

Liver involvement in endurance sport: a prospective observational study in athletes participating in a semi-marathon

Abstract

Background: The health benefits of endurance sports are undeniable. Nevertheless, sometimes during these sports, individuals can be exposed to acute physiological imbalances, sometimes pathological and serious. Unlike gastrointestinal complications that are frequent and often benign, liver damage is very rare and poorly understood during these sports. Our objective was to study the hepatic disturbances in athletes during endurance activity, as well as the various individual and environmental factors that may influence their occurrence and prognosis.

Methods: A prospective observational study in 50 military athletes participating in a semi-marathon in southeastern Tunisia.

Results: Hepatic and/or muscular cytolysis was observed in 53% of the runners for ALAT, 53% for ASAT, 38% for both ASAT and ALAT, 61% for creatinine phosphokinase, and 85% for lactate dehydrogenase. Total bilirubin was elevated (minimal cholestasis) in 36% of subjects and associated with hepatic cytolysis in 78% of cases. Only two serious cases of hepatitis were noted (ischemic liver injury). Further evolution was favorable in all cases. These clinico-biological disorders were significantly more frequent in younger, less trained, and less acclimatized athletes.

Conclusion: These complications deserve to be known and considered in endurance sports. Their best treatment remains preventive based on regular training, acclimatization, appropriate diet, and hydration.

Keywords: liver, endurance sport, cytolysis, exercise hepatitis, ischemic liver, athlete's hepatitis

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Salem Bouomrani,^{1,2} Aïda Hmidi,¹ Maher Beji^{1,2}¹Department of Internal medicine, Military Hospital of Gabès, Tunisia²Sfax Faculty of Medicine, University of Sfax, Sfax 3029, Tunisia

Correspondence: Prof. Salem Bouomrani, MD, PhD,
Department of Internal medicine, Military Hospital of Gabès,
Gabès 6000, Tel: +00216 98977555

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Introduction

Nowadays, endurance sports (running such as marathon and half-marathon, cycling, canoeing, rowing, combined events such as triathlons, etc.) are very popular due to the publicity about their supposed health benefits (reduction of metabolic risk factors and incidence of many cardiovascular diseases) and their accessibility to the general public.^{1,2} During these sports, individuals are often subjected to intense physical stress, exposing them to acute, sometimes pathological and serious, physiological imbalances.

Digestive manifestations during endurance sports are divided into three main types: esophagogastric, intestinal, and hepatic.³ Unlike gastrointestinal complications, which are frequent and often benign, liver damage secondary to endurance sports is very rare because the liver is an organ typically protected during physical activity due to its high blood flow.¹⁻⁴

Apart from the classic ischemic hepatitis associated with malignant exertional hyperthermia, which is exceptionally symptomatic but more frequent than the cases described,⁵⁻⁷ the occurrence of liver function abnormalities in endurance sports is rare,³⁻⁵ poorly understood, and characterized by its often atypical symptoms and complex pathophysiology.^{4,8}

Therefore, liver disorders related to sport deserve further study in order to understand their origin and pathogenesis, facilitate their diagnosis, management, and prevention.⁴

The aim of our study was to investigate liver abnormalities in athletes during endurance activities (half-marathon), as well as the various individual and environmental factors influencing their occurrence and prognosis.

Methods

Type and location of the study: This is a prospective observational study conducted in southeastern Tunisia, among a population of active military personnel belonging to the 1st Brigade of the Tunisian National Army and residing in the two governorates of Medenine and Gabès. The participants took part in a half-marathon over a total distance of 21.15 km in the governorate of Medenine (southeastern Tunisia).

Inclusion criteria: Active duty military personnel, aged 20 years or older, with no prior medical history (specifically, no renal, cardiac, or hepatobiliary diseases), and with normal initial physical examination and liver function tests (transaminases, direct and total bilirubin, and prothrombin time) were selected for this study. Subjects reporting incidents during previous competitions were excluded.

Study Protocol: All military personnel included in this study were previously and clearly informed of the protocol and procedures of the competition and gave their oral and written consent. Summoned 24 hours before the competition, the selected military personnel underwent a complete physical examination, including blood pressure, heart rate, respiratory rate, axillary temperature, cardiac and pulmonary auscultation, and abdominal palpation. They also

underwent blood tests, including a complete blood count (CBC), aspartate aminotransferase (ASAT), alanine aminotransferase (ALAT), direct (DB) and total (TB) bilirubin, creatine phosphokinase (CPK), lactate dehydrogenase (LDH), gamma-glutamyl transferase (γGT), alkaline phosphatase (ALP), prothrombin time (PT), urea, and plasma electrolytes (sodium, potassium, and chloride) to ensure their normal levels. Each candidate was asked to complete a detailed questionnaire detailing their usual physical activities, nutritional and behavioral habits (particularly smoking and alcohol consumption), level of preparation for the competition, and any medication or doping substances they may have used.

The physical examination and blood tests were conducted again on the morning of the competition before the start of the race (test 1) and 120 minutes after the race (test 2).

In cases where an abnormality was noted, the blood parameters were regularly monitored after the race and in a reproducible manner until they returned to normal.

During the race, medical support was provided by two fully equipped ambulances (each ambulance staffed by a general practitioner, two nurses, and an anesthesia/resuscitation technician), one at the front of the race and the other at the rear. Water stations with sponges were located every 3 to 5 km along the race course.

Upon arrival, functional symptoms were collected separately for each runner by two general practitioners.

Candidate distribution

Distribution according to age: the candidates were divided into three categories by ten-year intervals: category A (21 to 30 years), category B (31 to 40 years), and category C (≥41 years).

Distribution according to geographical origin: the runners were divided into two groups according to their governorate of residence. This distinction reflects the degree of acclimatization to the atmospheric conditions of the race: Group I (good, runners from the Medenine region where the competition took place) and Group II (poor, runners from the Gabès region).

Distribution according to training level: Based on the frequency and duration of physical activity sessions completed by the candidates, as well as the total duration of their training program preceding the race, candidates were divided into three groups: Group 1 (untrained or poorly trained: physical activity ≤ 3 hours per week for less than 3 weeks), Group 2 (moderately trained: physical activity of 4 to 6 hours per week for 3 to 5 weeks preceding the competition), and Group 3 (well-trained: activity > 6 hours per week for more than 5 weeks).

The start was staggered every 15 minutes between the three groups.

Statistical analysis: Data were entered using SPSS software for Windows 7 (version 20.0). The epidemiological, clinical, and paraclinical characteristics of the different groups were compared. Results were expressed as mean and standard deviation for quantitative variables, and as percentages for qualitative variables. Means were compared using Student's t-test or Kruskal-Wallis test. The association between qualitative variables was assessed using the chi-square test. A p-value < 0.05 was considered statistically significant.

Results

The atmospheric conditions (outside temperature, ambient humidity, altitude, wind direction and speed) on race day in both governorates are summarized in Table 1.

Table 1 Atmospheric conditions in the governorates of Gabès and Médenine on the day of the competition during the three hours of the race

	Temperature		Humidity		Wind speed		Wind direction	
	Gabès	Médenine	Gabès	Médenine	Gabès	Médenine	Gabès	Médenine
H1	21,6° C	24,6°C	0.46	0.25	4 N	10 N	E/NE	E/NE
H2	22,8° C	26,9°C	0.48	0.21	8 N	14 N	E/NE	E/NE
H3	25,4° C	29,4°C	0.35	0.19	10 N	14 N	E/NE	E/NE

H1, first hour; H2, second hour; H3, third hour; N, north; E, east; NE, northeast

We selected 50 male candidates. The small sample size is explained by the availability of our military personnel (only those belonging to the military athletics team who were out of service the day of the race participated).

The average age was 33 years [range 23-48]. Seventy-two percent of the runners were non-smokers and 94% did not consume alcohol. For the 6% who were occasional alcohol consumers (2-3 drinks/month), their last drink had been more than fifteen days before the competition.

Table 2 shows the distribution of runners according to age group, training level, and degree of acclimatization. The race lasted between 1 hour 30 minutes and 2 hours 20 minutes.

Table 2 Distribution of runners according to age group, training level and degree of acclimatization

	Number/50	Proportion (%)
Age group		
Category A (21-30 years)	16	32%
Category B (31-40 years)	21	42%
Category C (≥ 41 years)	13	26%
Training level		
Group 1 (poorly trained)	16	32%
Group 2 (moderately trained)	13	26%
Group 3 (well trained)	21	42%
Degree of acclimatization		
Group I (good)	26	52%
Group II (poor)	24	48%

We observed an increase in serum ASAT activity between the pre- and post-race periods in 26 competitors (53%). The mean value for analysis 1 was 32.5 IU/L, while that for analysis 2 was 36 IU/L, representing a 13% increase. An increase in serum ALAT activity was also found in 53% of the runners. The mean value for analysis 1 was 23.8 IU/L, while that for analysis 2 was 27.6 IU/L, representing a 16% increase. A simultaneous increase in serum activity of both

transaminases (ASAT and ALAT) was observed in 19 subjects (38%). These increases were significantly more pronounced in younger runners compared to older runners ($p=0.04$ for ASAT and <0.01 for ALAT), in those with poor or moderate training compared to those with good training ($p=0.03$ for ASAT and <0.01 for ALAT), and in those with poor acclimatization compared to those with good acclimatization ($p<0.01$ for both ASAT and ALAT) (Table 3).

Table 3 Variation in transaminase levels according to age group, training level, and degree of acclimatization

	ASAT				p	ALAT				
	N/%	M1 (UI/l)	M2 (UI/l)	P (%)		N/%	M1 (UI/l)	M2 (UI/l)	P (%)	p
Age group										
Category A (21-30 y)	10=62%	31	36	16		12=75%	22	30	36	
Category B (31-40 y)	10=50%	31	35	13	0.04	10=50%	22	25	13	<0.01
Category C (≥ 41 y)	6=46%	34	36	6		4=31%	29	29	0	
Training level										
Group 1 (poorly trained)	13=82%	29	37	27		15=94%	23	33	43	
Group 2 (moderately trained)	8=62%	35	42	20	0.03	7=54%	22	25	14	<0.01
Group 3 (well trained)	5=25%	33	33	0		4=20%	25	25	0	
degree of acclimatization										
Group I (good)	11=42%	31	32	3	<0.01	12=46%	27	30	11	<0.01
Group II (poor)	15=62%	34	39	15		14=58%	21	26	23	

N, number of runners who experienced an elevation in transaminases between tests 1 and 2; M1, mean transaminase level before the race; M2, mean transaminase level after the race; P(%), percentage increase in transaminases = $M2-M1/M1$

Total hyperbilirubinemia ($\geq 17 \mu\text{mol/L}$) was observed post-race in 18 of our participants (36%). It was minimal, with an increase ranging from 0.6 to 12.6 $\mu\text{mol/L}$ compared to baseline levels, and associated with hypertransaminasemia in 78% of cases and elevated LDH in 100% of cases. Regarding muscle enzymes, 85% of runners showed a moderate increase in LDH (maximum at 1.6N, with a mean increase of 98 IU/L), and 61% showed an increase in CPK activity (maximum at 2.7N, with a mean increase of 47 IU/L). These changes were associated with hypertransaminasemia in 93% of cases. No correlations were noted between the different groups for changes in muscle enzymes. Even minor abnormalities in biological tests had normalized in biochemical tests performed three and seven days after the competition in all cases.

Two cases of severe liver injury were recorded during this event: One case of acute hepatitis related to exercise-induced liver hypoxia: a 40-year-old man presented at 19 km of the race with watery diarrhea, fever of 38°C, hypotension, leukocytosis of 11,300/ mm^3 , thrombocytopenia of 74,000/ mm^3 , maximal liver cytolysis with ASAT at 39N and ALAT at 65N, PT at 56% initially then falling to 10% 10%, cholestasis with TB at 180 $\mu\text{mol/L}$ and DB at 98 $\mu\text{mol/L}$, and rhabdomyolysis (CPK at 46N and LDH at 8N) without renal failure; and one case of severe acute hepatitis at the eighth kilometer of the race in a 29-year-old man (sudden loss of consciousness, fever of 38°C, hypovolemic shock, leukocytosis at 12,700/ mm^3 , rhabdomyolysis (CPK at 3.5N and LDH at 2.2N) without renal failure, maximal hepatic cytolysis at 6N for ASAT and 8N for ALAT, and a PT of 49%. The outcome was favorable in both cases with appropriate resuscitation, with progressive normalization of liver function tests and a return to normal after forty days. In both cases, further paraclinical investigations revealed no abnormalities: abdominal ultrasound and CT scan, Doppler ultrasound of intra-abdominal vessels, upper gastrointestinal endoscopy, brain CT scan and lumbar puncture, blood cultures, echocardiography, and serological tests for hepatitis B, C, A, and E, HIV, CMV, EBV, and leptospirosis.

Apart from these two cases, no pathological values were observed for γGT and ALP as well as PT. Similarly, the CBC, plasma urea and blood ionogram did not significantly change between the two assessments (assessment 1 and 2).

Discussion

Endurance sports, due to their health benefits, particularly an overall improvement in quality of life, a slowing of physiological aging, and a reduction in coronary risk,⁹⁻¹³ have become very popular in recent decades. Conversely, they can have a negative, sometimes serious, impact that can lead to organ dysfunction (heart, liver, kidneys, etc.).^{3,4}

The digestive tract is one of the key systems in regulating adaptation and regeneration in athletes [14], explaining the frequency of digestive involvement during endurance sports; it is estimated that 20 to 50% of athletes experience gastrointestinal symptoms.¹⁴⁻¹⁶ These symptoms are one and a half to three times more frequent in elite athletes than in recreational athletes.¹⁵ Unlike the digestive tract, the liver, located downstream of the splanchnic circulation, is considered a relatively well-protected organ during physical exertion.^{1,2,4,5} Its arterial and venous vascularization is ensured by a double arteriovenous and portal capillary network. During exercise, the decrease in splanchnic blood flow leads to a decrease in hepatic blood flow. The decrease in hepatic blood volume thus varied from 14 to 18%;³ which made liver the least affected organ by vascular changes in the abdominal cavity.^{1,2,4,5}

During exertion, and despite its rich vascular network, the liver is subjected to stresses requiring constant adaptation. Liver damage occur When the adaptive mechanisms are overwhelmed.^{4,5} However, the liver remains a much less frequently affected organ than the rest of the digestive tract,^{1,2,4,5} and the hepatic biological disturbances induced by endurance sports are still poorly understood and often overlooked by clinicians: clinical presentation is often subtle, and

biochemical manifestations are frequently delayed by a few hours to a few days.^{1,2,4,5,8}

It is now recognized that intense and prolonged physical exercise, particularly marathon and half-marathon races, leads to a significant increase in all liver function tests (ASAT, ALAT, DB, TB, γ GT, and ALP), although without exceeding the upper limits of normal levels.^{1,2,4,5,8,17} The majority of this increase in transaminases stems from muscle lysis; liver damage is typically secondary and minimal.^{4,18} The predominance of elevated ALAT levels, as well as the

association of hypertransaminasemia with even minimal cholestasis or hepatocellular failure, confirms the hepatic origin of these enzymatic abnormalities.^{4,13,19,20}

In the absence of any underlying liver injury, bilirubin may be elevated due to the continuous hemolysis typical of intense and prolonged physical exercise.^{4,13}

Comparison of our results with those in the literature shows a comparable evolutionary profile for ALAT, while for ASAT our values were significantly lower than those of other authors (Table 4).^{21,23}

Table 4 Comparison of transaminase evolution profiles during endurance sports in different literature series

Enzyme	Author (sport)	De Paz JA ²¹ (100 Km)	Nuviala RJ ²² (marathon)	Priest JB ²³ (semi-marathon)	Our Study (semi-marathon)
ALAT (U/l)	Before	17.5	22.6	13	23.8
	After	24.8	23.7	22	27.6
	Average increase	7.3	1.1	9	3.8
ASAT (U/l)	Before	21.5	28.4	13	32.5
	After	63	44.1	22	36
	Average increase	41.5	15.7	9	3.5

This more significant cytolysis, predominantly affecting ASAT in the series by De Paz JA and Nuviala RJ, is mainly related to rhabdomyolysis given the severity of the exercise performed (marathon and 100 km race).^{21,22}

Hepatic involvement itself is constant in exertional hyperthermia or “exertional heat stroke”.^{4,6,7,24} This involvement manifests in 90% of cases as moderate, transient, and subclinical cytolysis.^{1,2,4,5} In 10% of cases, it is severe, resulting in acute liver failure, which is fatal in half of cases.^{1,4,6,7} This hepatitis can sometimes be fulminant and require emergency liver transplantation.^{1,4,6,19,25,26} Histologically; Hepatocyte destruction is presented in the form of necrosis with intracytoplasmic vacuolation, the centrilobular localization of which suggests an ischemic mechanism.^{4,5}

In mild cases, liver function tests are elevated immediately after running and remain so for the following 24 hours, except for γ GT, which begins to decrease from the sixth hour after the end of exercise.^{4,8} A return to normal levels is generally observed after two days.^{4,17}

The pathophysiology of liver damage during endurance sports involves relative tissue hypoxia/ischemia secondary to reduced splanchnic blood flow, excessive production of free radicals and oxidative stress, and exercise-induced mitochondrial dysfunction.²⁷⁻²⁹ All of these factors lead to suffering and lysis of hepatocytes, more or less marked depending on the nature and duration of the effort, which in extreme cases can lead to shock liver or classic “hypoxic athlete’s hepatitis”, which remains exceptional.^{27,29-31}

Hepatobiliary disorders caused by endurance sports are primarily determined by the nature, duration, and intensity of the physical exercise;^{1,2,4,5,26} many other factors influence the onset and severity of these disorders, such as age, sex, hydration status, training and acclimatization levels, medication and dietary intake, and any underlying pathologies. Indeed, these disorders appear to be more frequent in young, female athletes who are dehydrated, undertrained, poorly acclimatized, and those with pre-existing liver disease and/or taking substances potentially toxic to the liver and gastrointestinal tract (non-steroidal anti-inflammatory drugs, anabolic steroids,

etc.).^{1,2,4,32} Hereditary genetic factors, particularly muscle enzyme determinants, are also implicated.^{4,13,33}

All of these findings indicate that clinical signs and variations in liver function tests must be considered when selecting and preparing candidates for high-level competitions;^{4,8,17} and similarly, when selecting military personnel for special missions requiring intense and/or prolonged physical exertion.

Recommendations to avoid or minimize liver and digestive system involvement during endurance sports include regular training, lifestyle modifications, suitable diet, adequate hydration, and the avoidance of all doping products.^{1,2,15,34}

Conclusion

Hepatic manifestations associated with endurance sports remain exceptional but potentially fatal, and deserve to be well understood by all healthcare professionals. Thus, and based on this study, we can conclude that:

Biologically: intensive daily training can lead to a moderate elevation of liver enzymes (ALAT and ASAT), without being linked to a precise etiology and without associated muscle damage. Besides the primary role of the intensity of the effort, the training level and the diet could play a role.

- The most serious liver involvement is the exercise-induced heat stroke (ischemic hepatitis or athlete’s hepatitis); this is indeed an exceptional but potentially fatal form with neurological disorders, temperature exceeding 40°C, and significant liver cytolysis that can progress to acute hepatocellular failure requiring emergency liver transplantation, most often in the context of multiple organ failure.
- All of these disorders are significantly more prevalent and pronounced in younger athletes, those who are less well-trained, and those who are poorly acclimatized to the conditions of the competition.
- These disorders, as well as the changes in various liver function parameters during and after physical activity, are important to

understand for both sports physicians and laboratory professionals in order to interpret them correctly in the context of competition or intense and prolonged physical activity.

- Prevention of these complications relies primarily on proper physical preparation, effective hydration, and prior acclimatization.

Conflicts of interest

The authors declare that there are no conflicts of interest.

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