Collaboration; MDRD - Modification of Diet in Renal Disease; BMI - Body mass index; CrCl – creatinine clearance; C-G - Cockcroft-Gault , BSA – body surface area

Albumin to creatinine ratio

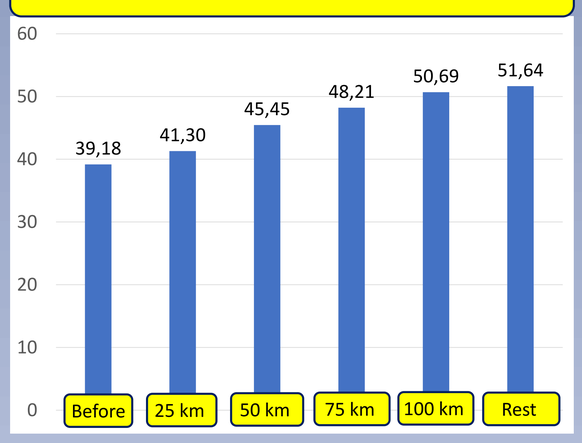
ACR was normal before run. The significant increase was observed in everyone.
There was the rapid increase of ACR during the last 25 km when the rate was the lowest.
There was no correlation between run rate and ACR.

	Before	25km	50km	75km	100km	rest
ACR (mg/g)	8,62 ± 3,14	12,31 ± 5,6*	16,08 ±5,43*	20,95 ± 12*	49,7 ± 50,39*	24,85 ± 19,86*
Run rate (min/km)	NA	6:03 ± 0,26	6:48 ± 0:53*	7:09 ± 0:53*	7:24 ± 0:57*	NA

*significant differences between pre race value and result in particular phases, p < 0.05
Abbreviations: ACR – albumin to creatinine ratio; NA - not applicable

Relative changes of GFR, creatinine, urea and UA

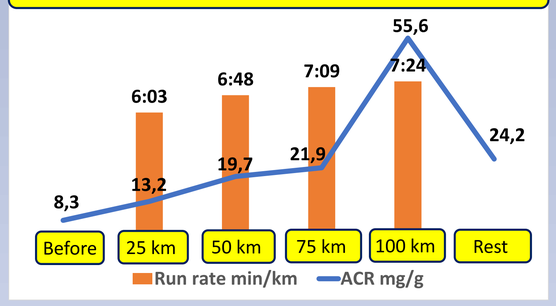
Urea : creatinine ratio



CONCLUSIONS

In contrast to the majority of previous studies we did not observed any decrease of the kidney function during an ultramarathon. According to some authors the incidence of AKI in healthy runners after ultramarathon is close to 100%.
Presented study is somehow unique because urine was collected 4 times during the 100km run and creatinine clearance was measured. In the previous studies serum creatinine level was measured and estimated GFR was calculated. Serum creatinine is the best marker of kidney function but is not ideal. Its level is influenced not only by kidney function but also by muscle metabolism. The rise of creatinine after exercise is caused by a muscle damage.
The formulas used to estimate GFR seems to be useless in young healthy man during physical exercise.
The second interesting finding of the study was that ACR was not related to intensity of the run but rather reflected a complete physical exhaustion. The highest ACR was observed at the end of the study when the running pace was very low.

Changes of ACR and run rate



Authors

Wojciech Ratkowski won a Polish Championship in Marathon in 1984 (left).
WR and WW during 78-km mountain marathon in Bieszczady Mountains in 2015 (right).

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