Assessment of dietary consumption and time-course of changes in serum lipids and lipoproteins before, during and after Ramadan in young Algerian adults

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ABSTRACT

Introduction: During the month of Ramadan, fasting is obligatory for all healthy adult Muslims, with the only exempted adults being those who have to travel or are sick. The aim of this study was to see whether changes in food intake and meal patterns during Ramadan fasting could modify serum lipid and lipoprotein parameters in healthy Algerian young men and women volunteers. The time-course prospective study was done in order to investigate at what time eventual changes to these parameters occur during Ramadan and their disappearance after Ramadan.

Methods: Subjects were interviewed by trained interviewers using the method of the "seven day recall and record", before, during and after Ramadan. The serum lipid and lipoprotein contents were analysed at different times.

Results: The total energy intake was higher during Ramadan (13 and 11 MJ/day) than before and after Ramadan (11 and 9 MJ/day) in men and women, respectively. In the second week of Ramadan, carbohydrate intake was elevated by 22 percent and 24 percent in men and women, respectively, compared to before and after Ramadan. At the end of Ramadan, the low density lipoproteins (LDL) percentages decreased by 20 percent in women and 55 percent in men compared to the values obtained before Ramadan. In both groups, the amount of serum high density lipoproteins (HDL) was 1.4-fold higher, in particular on day 28 of Ramadan, in comparison with the period before and after Ramadan. Indeed, a progressive decrease in LDL-C was noted in women and was particularly drastic in men. In contrast, HDL-C had increased by 30 percent on day 15 of Ramadan, compared to before Ramadan.

Conclusion: This study shows that striking changes in nutritional habits during Ramadan may be useful in reducing LDL levels and in increasing HDL levels. The young Muslim's diet during Ramadan may contribute to favourable modifications of the serum lipoprotein profile related to cardiovascular protection.

Keywords: cholesterol, dietary consumption, lipids, lipoproteins, Ramadan

Singapore Med J 2009; 50(3): 288-294

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INTRODUCTION

Ramadan is the holiest month in the Islamic calendar and Muslims fast during this month. The details of Ramadan fasting have been well described.[1-3] Ramadan fasting is partial, because food and water intake is permissible from sunset to dawn. Fasting during Ramadan causes a radical change in lifestyle for the period of one lunar month. The quality of ingested nutrients can also differ during Ramadan compared with the rest of the year. The fasting period per day may vary depending on the geographical location of the country and the season of the year, and can be as long as 18 hours/day in the summer. Furthermore, a decrease in meal frequency[4] and sleep duration,[5] together with a reduction in daily physical activities during Ramadan,[6] have been reported. Ramadan fasting provides an excellent opportunity to study the effects of a prolonged reduction in meal frequency on body metabolism. The available data is inconclusive and contradictory. The Ramadan diet generally involves reduced food, and in particular fat,[5] intake and a reduction in body weight.[4-7] However, an increase in energy consumption and body weight is possible during this month among certain groups.[8] It has been established that several metabolic responses occur at the end of the first week and adaptations are observed in the last week of Ramadan.[9] These metabolic responses involving carbohydrate, protein and lipid parameters remain controversial. During Ramadan, a high carbohydrate and high fat diet, as well as body weight loss, have been reported by Hallak and Nomani.[10] Aldouni

et al have shown that mean body weight declined by 26% on day 29 of Ramadan in a Moroccan population, whereas during Ramadan, the diet pattern of the subjects showed an increase in total energy intake due to carbohydrates and proteins but not fats, compared to their usual diet throughout the rest of the year.[11]

Serum uric acid concentrations are increased during the fasting duration.[7,12] The changes in plasma uric acid concentrations in men are negatively correlated with their body weight variations, i.e. plasma uric acid values generally increase with weight loss during Ramadan.[13] These findings also suggest that a high vegetable-fat diet, which includes unsaturated lipids, can prevent the elevation of the plasma uric acid value associated with weight loss during Ramadan. El-Hazmi et al showed in their examination of 36 male volunteers that Ramadan fasting may affect the amounts of several haematological and biochemical parameters.[14] During Ramadan fasting, a significant increase in total serum cholesterol (TC) concentrations is noted.[7] Aldouni et al demonstrated that the first time of Ramadan fasting affected the lipid and lipoprotein metabolism in healthy adult male volunteers.[11] Indeed, at the end of Ramadan, the levels of very low density lipoprotein-triacylglycerol (VLDL-TG) and VLDL-TC increased, plasma cholesterol was enhanced concomitantly to increase high density lipoprotein-cholesterol (HDL-C) and remained elevated one month after Ramadan, in contrast to low density lipoprotein-cholesterol (LDL-C) levels, which showed a significant decrease that was also maintained one month after Ramadan. The results reported by Sliman and Khatib showed no change in the TG/TC and LDL-C/HDL-C ratios.[15] The physiological changes that occur during Ramadan are not well known. In fact, studies on the effects of Ramadan fasting on blood lipids, lipoproteins and apolipoproteins (apo) are scarce, have shown variable results and remain incomplete. The aim of the present investigation was to study whether changes in food intake and eating patterns during Ramadan fasting could modify serum lipid and lipoprotein parameters. The time-course prospective study was done in order to investigate at what time eventual changes of these parameters occur during Ramadan and their disappearance after Ramadan.

METHODS

Healthy volunteers (22 men and 24 women), who were students of the Es-Senia University of Oran, West Algeria, and who fasted during the month of Ramadan, were selected. Their mean age was 24 ± 3 years, and their body mass index (BMI) was 22–25 kg/m^2. Subjects were interviewed by trained interviewers using an adapted and structured questionnaire. Their body weight was noted at each time period. The method of the "seven day recall and record" required the subjects to record in a notebook the quality and the quantity of all food that they consumed every day consecutively for one week: on days 15–8 before Ramadan, days 1–7, 14–21, 21–28 during Ramadan and days 8–15 after Ramadan. For each particular dish, the patient was asked how frequently it was eaten and whether the usual portion was small, medium or large (graduated measure, soup and coffee spoons, dinner and soup plates, etc). Exact portion sizes for food not found in the food lists but consumed by the subjects were elicited. Food intake was converted into nutrients and energy via the consumption food table using the method of Souci et al.[16] Blood samples were drawn by antecubital venipuncture of subjects after 12 ± 2 hours of fasting at six timepoints: at the beginning of the study (baseline of the experiment period corresponding to day 15 before the beginning of Ramadan fasting) between 08.00 and 09.00, then at days 7, 15 and 28 during Ramadan between 15.00 and 16.00, and at days 8 and 15 after Ramadan between 08.00 and 09.00. After separation from the cells by low speed centrifugation 600 × g (Sigma, 4K10 Bioblock Scientific, Germany) for 15 min at 4°C, serum was preserved with 0.1% Na_2-EDTA and 0.02% sodium azide. The purpose of this study was explained to the subjects, and the investigation was carried out with their consent. The protocol was approved by the West Hospital Committee of Oran on Human Subjects.

The serum uric acid concentration level was determined according to the enzymatic method (Sera Pak Miles kit, Milan, Italy). Total protein contents were measured using the method of Lowry et al,[17] with bovine serum albumin (Sigma Chemical Co, St Louis, MO, USA) used as a standard. Serum apo A-I and apo B100 amounts were determined by immunoelectrophoresis using monoclonal antibodies and ready-to-use plates (Hydragel Sebia kit, Issy-Les-Moulineaux, France). TG and TC were assayed

Table I. Body weight in both genders before, during and after Ramadan.

Period	Mean ± SEM of body weight (kg)	
	Women (n = 24)	Men (n = 22)
Before Ramadan		
Day 15	53 ± 8	70 ± 9
During Ramadan		
Day 7	53 ± 7	69 ± 9
Day 15	52 ± 8	69 ± 10
Day 28	52 ± 9	70 ± 10
After Ramadan		
Day 8	53 ± 9	70 ± 10
Day 15	54 ± 9	70 ± 11

SEM: standard error of the mean
After analysis of variance, classification of the means was performed using Duncan's multiple range test.

Table II. Total energy intake and various nutrients.

	Before Ramadan Days 15–8		During Ramadan Days 1–7		During Ramadan Days 14–21		During Ramadan Days 21–28		After Ramadan Days 8–15	
	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men
Total energy (MJ)	10 ± 0.7^{by}	11 ± 0.6^{ay}	11.1 ± 0.5^{bx}	13.4 ± 1.5^{ax}	11.6 ± 0.9^{bx}	13 ± 1.1^{ax}	11.7 ± 0.6^{x}	12.4 ± 1.4^{x}	9.7 ± 105^{by}	11.2 ± 1.3^{ay}
Total proteins (MJ)	1.3 ± 0.5	1.5 ± 0.2	1.5 ± 0.5	1.8 ± 0.2	1.6 ± 0.5	1.4 ± 0.9	1.5 ± 0.3	1.7 ± 0.6	1.3 ± 0.3	1.6 ± 0.2
% of daily energy	13	13	14	13	12	12	13	14	13	14
Vegetable proteins (%)*	69	57	63	57	66	57	63	58	64	57
Animal proteins (%)*	31	43	37	43	34	43	37	42	36	43
Total fats (MJ)	2.6 ± 0.5	2.7 ± 0.2	2.5 ± 0.3	2.8 ± 0.3	2.7 ± 0.3	2.3 ± 0.5	2.8 ± 0.5	3.2 ± 0.2	2.5 ± 0.6	2.8 ± 0.3
% of daily energy	26	24	22	21	23	22	24	26	26	25
Polyunsaturated fats (%)*	27	29	24	25	32^{b}	25^{a}	26	26	30	30
Saturated fats (%)*	36	33	33	35	36	35	35	39	35	35
Monounsaturated fats (%)*	37	38	43	40	32^{b}	40^{a}	39	35	35	35
Total carbohydrates (MJ)	6.2 ± 0.5^{y}	7.1 ± 0.3^{y}	7.5 ± 0.5^{xb}	8.8 ± 1.3^{xa}	7.5 ± 1.0^{xb}	9 ± 1.2^{xa}	7.4 ± 0.6^{x}	7.5 ± 0.4^{x}	5.9 ± 0.7^{y}	6.8 ± 1.1^{y}
% of daily energy	63	61	66	64	66	65	60	63	61	61
Complex carbohydrates(%)*	80^{y}	84	77	83	67^{bx}	89^{a}	70	80	83^{y}	83
Sugars (%)*	20^{y}	16	23	17	33^{bx}	11^{a}	30	20	17^{y}	17
Cholesterol (mg)	250 ± 35	270 ± 11	310 ± 16	285 ± 10	275 ± 22	257 ± 58	280 ± 21	235 ± 31	278 ± 25	290 ± 11

*% of total proteins, fatty acids or carbohydrate amounts. Data is expressed as the mean ± SEM for 24 young women and 22 young men. After analysis of variance, classification of the means was performed using Duncan's multiple range test: (1) between both groups for each period, where means with different superscript letters (a and b) along the same column are significantly different ($p < 0.05$); (2) within each group over different periods, where means with different superscript letters (x and y) are significantly different ($p < 0.05$).

by enzymatic methods (Boehringer kits, Mannheim, Germany). Serum was adjusted to 1,210 g/ml by the addition of crystalline KBr (0.322 g/ml serum) according to Redgrave et al.[18] Lipoproteins of density < 1,210 g/ml were isolated by a single ultracentrifugation flotation (Model LE 80 Ultracentrifuge, 50 Ti rotor, Beckman Instruments, Palo Alto, CA). All centrifugations were performed at 122,000 × g at 15°C for 48 hours. Lipoproteins were dialysed against 0.15 mol/L NaCl and 1 mmol/L Na_2EDTA, pH 7.4 at 4°C in Spectra/Por 2 dialysis tubing (Spectrum Medical Industries, Los Angeles, CA, USA) for 24 hours. Lipoprotein fractions VLDL (d < 1,006), LDL (1,019 < d < 1,063) and HDL (1,063 < d < 1,210) were isolated from total lipoproteins by a single-spin discontinuous gradient centrifugation performed at 274,000 × g at 15°C, according to the method of Havel et al.[19] TGs, phospholipids (PL), TC and unesterified cholesterol (UC) amounts were determined by the enzymatic methods (Boehringer kits, Mannheim, Germany). Cholesteryl ester (CE) contents were estimated as 1.67 multiplied by the esterified cholesterol amounts. This factor took into account the average molecular weight of cholesterol-esterifying fatty acids. Serum lipoprotein amounts, expressed in mg/L serum, were determined by the addition of their total apo, TG, PL, UC and CE contents. Statistical evaluation was carried out by the analysis of variance and classification of the means using Duncan's multiple range test[20] (Stat view 512+, Brain Power, Calabasas, CA, USA): (1) between the two groups (men and women), at each time, where means with different superscript letters (a and b) for each component were significantly different ($p < 0.05$); and (2) within each group over time, where means with different superscript letters (x, y and z) were significantly different ($p < 0.05$). Linear regression analysis was used to determine the correlation between different nutrients and serum parameters, and the Ramadan duration.

RESULTS

There was no significant difference in the mean body weight of young male and female students before, during and after Ramadan (Table I). The mean energy intake and the various nutrients taken before, during and after Ramadan in both genders are shown in Table II. The mean energy intakes were respectively higher for both male and female subjects at different periods during Ramadan (days 1–7, 14–21, 21–28) (13 MJ/day and 11 MJ/day) compared with before and after Ramadan (11 MJ/day and 9 MJ/day) ($p < 0.05$). In addition, the energy intake in women was 85% and 82% of that noted in men during and after Ramadan, respectively. Both men and women consumed approximately a similar percentage of protein per day (12%–14% of daily energy intake). In men, vegetable proteins comprised 57% of total protein intake before, during and after Ramadan, while in women, vegetable proteins represented about 64% of total protein intake during Ramadan, compared to before (69%) and after (64%) Ramadan.

High carbohydrate intakes were recorded and it was observed that on from days 14–21 during Ramadan, carbohydrate intake was elevated by 22% and 24% in men and women, respectively, compared to the values before

and after Ramadan. For days 14–21 during Ramadan, carbohydrate intake was higher in men than in women ($p < 0.05$), and sugars in women represented 33% of total carbohydrates vs. 20% and 17% before and after Ramadan, respectively. Total fat intake was not significantly different before, during and after Ramadan (Table II). Indeed, saturated fatty acid (SFA), polyunsaturated fatty acid (PUFA) and monounsaturated fatty acid (MUFA) intakes (expressed in terms of the percentage of total fatty acids) were qualitatively similar during and after Ramadan. On days 14–21 during Ramadan, PUFA contents were only 1.3-fold higher in women than in men. Cholesterol intake was unchanged during the Ramadan period (< 300 mg/day) and was similar in both groups (Table II). The meal frequency during Ramadan was similar between men and women for the three time periods of the study (Table III). During Ramadan, total energy intake was divided into one large meal (60% of total energy), followed by a smaller meal (40% of total energy intake) four hours later. In contrast, our subjects obtained their daily energy intake in four meals before and after Ramadan. Serum total proteins, uric acid, apo A-I and apo B100, TG and TC levels are presented in Table IV. There was no significant difference in the serum uric acid, total proteins, apo A-I, apo B100 and lipids concentrations levels between men and women, before, during and after Ramadan. In men, the serum TG value increased significantly at days 7 and 15 of Ramadan fasting compared to the value noted before Ramadan. After Ramadan, these values had a tendency to diminish, but not significantly, and this was due to large individual variations. At day 15 during Ramadan, serum TC values increased by +35% and +31% in men and women, respectively, compared with those observed before and after Ramadan ($p < 0.05$), but these values were lowered at the end of Ramadan.

Serum VLDL, VLDL-TG, LDL and HDL, LDL-C and HDL-C values are shown in Table V. At day 15 during Ramadan, serum VLDL amounts in both groups were threefold lower than the values noted before and after Ramadan, but this decrease was more important in women than in men. Indeed, the VLDL-TG contents were 3.4- and 3.2-folds lower in women and men, respectively. Significant differences in LDL and HDL levels were noted between men and women ($p < 0.05$) during the three time periods of the study. In men, during Ramadan, the LDL amounts were decreased significantly ($p < 0.05$) compared to day 15 before and after Ramadan; the values were then increased to the level found before Ramadan. In contrast, in women, LDL levels decreased only at day 28 of Ramadan. At the end of Ramadan, the LDL percentages decreased by 20% in women and 55% in men compared with day 15 before Ramadan. At day 28 of Ramadan, LDL-C values were lower only in men (67% of the values observed at day 15 before Ramadan). In both groups, serum HDL amounts were 1.4-fold higher, in particular at day 28 of the Ramadan period compared with day 15 before and after Ramadan. Indeed, a progressive decrease in LDL-C levels was noted in women but was drastic in men. In contrast, HDL-C was increased by 30% during Ramadan compared to the values before Ramadan. In men and women respectively, relationships were noted between the Ramadan duration and total energy intake ($r +0.68$ and $r +0.63$, $p < 0.01$), and carbohydrate intake ($r +0.72$ and $r +0.69$, $p < 0.01$). Ramadan duration was positively correlated to serum TC values ($r +0.80$ and $r +0.78$, $p < 0.001$) in men and women, respectively. Moreover, inverse relationships were found between Ramadan duration and LDL-C ($r +0.78$, $p < 0.01$; $r +0.60$, $p < 0.05$) on the one hand, and inversely positive correlations were noted between Ramadan duration and HDL-C ($r +0.78$, $p < 0.01$; $r +0.60$, $p < 0.05$) on the other.

Table III. Meal times and the relative importance of their energy intake.

Meal times	During Ramadan (%)	Before and after Ramadan (%)	
		Men (n = 22)	Women (n = 24)
Breakfast 07:00–08:00		16	19
Lunch 12:00–13:00		37	34
Snack 15:00–17:00		11	16
Dinner 19:00–20:00	60	29	27
Night meal 00:00–04:00	40		
Nibbling		7	4

DISCUSSION

Reports on the effects of Ramadan fasting have been inconsistent. In the present study, we have investigated whether changes in food intake and eating patterns during Ramadan can modify serum TG and TC, uric acid, total proteins, apo A-I, apo B100 and lipoprotein concentration levels. Moreover, the time-course study was done to observe at what time eventual changes appeared during Ramadan and at what time their disappearance was observed after Ramadan. Many physiological changes observed during Ramadan are probably due to the changes in eating patterns and meal frequency as well as in sleep duration.[21] In this study, there was no effect of Ramadan fasting on body weight and BMI, despite the marked changes in food

Table IV. Serum total proteins, uric acid, apo A-I and apo B100, triacylglycerols (TG) and total cholesterol (TC) levels before, during and after Ramadan.

Period	Total proteins (g/L)	Uric acid (mmol/L)	Apo A-I (g/L)	Apo B100 (g/L)	TG (mmol/L)	TC (mmol/L)
Before Ramadan						
Day 15						
Women	66 ± 8	0.35 ± 0.10	1.32 ± 0.37	0.81 ± 0.30	0.67 ± 0.26	5.28 ± 1.49^{y}
Men	64 ± 9	0.36 ± 0.08	1.31 ± 0.28	0.76 ± 0.13	0.72 ± 0.36^{y}	5.34 ± 1.65^{y}
During Ramadan						
Day 7						
Women	66 ± 8	0.44 ± 0.10	1.25 ± 0.20	0.80 ± 0.25	0.53 ± 0.21	6.57 ± 1.90^{x}
Men	61 ± 7	0.42 ± 0.06	1.20 ± 0.15	0.70 ± 0.10	0.90 ± 0.65^{x}	8.97 ± 0.95^{x}
Day 15						
Women	63 ± 8	0.44 ± 0.10	1.09 ± 0.22	0.74 ± 0.18	0.58 ± 0.18	8.15 ± 1.23^{x}
Men	60 ± 8	0.38 ± 0.10	1.06 ± 0.11	0.68 ± 0.11	0.97 ± 0.30^{x}	7.71 ± 1.98^{x}
Day 28						
Women	60 ± 9	0.36 ± 0.20	0.94 ± 0.19	0.59 ± 0.07	0.93 ± 0.50	6.01 ± 1.78^{xy}
Men	58 ± 8	0.35 ± 0.12	0.93 ± 0.13	0.61 ± 0.14	0.69 ± 0.36	6.60 ± 1.29^{xy}
After Ramadan						
Day 8						
Women	70 ± 17	0.35 ± 0.05	1.11 ± 0.12	0.67 ± 0.11	0.88 ± .037	5.53 ± 1.08^{y}
Men	68 ± 12	0.33 ± 0.08	1.08 ± 0.12	0.65 ± 0.09	0.53 ± 0.33	5.01 ± 1.20^{y}
Day 15						
Women	71 ± 10	0.34 ± 0.04	1.25 ± 0.18	0.71 ± 0.05	0.68 ± 0.20	5.18 ± 0.49^{y}
Men	73 ± 12	0.37 ± 0.10	1.19 ± 0.23	0.76 ± 0.10	0.74 ± 0.26^{x}	5.14 ± 0.58^{y}

Data is expressed as mean ± SEM of 24 women and 22 men. After analysis of variance, classification of the means was performed using Duncan's multiple range test: within each group over different periods, where means with different superscript letters (x and y) are significantly different ($p < 0.05$).

habits. These results are in agreement with those of Nomani et al and Maislos et al.[13,22] However, the decrease in food intake and body weight was observed during Ramadan as mentioned by Angel and Schwartz, Husain et al, Fedail et al, Aldouni et al and Gumaa et al.[4,5,7,11,12] Our findings are also in agreement with those of Frost and Pirani, which showed a high total energy intake with a constant body weight in Saudi subjects,[8] but contradicted those found in Indian Muslims, which showed a decrease in daily energy intake.[23] These discrepancies could probably be explained by the food habits in different Islamic countries. During Ramadan, most of the participants engage in some activities (walking or leisure activities) after their evening meal. In addition, sleep duration was shorter during Ramadan (averaging about six hours per night).

In the present study, a high total energy consumption level characterised both groups during Ramadan compared to the periods before and after Ramadan. This increased daily energy intake during Ramadan was mainly due to a high carbohydrate intake. During Ramadan, the proportion and types of carbohydrates consumed were different compared to the usual Tunisian food habits.[24] In fact, Tunisian food habits consist of a significant intake of proteins and fats and a low intake of carbohydrates. During Ramadan, carbohydrate intake was found to be higher in men than in women ($p < 0.05$), due to their consumption of dates, honey, pastry, sweets and soft drinks. Aldouni et al have shown that the dietary patterns of the subjects result in an increased total energy intake due to carbohydrates and proteins with no fat, compared to their usual diet throughout the rest of the year.[11] Data reported in Table II showed that the total fat intake was not significantly different in the fasting period as compared to the periods before and after Ramadan. Indeed, the dietary SFA, PUFA and MUFA levels consumed by the subjects remained unchanged during the study. Our data indicated that in young men and women, the average serum uric acid concentrations were not significantly different during the study (Table IV). Indeed, Fedail et al[7] and Hallak and Nomani[10] showed that uric acid excretion was not modified, but their subjects had an energy intake which was less than the daily recommended intake, and a significant body weight loss, suggesting the catabolism of body cell mass among their subjects. On the other hand, Scott and Sturge[25] and Yamashita et al[26] observed a reduction in the serum uric acid value with a body weight loss, but only in the obese subjects.

Serum TG levels in men and TC concentrations in both groups increased significantly at days 7 and 15 of Ramadan fasting compared to the respective amounts before Ramadan. These values were decreased but not significantly for TG in men after Ramadan, and this was due to large individual variations (Table IV). Angel and Schwartz found no significant difference in the blood cholesterol value during or after Ramadan, with an energy intake of 7,75 MJ/day during Ramadan.[4] It could be suggested that a decrease in eating frequency might elevate cholesterol levels and predisposed the subjects to ischaemic heart disease. The increase in the cholesterol levels in our subjects

Table V. Serum VLDL, VLDL-TG, LDL and HDL amounts and their respective cholesterol values.

Days	VLDL (g/L)	VLDL-TG (mmol/L)	LDL (g/L)	LDL-C (mmol/L)	HDL (g/L)	HDL-C (mmol/L)
Before Ramadan						
Day 15						
Women	0.95 ± 0.60^{x}	0.41 ± 0.06^{bx}	1.87 ± 0.10^{bx}	2.56 ± 0.81	2.00 ± 0.42^{y}	2.43 ± 0.81
Men	1.01 ± 0.20^{x}	0.55 ± 0.03^{ax}	2.22 ± 0.50^{ax}	2.86 ± 0.52^{ax}	1.70 ± 0.26^{z}	1.96 ± 0.31^{y}
During Ramadan						
Day 7						
Women	0.47 ± 0.06^{bxy}	0.20 ± 0.06^{by}	2.02 ± 1.10^{ax}	3.22 ± 1.10	2.30 ± 0.50^{ax}	2.67 ± 0.94
Men	0.95 ± 0.27^{ax}	0.52 ± 0.04^{ax}	1.86 ± 0.30^{by}	3.17 ± 0.30^{xy}	2.00 ± 0.40^{by}	2.20 ± 0.40^{xy}
Day 15						
Women	0.27 ± 0.02^{by}	0.12 ± 0.02^{z}	2.00 ± 1.50^{ax}	2.20 ± 1.50	2.50 ± 1.70^{ax}	2.79 ± 0.10
Men	0.32 ± 0.01^{ay}	0.17 ± 0.02^{y}	1.40 ± 0.30^{bz}	3.89 ± 0.30^{y}	2.10 ± 0.30^{ax}	2.82 ± 0.60^{x}
Day 28						
Women	0.60 ± 0.08^{xy}	0.28 ± 0.09^{by}	1.50 ± 0.11^{ay}	2.22 ± 0.9^{xy}	2.70 ± 0.20^{x}	2.90 ± 0.03
Men	0.89 ± 0.26^{x}	0.49 ± 0.04^{ax}	1.00 ± 0.20^{by}	1.94 ± 0.11^{b}	2.22 ± 0.30^{y}	2.29 ± 0.42^{xy}
After Ramadan						
Day 8						
Women	0.88 ± 0.07^{x}	0.38 ± 0.07^{bxy}	1.80 ± 0.10^{by}	2.36 ± 0.59	1.90 ± 0.50^{ay}	2.56 ± 0.88
Men	0.95 ± 0.02^{x}	0.52 ± 0.03^{ax}	1.98 ± 0.40^{ay}	2.50 ± 0.26^{xy}	2.16 ± 1.80^{by}	2.12 ± 0.38^{xy}
Day 15						
Women	1.00 ± 0.60^{x}	0.40 ± 0.07^{bax}	1.80 ± 0.10^{bx}	2.44 ± 0.12	1.90 ± 0.40^{y}	2.45 ± 0.80
Men	1.01 ± 0.23^{x}	0.55 ± 0.06^{ax}	2.21 ± 0.50^{ay}	2.40 ± 0.46^{x}	1.60 ± 0.20^{z}	1.90 ± 0.22^{y}

Data is expressed as mean ± SEM for 24 young women and 22 young men. After analysis of variance, classification of the means was performed using Duncan's multiple range test: (1) between both groups for each period, where means with different superscript letters (^{a} and ^{b}) in the same column are significantly different ($p < 0.05$), and (2) within each group over different periods, where means with different superscript letters (^{x,y} and ^{z}) are significantly different ($p < 0.05$).

may be due to two reasons. First, the intake of a large meal after several hours of fasting may cause an increase in endogenous cholesterol synthesis; and second, the type of food consumed during Ramadan fasting, i.e. rich in carbohydrates, may further contribute to both exogenously- and endogenously-derived cholesterol.[14] Our data did not support that of previous reports that showed no change in serum TG concentrations[7] or increased serum TG values concomitant to high VLDL-TG in men.[27] Gumaa et al noted a gradual increase in the TG amounts, but a decrease in TC during the whole month of Ramadan.[12] On the contrary, Nomani et al showed a blood TG decrease at the end of Ramadan.[13] In our study, the serum VLDL amounts were threefold lower at day 15 of Ramadan than the values obtained at day 15 before and after Ramadan, with a marked decrease in VLDL-TG (Table V). At day 28 of Ramadan, LDL amounts and LDL-C levels were lowered, whereas HDL amounts and HDL-C levels increased significantly during Ramadan. These results are in agreement with those of Nicholls and Scott,[28] which showed that Ramadan fasting was related to lowered serum cholesterol values, with a subsequent reduction in LDL-C and an increase in HDL-C. The beneficial effect of increased meal frequency on plasma lipids was reported by Gwinup et al.[29] Similarly, Irwin and Feeley showed that in 15 healthy women, the mean serum TC value and LDL–C concentrations were significantly lower when the daily dietary intake was divided into three equal meals than when it was served in one large and two small meals.[30] Low serum LDL-C and high HDL-C levels during Ramadan help to prevent cardiovascular diseases. These results may be due to the type of food consumed. Indeed, the specific types of food consumed by the participants during Ramadan which could contribute to this increase are primarily, high fish consumption (rich in omega-3 series PUFA, especially eicosapentaenoic acid (EPA, 20: 5n–3) and docosahexaenoic acid (DHA, 22: 6n–3), and secondarily, a large consumption of legumes (chick pea), cereals (wheat, bread) and fruits, which are rich in antioxidants (vitamins C and E, β-carotene, selenium, α-tocopherol and flavonoids). These have been shown to be related to a lower risk of cardiovascular diseases. In conclusion, the main findings of this study are that the body weight of male and female subjects remained unchanged before, during and after Ramadan, despite the high daily total energy intake divided into two meals with marked variations in qualitative food intake during Ramadan. The changes consist essentially of a high carbohydrate diet with an exclusively nocturnal consumption, particularly in women. Finally, this study suggests striking changes in the eating patterns during Ramadan, which may be useful in reducing LDL-C and increasing HDL-C levels, and may contribute to lowering the risks of coronary heart disease.

ACKNOWLEDGEMENT

The authors are indebted to Anne Magnet, University of Burgundy, France, for editing the manuscript.

REFERENCES

1. Ziaee V, Razaei M, Ahmadinejad Z, et al. The changes of metabolic profile and weight during Ramadan fasting. Singapore Med J 2006; 47:409-14.
2. Bener A, Hamad A, Fares A, Al-Sayed HM, Al-Suwaidi J. Is there any effect of Ramadan fasting on stroke incidence? Singapore Med J 2006; 47:404-8.
3. Al Suwaidi J, Bener A, Suliman A, et al. A population based study of Ramadan fasting and acute coronary syndromes. Heart 2004; 90:695-6.
4. Angel JF, Schwartz NE. Metabolic changes resulting from decreased meal frequency in adult male Muslims during the Ramadan fast. Nutr Rep Int 1975; 11:29-38.
5. Husain R, Duncan MT, Cheah SH, Ch'ng SL. Effect of fasting in Ramadan on tropical Asiatic Moslems. Br J Nutr 1987; 58:41-8.
6. Sulimani RA, Famuyiwa FO, Laajam MA. Diabetes mellitus and Ramadan fasting: the need for a critical appraisal. Diabet Med 1988; 5:589-91.
7. Fedail SS, Murphi D, Salih SY, Bolton CH, Harvey RF. Changes in certain blood constituents during Ramadan. Am J Clin Nutr 1982; 36:350-3.
8. Frost G, Pirani, S. Meal frequency and nutritional intake during Ramadan: a pilot study. Hum Nutr Appl Nutr 1987; 41:47-50.
9. Hakkou F, Tazi A, Iraki L. Ramadan, health and chronobiology. Chronobiol Int 1994; 11:340-2.
10. Hallak MH, Nomani MZ. Body weight loss and changes in blood lipid levels in normal men on hypocaloric diets during Ramadan fasting. Am J Clin Nutr 1988; 48:1197-210.
11. Adlouni A, Ghalim N, Benslimane A, Lecerf JM, Saile R. Fasting during Ramadan induces a marked increase in high-density lipoprotein cholesterol and decrease in low-density lipoprotein cholesterol. Ann Nutr Metab 1997; 41:242-9.
12. Gumaa KA, Mustafa KY, Mahmoud NA, Gader AMA. The effects of fasting in Ramadan. Serum uric acid and lipid concentrations. Br J Nutr 1978; 40:573-81.
13. Nomani MZ, Hallak MH, Nomani S, Siddiqui IP. Changes in blood urea and glucose and their association with energy-containing nutrients in men on hypocaloric diets during Ramadan fasting. Am J Clin Nutr 1989; 49:1141-5.
14. El-Hazmi MAF, Al-Fallah FZ, Al MoflehI A. Effect of Ramadan fasting on the value of hematological and biochemical parameters. Saudi Med J 1987; 8:171-6.
15. Sliman NA, Khatib FA. Effects of fasting during Ramadan on weight and some blood constituents in healthy Muslims. Nutr Rep Int 1988; 38:1299-6.
16. Souci SW, Fachmann W, Kraut H. La composition des aliments. Tableaux des valeurs nutritives, 6th ed. Stuttgart: CRC Press & Medpharm Scientific Publishers, 2000; 5-1182.
17. Lowry OH, Rosebrough NJ, Farr AL, Randall RJ. Protein measurement with the Folin phenol reagent. J Biol Chem 1951;193:265-75.
18. Redgrave TG, Roberts DCK, West CE. Separation of plasma lipoproteins by density-gradient ultracentrifugation. Anal Biochem1975; 65:42-9.
19. Havel RJ, Eder HA, Bragdon JH. The distribution and chemical composition of ultracentrifugally separated lipoproteins in human serum. J Clin Invest 1955; 34:1345-53.
20. Duncan DB. Multiple range and multiple F-tests. Biometrics 1955; 11:1-42.
21. Aziz F, Rasouli HA. Serum glucose, bilirubin, calcium, phosphorus, protein and albumin concentrations during Ramadan. Med J Islam Repub Iran 1987; 1:38-41.
22. Maislos M, Khamaysin N, Assali A et al. Marked increase in plasma high-density-lipoprotein cholesterol after prolonged fasting during Ramadan. Am J Clin Nutr 1993; 57:640-2.
23. Chandalia HB, Bhargau A, Kataria V. Dietary pattern during Ramadan fasting and its effects on the metabolic control of diabetes. Pract Diabetes 1987; 4:287-9.
24. el Ati J, Beji C, Danguir J. Increased fat oxidation during Ramadan fasting in healthy women: an adaptative mechanism for body-weight maintenance. Am J Clin Nutr 1995; 62:302 -7.
25. Scott JT, Sturge RA. The effect of weight loss on plasma and urinary uric acid and lipid levels. Adv Exp Med Biol 1977; 76B:274-7.
26. Yamashita S, Matsuzawa Y, Tokunaga K, Fujioka S, Tarui S. Studies on the impaired metabolism of uric acid in obese subjects: marked reduction of renal urate excretion and its improvement by a low-caloric diet. Int J Obes 1986; 10:255-64.
27. Shoukri MI. Effect on fasting in Ramadan on plasma lipoproteins. Saudi Med J 1986; 6:561-5.
28. Nicholls A, Scott JT. Effect of weight-loss on plasma and urinary levels of uric acid. Lancet 1972; 2:1223-4.
29. Gwinup G, Byron RC, Roush WH., Kruger F, Hamwi GJ. Effect of nibbling versus gorging on serum lipids in man. Am J Clin Nutr 1963; 13:209-13.
30. Irwin MI, Feeley RM. Frequency and size of meals and serum lipids, nitrogen and mineral retention, fat digestibility, and urinary thiamine and riboflavin in young women. Am J Clin Nutr 1967; 20:816-24.