The Effects of Ramaḍān Fasting on Maximum Oxygen Uptake and Maximum Performance

Najwa Sweileh, MA, Gary Hunter, PhD, Amy Schnitzler, MA
Birmingham, AL

DOI: http://dx.doi.org/10.5915/22-4-14314

Abstract

The purpose of this study was to test maximal aerobic capacity and maximal performance during Ramaḍān fasting. Six volunteer subjects participated in the experiment. Venous blood samples were drawn, three-day dietary records were obtained, and body composition was measured before Ramaḍān and during both the first and last weeks of Ramaḍān. Venous blood samples were analyzed for sodium, chloride, and protein. Treadmill measurements of maximum oxygen uptake ($\dot{V}O_2$ max), ventilation, and respiration rate were recorded during the mornings and afternoons pre-Ramaḍān, during the first week of Ramaḍān, and during the last week of Ramadan. First week Ramaḍān tests showed a decrease in $\dot{V}O_2$ max with a return to the pre-fasting levels in the last week. Ventilation and heart rate did not change, but respiration rate significantly decreased in the afternoon tests. Sodium, chloride, and protein increased during the first week and returned to the pre-fasting levels during the last week of Ramaḍān. Body weight significantly decreased throughout the experiments. While percent fat decreased during the last week, lean weight did not change. This study indicates a state of dehydration occurred during the first week of Ramaḍān which was responsible for the decrease in body weight and may have contributed to the decrease in $\dot{V}O_2$ max. Rehydration took place by the last week of fasting with $\dot{V}O_2$ max returning to pre-Ramaḍān levels.

Key words: *Ramaḍān, fasting maximum oxygen uptake, weight loss, maximal performance, dehydration.*

Ramaḍān is the ninth month of the Islamic lunar calendar and during this month all capable Muslims must fast.[1] Fasting demands complete abstinence from food and drink from dawn to sunset every day during Ramaḍān. Muslims take two main meals: Saḥoor, which is the predawn meal, and Iftār, which breaks their fast after sunset.[1]

Large quantities of carbohydrate are consumed in Ramaḍān in the form of sugar-sweetened juices and pastries; in addition, total fluid intake decreases.[2] There is also a loss in body weight[3] and a reduction in frequency of eating and energy intake,[4] as well as reduction in energy expenditure and respiratory quotient during rest.[3]

From Department of Health, Physical Education and Recreation, the University of Alabama at Birmingham.

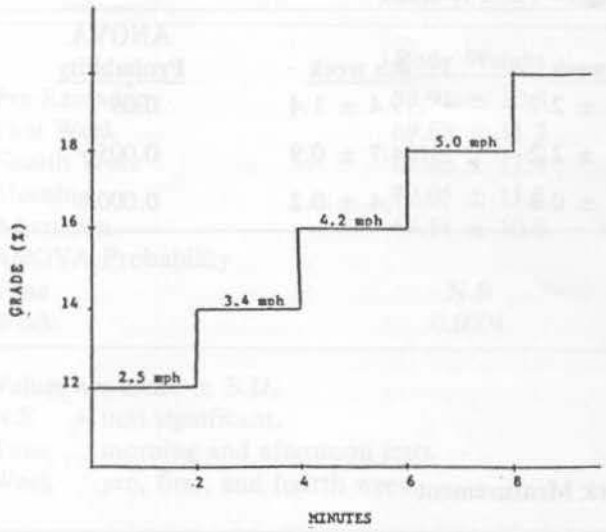
Reprint Requests: Dr. Gary Hunter
Department HEPE Rm #113
Education Building
UAB
Birmingham, AL 35294

Some of the biochemical changes noted during fasting are an increase in serum uric acid, triglycerides, cholesterol, thyroxine,[5,6] and a reduction in blood glucose.[7]

Muslim athletes also observe fasting during Ramaḍān as a requirement of their religion. The metabolic changes during Ramaḍān may affect their performance. One study by Schmahl[8] reported an increased incidence of hypovolemic shock in laborers during Ramaḍān and recommended a reduction in heavy labor during this time. Pequignot, Peyrin, and Peres[9] observed that when untrained male subjects fasted for fifteen hours, work time to exhaustion at 80% $\dot{V}O_2$ max, was decreased. So far as we know, no other studies have reported performance changes during the religious month. Since fluid and energy deprivation occur during Ramaḍān, and marked fluctuations in blood parameters are noted, it would seem important to measure performance and aerobic capacity at different times during the day in Ramaḍān.

Therefore, the objective of this study was to observe fluctuation in aerobic work capacity during

Figure 1. Modified Bruce Protocol



Ramaḍān fasting.

Methods

Five healthy male Muslims and one female Muslim, ages 22 to 31, served as subjects. All subjects completed a health questionnaire and gave informed consent. Physical characteristics of the subjects, age, height, weight and percent body fat, were measrued prior to the test.

All subjects completed a total of six maximal exercise tests. Morning and afternoon tests were completed one week before Ramaḍān, during the first week of Ramaḍān, and during the last week of Ramaḍān. Exercise heart rate was monitored during the last 10 seconds of each work load. Oxygen uptake was continuously recorded every 30 seconds.

A modified Bruce protocol treadmill test (Figure 1) was used to evaluate aerobic work capacity.[10] The test was terminated when volitional fatigue occurred. Oxygen uptake and exercise heart rate were continuously monitored throughout this test. Respiratory quotient of at least 1.0, or heart rate within 10 beats of age -predicted maximum were considered as a criteria for $\dot{V}O_2$ max.

Maximal oxygen uptake was determined during the modified Bruce protocol treatmill test. This protocol consisted of a continuous increase in both the speed and percent grade of the treadmill. Five minutes warm-up was allowed at 10% grade and 2.5 mph. Work load was increased every two minutes thereafter: 1) 12% grade at 2.5 mph, and 2) 14% grade at 3.4 mph. Each work load after that was completed with an increase of 2% grade and 0.8 mph, until voluntary exhaustion occurred.

Respiratory gases were collected in a mixing chamber and analyzed continuously. Oxygen was analyzed on a Beckman OM11; CO_2 on a Beckman LB-2; and volume of gas was measured on a Parkinson-Cowan dry gas meter. Determinations were made on line using a Rockwell International AIM 65 computer. The analyzers were calibrated before and after each measurement with micro-Schollander analyzed gases. Heart rate was monitored on a Burdick electrocardiogram unit.

Table 1. Physical characteristics of the subjects.

Id	Age (Years)	Sex	Height (cm)	Body Weight (kg)	% Body Fat
1	31	F	170.0	57.17	18.9
2	22	M	180.0	71.74	12.7
3	29	M	160.0	67.73	26.1
4	24	M	177.8	82.27	33.6
5	28	M	175.3	85.69	-
6	29	M	172.2	60.68	18.3
M	27.1		172.3	70.88	21.9
SD	±3.4		±7.3	±11.28	±8.1

Venous blood samples of 10 ml were drawn at 6:00 p.m., four days before Ramaḍān, on the third day of Ramaḍān and during the fourth week of Ramadan. Blood samples were analyzed for sodium, chloride, and protein.

The subjects kept records of food intake prior to Ramadan, during the first week of Ramaḍān, and during the last week of Ramaḍān. Sample portions were estimated using nutrition plastic samples. Three consecutive days, including at least one weekend day were recorded for each of the three weeks of the tests. These measures were analyzed using a computerized nutrition system, The Food Processor, published by ESHA.[11]

To evaluate the differences across time for each of the performance variables, one way analysis of variance with repeated measures was performed for blood analyses, body composition, and dietary record. Two way analysis of variance with repeated measures was performed for all other variables. Statistical significance was set at 0.05.

Results

Physical characteristics of the subjects before Ramaḍān are presented in Table 1. It includes age, height, percent body fat, and weight for each subject during the control period. Blood analysis results are presented in Table 2. A significant increase in sodium, chloride, and protein was observed during the first week of Ramaḍān (1.8%, 4.0%, and 8.7%, respectively), with a return to prefasting levels during the last week of Ramaḍān. The data from blood analysis indicate that hemoconcentration occurred during the first week of Ramaḍān. The return of the concentration of the substances analyzed to normal

Table 2. Blood analysis

	Pre-test	1st week	4th week	ANOVA Probability
Sodium mEq/liter	139.9 ± 0.6	142.4 ± 2.7	139.4 ± 1.4	0.03
Chloride mEq/liter	104.2 ± 1.6	108.3 ± 2.2	104.7 ± 0.9	0.005
Protein g/deciliter	7.6 ± 0.3	8.2 ± 0.3	7.4 ± 0.2	0.0003

Values are mean ± SD.
N.S = non significant.

Table 3. Maximal Work Measurement

	Maximum Oxygen Uptake liters/ minute	Maximum Oxygen Uptake milliters/ kilogram/minute	Ventilation liter	Heart Rate beat/minute	Respiration Rate breaths/minute
Morning	2.71 ± 0.42	38.99 ± 4.79	94.52 ± 27.0	187. ± 7.1	51.7 ± 13.6
Afternoon	2.72 ± 0.40	39.53 ± 4.45	94.67 23.7	185.7 ± 6.7	49.4 ± 12.7
Pre-test	2.75 ± 0.39	39.07 ± 4.17	91.35 19.3	186.6 ± 6.9	50.9 ± 13.2
1st Week	2.63 ± 0.42	38.16 ± 5.03	95.97 28.1	185.2 ± 7.2	50.5 ± 13.1
4th Week	2.77 ± 0.44	40.56 ± 4.51	96.48 28.4	187.2 ± 6.9	50.3 ± 13.8
ANOVA Probability					
Time	N.S	N.S	N.S	N.S	0.02
Week	0.03	0.03	N.S	N.S	N.S

Values are mean ± SD.
N.S = non significant.
Time : morning and afternoon.
Week : pre, first week, and fourth week.

pre-fasting levels by the last week of fasting indicates a return to pre-Ramaḍān hydration state.

Maximal work measurements (Table 3) showed a significant decrease in VO_2 max (liter/minute) during the first week of Ramadan with a return to pre-fasting values by the end of Ramadan. Relative VO_2 max (ml/kg/minute) also increased significantly between the first and last week of Ramadan; however, the decrease between the pre-Ramadan and first week Ramadan values was greatly attenuated. Ventilation rate and heart rate did not change significantly. Respiratory rate was significantly lower in the afternoon tests.

Body weight and body composition data are presented in Table 4. Body weight was significantly reduced over time. Percent weight reduction during the first week was 1.7%. By the last week of Ramaḍān, an additional weight loss of about 1.2% was observed. No change in the percent of body fat occurred during the first week of Ramaḍān; however, at the fourth week, percent fat values were significantly less (2.8%) than those of the first week of Ramaḍān. Lean weight did not change significantly during the experiment.

Analyses of food and water consumption (Table 5) indicate a significant decrease in total caloric intake by about 38% during Ramaḍān. Percent protein intake significantly decreased while the percent fat intake significantly increased. Percent carbohydrate intake did not change. Total fluid intake significantly decreased during Ramaḍān compared to the pre-fasting level. Fluid intake in the last week of Ramaḍān was higher than during first week of Ramaḍān by about 14%.

Discussion

Several factors indicate that dehydration occurred during the first few days of Ramaḍān, but then returned to pre-Ramaḍān values by the last week of Ramaḍān.

Table 4. Body weight and body composition.

	Body Weight	Percent Fat	Lean Weight
Pre-Ramaḍān	70.91 ± 10.8	21.9 ± 8.1	52.82 ± 6.1
First Week	69.68 ± 11.2	21.5 ± 8.0	51.97 ± 7.1
Fourth Week	68.86 ± 11.4	19.1 ± 7.5	52.87 ± 6.7
Morning	70.05 ± 11.2	-	-
Afternoon	69.58 ± 10.8	-	-
ANOVA Probability			
Time	N.S	-	-
Week	0.0001	0.04	N.S

Values are mean ± S.D.
N.S = non significant.
Time : morning and afternoon tests.
Week : pre, first, and fourth week.

Table 5. Average daily nutrient consumption from 3-day record.

	Pre-test	1st week	4th week	ANOVA Probability
Caloric Intake	1853 ± 150	1232 ± 221	1215 ± 243	0.00
% Carbohydrate	61.83 ± 22	60.67 ± 29	62.17 ± 47	N.S
% Protein	20.00 ± 9	19.67 ± 10	20.33 ± 8	0.04
% Fat	18.33 ± 10	19.67 ± 11	18.33 ± 6	0.04
Water Intake,	2.0 ± 0.31	1.48 ± 0.24	1.57 ± 0.25	0.00

Values are mean ± S.D.
N.S = non significant.

First, average body weight decreased significantly, by 1.23 kg during the first few days of Ramaḍān. This loss in body weight is consistant with other studies.[3,4] Percent fat did not change significantly during this time period. Thus, the decrease in body weight is consistant with either a loss in muscle or a loss in water. Since only seven days separated the two tests, it is unlikely signifiant lean weight loss would occur. In addition, water intake decreased by 0.52 liters a day during the first week of Ramaḍān or a total of 1.56 liters for the first three days of Ramaḍān. This would be equivalent to 1.55 kg, closely approximating the 1.23 kg of actual weight loss. By the last week of Ramaḍān, body weight had decreased another 0.82 kg. Percent fat, however, decreased significantly, namely 2.8% or 2.33 kg, which accounted for all the loss in body weight and indicated the hydration state returned to normal.

Second, sodium, chloride, and protein values were significantly higher in the first week of Ramaḍān than either the pre-Ramaḍān or fourth week of Ramaḍān. Pre-Ramaḍān and fourth week Ramaḍān values for sodium, chloride, and protein were very simlar with no significant differences found. These results are consistent with the results of Sawka et al[12] and Vaccaro et al[13] in which dehydration was associated with hemoconcentration. Since Muslim fasting requires abstinence from food and drink during the day, this could be a possible explanation for the dehydration. Consistent with these results, Mustafa et al[2] reported that the negative fluid balance early in Ramaḍān becomes balanced in the last two weeks of Ramaḍān, presumably due to an increase in water intake during the night or increased reabsorption of water in the kidneys. Dietary records indicate that fluid intake was slightly higher during the last week of Ramaḍān than in the first week of Ramaḍān, but still well below the two liters consumed each day prior to Ramaḍān. The fluid balanced observed must be at least in part due to adaptations by the kidneys.

Initiation of caloric restriction is also consistent

with water loss. Van Itallie and Yang[14] reported that with caloric restriction, weight loss was composed of 66% water in the early stage, mostly due to the 3 to 4 grams of water that is liberated for each gram of body glycogen metabolized. Consistent with these results, Brownell et al[15] reported that caloric restriction increased water loss during the first period of caloric restriction. Since the subjects consumed an average pf 600 kcal less each day during the first week of Ramaḍān, some water loss during this time period could have been due to glycogen reduction.

Dietary record deficit corresponds closely to calculated fat losses and body weight losses. The calculated energy deficit from the first day to the last day of testing was approximately 17,472 kcal, which is equal to 2.21 kg of fat (7700 kcal/kg fat). This corresponds very closely to the fat loss of 2.23 kg that was calculated from the percent fat/body weight data and the 2.05 kg of body weight the subjects actually lost.

It is apparent that by the last week of Ramaḍān weight losses are confined to fat. Consistent with this, Van Itallie et al[14] reported that with caloric deficit, the body adapts by increasing the utilization of its stored fat and by conserving protein and water.

When measured in liters/minute, maximum oxygen uptake decreased between the pre-Ramaḍān to first-week Ramaḍān tests; however, when measured in ml/kg/minute, maximum oxygen uptake varied little. It appears the dehydration reduced maximum oxygen uptake slightly, but the loss in body weight lessened the reduction in maximum oxygen uptake when oxygen uptake is reported relative to body weight. Since most popular endurance activities include the movement of the individual's body weight, the relative aerobic measure is of more value in determining maximum work performance.

This finding is consistent with studies in which maximum oxygen uptake was observed under conditions of heat stress and dehydration.[16,17] Several studies have shown that dehydration becomes a problem in maximal work performance only after dehydration weight losses exceed 3 to 6% of body weight.[12]

In this study the average first-week weights were only 1.7% lower than the initial body weights, evidently sufficient to decrease absolute maximum oxygen uptake, but insufficient to decrease relative maximum oxygen uptake.

Absolute maximum oxygen uptake increased during the last week of Ramaḍān to pre-Ramaḍān values, while relative maximum oxygen uptake increased to higher than pre-Ramaḍān levels. The increase over first-week Ramaḍān values is easy to explain since hydration state had returned to normal by the fourth week of Ramaḍān. The increase in maximum oxygen uptake over the pre-Ramaḍān values is a little more difficult to explain since none of the subjects began training programs or increased activity during the study. This increase in maximum oxygen uptake could be related to losses in percent fat. Lean tissue is much more active metabolically than fat tissue. An increase in the ratio of lean to fat should increase relative maximal metabolic rate even in the absence of training.

Heart rate and ventilation did not change, but respiration rate significantly decreased during the afternoon tests. The reason for that is not clear.

Although further study is necessary to evaluate maximal aerobic capacity during Ramaḍān, the results of the study indicate dehydration can be a problem during the first week of Ramaḍān. Performance in events that athletes move their body weight for relatively short time periods, i.e., less than 10 minutes, will probably not be affected. However, long duration training or competition in which significant water loss occurs will probably be a problem if the athlete begins the activity in a dehydrated state. Coaches should reduce training load, especially in hot environments, until athletes adjust to reduced fluid and caloric intake. Coaches should also encourage increased fluid intake.

References

1. Sakr AH. Fasting in Islām. J Am Diet Assoc 1975;67:17-21.
2. Mustafa KY, Mahmoud NA, Gumaa KA, Gader AM. The effects of fasting in Ramadan: 2. Fluid and electrolyte balance. Br J Nutr 1978;40:583-589.
3. Husain R, Duncan MT, Cheah SH, Ch'ng SL. Effects of fasting in Ramadan on tropical Asiatic Moslems. Br J Nutr 1987;58:41-48.
4. Angel JF, Schwartz NE. Metabolic changes resulting from decreased meal frequency in adult male Muslims during the Ramaḍān fast. Nutr Rept Int 1975;11:29-38.
5. Fedail SS, Murphy D, Salih SY, Bolton CH, Harvey RF. Changes in certain blood constituents during Ramaḍān. Am J Clin Nutr 1982;36:350-353.
6. Gumaa KA, Mustafa, KY, Mahmoud NA, Gader AM. The effects of fasting in Ramaḍān: 1. Serum uric acid and lipid concentrations. Br J Nutr 1978;40:573-581.
7. Nomani MZA, Hallak MH. Changes in body weight, blood glucose, urea and uric acid levels and relationship with energy nutrients in men during the fasting month of Ramaḍān. Fed Proc 1986;45:705 (abstr).
8. Schmahl FW. Prevention of hypovolemic shock in Moslem laborers observing the religious month of Ramaḍān. Circ Shock 1986;19:199 (abstr).
9. Pequignot JM, Peyrin L, Peres G. Catecholamine-fuel interrelationships during ex-

ercise in fasting men. J Appl Physiol 1980;48:109-113.
10. American College of Sports Medicine. Guidelines for exercise testing and prescription. 3rd ed. Philadelphia: Lea and Febiger, 1986.
11. The Food Procesor. 2nd ed. ESHA Corporation, 1985.
12. Sawka MN, Young AJ, Francesconi RP. Thermoregulatory and blood resposes during exercise at graded hypohydration levels. J Appl Physiol 1985;59:1394-1401.
13. Vaccaro P, Zauner CW, Cade JR. Changes in body weight, hematocrit and plasma protein due to dehydration and rehydration in wrestlers. J Sports Med 1976;16;:45-52.
14. Van Itallie TB, Yang M. Diet and weight loss. N Engl J Med 1977;297:1158-1161.
15. Brownell KD, Steen SN, Wilmore JH. Weight reduction practices in athletes: Analysis of metabolic and health effects. Med Sci Sport Exerc 1987;19:546-556.
16. Saltin B. Aerobic and anaerobic work capacity after dehydration. J Appl Physiol 1964;19:1114-1118.
17. Armstrong L, Costill DL, Fink WJ. Influence of diuretic-induced dehydration on competitive running performance. Med Sci Sports Exerc 1985;17:456-461.