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PHYSIOLOGICAL ADAPTATIONS TO EXERCISE DURING A SHORT-TERM FASTING

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A b s t r a c t

Metabolic responses to physical activities in subjects on normal diets are well known, but only a few studies have assessed the effects of dietary conditions on endurance performance during a ritual fasting such as Ramadan. We undertook the present study to gain more information into alterations in physiological parameters induced by a short-term fasting. Young and healthy athletes performed high intensity exercise, lasting for one hour, on two occasions, i.e., on a normal diet and after fasting for 11 hours. The blood glucose concentration, body temperature, heart rate and arterial blood pressure were determined at rest and at regularly intervals during physical activity. Fasting was clinically well tolerated by all the subjects. During exercise there were no differences in glycaemia, heart rate, blood pressure or body temperature between subjects under the two different diet conditions. The subjects on a normal diet showed an increase in central temperature and blood glucose levels at rest.

K e y w o r d s

Fasting, Glycaemia, Central temperature, Exercise, Ramadan

INTRODUCTION

Metabolic responses to physical activities under usual dietary conditions are well known (*1*) but very few studies have attempted to assess effects of dietary manipulations and biological responses and endurance performance during ritual fasting such as Ramadan (*2, 3, 4*).

The aim of this trial was to obtain more information on eventual alterations induced by the ritual fasting of Ramadan at rest and during hard physical activities at an elevated ambient temperature and to be able to provide advice to young sportsmen periodically engaged in competitive sports even during periods of diurnal fasting.

MATERIALS AND METHODS

SUBJECTS

Twelve young men participated in this study. The mean age was 22.5 ± 1.7 years, and mean weight and height were 72.7 ± 6.9 kg and 1.76 ± 0.06 m, respectively. All subjects came from the tropical region and were students of the Institute of Sports. They were engaged in collective or

individual physical activities 3 hours daily. Consequently, they were well trained and naturally adapted to a hot climate.

Environmental conditions

Experiments were carried out in Dakar (Senegal), which lies by the sea at 13° North latitude in the tropical region, in March. This month is a relatively warm period; at the time of the trial, ambient temperature ranged from 21° C at 6.00 AM to 32° at 6.00 PM, and relative humidity ranged from 85 to 70%. The experimental room was set up in the „Institute National de l'Éducation populaire et des Sports".

Apparatus

Bicycle ergometer allowing permanent control of exercise intensity. This intensity was submaximal, corresponding to 75% of maximal heart rate according to the Astrand's formula (*1*) and was maintained constant during the entire test.

ECC recorder for a constant monitoring of heart rate (HR) so that the immediate adjustment of a power output was possible every 5 min to preserve a steady state.

One-touch equipment for instantaneous measurement of glycaemia in blood samples taken from the ball of a finger.

Electronic multi-channel thermometer permitting simultaneous periodic determinations of ambient, skin (cutaneous) and rectal (central) temperatures.

Mercury tonometer used for periodic blood pressure measurements.

Experimental design

The subjects participated in two trials, in the first they ate normally and in the second they fasted. The trials were separated by at least 2 weeks.

In the first trial, the subjects were involved in normal activities of the Institute. They kept off alcohol, coffee and tobacco and rested after lunch. They came to the laboratory 20 min before the test for assessment of their body weight and height, plasma glucose concentration, ambient and body temperatures. The submaximal test with a steady state lasted 1 hour. Temperatures and blood pressure were measured every 10 min and glycaemia was assessed every 20 min.

During the fasting period (Ramadan), the subjects had breakfast at 5.00–5.30 AM and did not eat or drink anything till sunset (6.30–7.00 PM). They carried out regular activities till 12 AM, including individual and collective sports or training. Then they rested till the test, which was preceded by the measurements as described above.

The local ethical committee approved of the experimental protocol and informed consent was obtained from each participant.

Data analysis

Data are given as mean ± SD. Standard statistical methods, including analysis of variance and Student's paired *t*-test, were applied as appropriate. The results at $P < 0.05$ were considered statistically significant.

RESULTS

None of the subjects reported any problem as a consequence of the short fasting and none of them was hypoglycaemic or even tired by fasting before the test.

The fasting was accompanied by a mean weight decrease of 2.9 ± 6.7 kg, (4% loss of weight, $P < 0.05$). A further decrease in weight associated with one-hour activity was 0.9 kg (1.3% weight loss) under normal diet conditions and 0.8 kg (1.1%) during fasting. The difference between these conditions was not significant.

Plasma glucose levels are shown in *Table 1*. They were in the normal range at rest and decreased significantly with physical activity by 20% during the first 20 min; they remained at this level during the rest of exercise. After 11 hours of fasting, glycaemia at rest was significantly lower (by 21%) than with a normal diet. It did not change significantly either after 20 min of exercise or during the whole exercise.

There was no significant difference between heart rate values at rest (normal and fasting diet, 67.3±5.7 cpm and 67.0±6.7 cpm, respectively) and those during exercise (normal and fasting diet, 147.9±1.4 cpm and 148.2±1.1 cpm, respectively).

Arterial blood pressure values at rest and during exercise are shown in *Table 2*. There were no statistically significant differences. Physical activity resulted in a 41% increase in systolic blood pressure and this level remained almost constant throughout the exercise. Diastolic blood pressure did not change in any situation.

The normal diet or fasting had no effect on skin temperature and there was no difference between rest and exercise values. With fasting, rectal temperature was lower at rest ($P<0.05$), but achieved the same value as that with normal diet at the end of exercise (*Table 3*).

Table 1
The effect of fasting and normal diet on plasma glucose levels

	At rest (ml/l)	During exercise (ml/l)		
		20 min	40 min	60 min
Normal diet	9.3 ± 1.1*	7.4 ± 0.9	7.3 ± 0.7	7.4 ± 0.6
Fasting	7.3 ± 0.1	7.1 ± 1.0	7.4 ± 1.0	7.2 ± 1.1

*, statistical differences between the rest value and exercise values (P< 0.01) within the row.

Table 2
Mean values of systolic and diastolic blood pressure on the double trial

	At rest (mmHg)	During exercise (mmHg)		
		20 min	40 min	60 min
Normal diet	124/ 78	172/ 80	179/ 80	177/ 80
Fasting	120/ 81	179/ 81	169/80	172 / 78

Table 3
The effects of normal diet and fasting on body temperature before and during exercise

Diet	Skin temperature (°C)		Rectal temperature (°C)	
	Rest	End of exercise	Rest	End of exercise
Normal diet	34.3 ± 1.8	33.8 ± 1.9	37.3 ± 0.4*	37.9 ± 0.3
Fasting	32.6 ± 2.1	31.8 ± 1.8	36.8 ± 0.3	37.9 ± 0.4

*, statistical difference (P< 0.05) between the values within the column

DISCUSSION

Generally, fasting leads to mobilisation of liver glycogen (with an increased gluconeogenesis) and to elevated values of free fatty acids (*5*) for maintaining a sufficient blood glucose concentration at rest. Nevertheless, according to various authors, the effects of fasting on glycaemia at rest have been reported to vary from an increase (*5*) to a decrease (*6,7)* with no change on many occasions (*8,9*). Certainly, differences in diet, various levels of activities during fasting and/or different degrees of physical training may explain these diverse findings.

In our study, plasma glucose levels during fasting were lower at rest than those under normal diet conditions. However, during exercise the diet had no effect on plasma glucose concentrations. Heart rate and blood pressure both at rest and during exercise, which was set up at an submaximal intensity corresponding to 75% of maximal heart rate according to the Astrand's formula (*1*), was not influenced by dietary conditions. These, however, had an effect on central (rectal) temperature at rest, which is related to thermogenesis induced by food (10); under the normal diet central temperature was significantly increased. There was no difference in central and skin temperature at the end of exercise between normal diet and fasting conditions.

Two risk factors are related to exercise in a hot climate without food and water intake, i.e., hypoglycaemia and hypothermia (*4*). Fasting before physical activity may lead to muscle glycogen sparing and exercise results in mobilisation of liver glycogen with increased gluconeogenesis and a much greater use of free fatty acids for fuel (*9, 11, 12, 13*). These mechanisms facilitate the maintenance of a sufficient blood glucose concentration during physical activities. Similar findings were made in rats (*14*). In humans, fasting for 24 h has resulted in a reduction of performance capacity (*9*) or a shorter time before exhaustion occurred (*15*). We did not observe such deleterious effects of fasting because our protocol involved only a 75% of the maximal exercise intensity for a relatively short time (1 h) at ambient temperature that was not much elevated (*16*).

It can be concluded that young Muslim sportsmen can carry on their exercise during fasting periods in a hot climate with no harmful effects, supposing they are well informed, trained and adapted to hot weather. Top competitive sports, however, should be avoided during Ramadan.

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FYZIOLOGICKÁ ADAPTACE NA TĚLESNOU AKTIVITU BĚHEM KRÁTKODOBÉHO PŮSTU

S o u h r n

Metabolické odpovědi na tělesnou aktivitu při normálním příjmu potravy jsou dobře známy, ale jen málo studií se zabývalo hodnocením vlivu stravování na tělesnou výkonnost, zvláště během postních období jako je Ramadan. Tato studie byla provedena s cílem získat více informací o změnách fysiologických parametrů vyvolaných krátkodobým půstem. Mladí a zdraví atleti cvičili s vysokou intenzitou po jednu hodinu za podmínek normální diety a po jedenácti hodinách hladovění. Koncentrace glukozy v plasmě, tělesná teplota, srdeční frekvence a krevní tlak byly měřeny v klidu a během cvičení. Hladovění bylo dobře tolerováno všemi jedinci. Během cvičení jsme nenalezli rozdíly v hladině glukózy v plasmě, srdeční frekvenci, tlaku a tělesné teplotě mezi oběma dietami. V klidu normální příjem potravy zvýšil centrální teplotu a hladinu glukózy v plasmě.

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