

The Dietary Composition of Pre-fast Meals and its Effect on 24 Hour Food and Water Fasting

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Key words: fasting, pre-fast meal, meal composition, macronutrients, food

Abstract

Background: Fasting is required by the Jewish and Islamic religions, and may sometimes be necessary for non-religious reasons as well. Very little empiric data are available on the effect of 24 hours of food and water deprivation.

Objectives: To compare the effects of the dietary composition of different pre-fast meals on subjective discomfort and various other parameters of a 24 hour food and water fast.

Methods: Thirteen volunteers of both genders participated in a non-randomized crossover study. Each consumed three different equicaloric pre-fast meals in which the main source of calories was protein (49% of calories), carbohydrate (86%), or fat (69%). Weight, heart rate, blood pressure, blood and urine were tested before and after 24 hours of fasting, and the subjective evaluations of the discomfort during the three fasts were compared.

Results: After the protein-rich meal greater discomfort and more side effects were reported. Weight and blood pressure decreased at the end of the fasts that followed each of the three meals; heart rate increased after the high fat and carbohydrate meals but not after the protein meal. The main laboratory findings were a 40% increase in blood urea nitrogen and higher urine osmolarity after the protein-rich meal than after the other meals.

Conclusion: A protein-poor pre-fast meal is likely to be followed by easier fasting.

IMAJ 2001;3:657-662

For Editorial see page 667

The 24 hour* food and water fast of *Yom Kippur* (Day of Atonement), one of the more commonly observed Jewish religious practices, occurs towards the end of summer in the Northern Hemisphere. Such fasting during hot weather usually results in discomfort and unpleasant side effects. This is also the case for people fasting because of the dictates of other religions, or for non-religious reasons. However, there have

been no studies on how such fasts might be made more tolerable.

The present study was performed to determine whether the discomfort of a food and water fast could be influenced by the composition of the meal preceding the fast, and if so, what basic nutritional component(s) would promote the easiest fasting. We therefore challenged volunteers with three different pre-fast supper meals: high fat, high carbohydrate, and high protein. The subjects then evaluated their discomfort during each of the subsequent fasts. We also determined the effect of the fasts on various physical measurements and blood and urine parameters.

Methods

Subjects

The study group comprised 13 normal volunteers (8 females and 5 males; mean age 45.1 ± 12.8 years, range 20–64; mean body mass index 25.1 ± 3.8 , range 19.5–30.8). They were all employed in indoor sedentary jobs throughout the study, and most worked in air-conditioned areas. None of the subjects had experienced any unusual difficulty during previous religious fasts, none had any metabolic disorders, and none was pregnant. Each signed an informed consent form as required by the Helsinki Committee.

Meals

Three types of supper meals of natural foods were designed to be equicaloric and to contain equal amounts of sodium and of water, but to differ in the main source of calories. Fat constituted 69% of the calories of the fat-rich meal, carbohydrate 86% of the carbohydrate-rich meal, and protein 49% of the protein-rich meal. Greater proportions of any of the three main components made the meals unpalatable. The menus and analyses of the ingredients of each meal are given in Appendix 1.

On the day of the pre-fast supper, subjects were instructed to eat and drink as they usually did before a fast, until 2 hours before the experimental meals when eating and drinking were prohibited. The subjects were then served the meals in groups on weekdays (not preceding religious fasts), on any 3 of 6 suggested days at their convenience. The meal types (rich in protein, carbohydrates, or fat) were freshly prepared and served at least a week apart, and the subjects were asked to consume

* Jewish religious fasts last 24–25 hours depending on the calendar date.

the entire contents of each meal. After the meals they then went about their usual activities, but did not eat or drink again until the communal post-fast supper, 24 hours after the pre-fast supper.

Subjective evaluations

Three types of evaluation were made by each subject regarding each of the three fasts:

- Overall discomfort during each experimental fast compared with discomfort usually experienced during previous religious fasts. Scoring was from -3 (much less discomfort), through 0 (no difference) to +3 (much more discomfort).
- Degree of hunger and of thirst were recorded at 2 hour intervals during the final 8 hours of the fast. Scoring was from 0 (none) to 10 (severe).
- Specific symptoms (weakness, nausea, vertigo, and headache) were recorded as experienced.

Objective determinations

Before each fast, subjects voided and the urine was discarded. Weight, heart rate and blood pressure (measured three times in the right arm, in a sitting position, with a Baumanometer and manual cuff) were determined and a venous blood sample was drawn for hematological and chemical analyses in coded test tubes. At the end of each fast all measurements and analyses were repeated. All urine passed during the fast was collected, the volume measured, and a sample taken for chemical analysis. All hematological profiles were done within 2 hours of blood drawing. Urine samples and plasma were frozen and stored for chemical analysis, which was performed within 24–48 hours by standard automated methods.

Statistical analysis

The *t*-test for paired observations, Wilcoxon test, or chi-square tests were used, as appropriate, to test for significance of changes. $P < 0.05$ was considered significant. Values before and after each fast were compared, as well as those after each of the different fasts.

Results

All 13 volunteers completed the three fasts. The heat load (average of dry and wet bulb thermometer readings) was in the very low range (< 22 units) on all six experimental fast days (for those whose pre-fast meals were rich in protein, carbohydrate and fat, respectively, the heat load was 19.1, 14.4 and 19.6 units; temperature was 26, 20 and 23°C; and humidity 42, 72 and 63% saturation). A few subjects found finishing the protein meal difficult due to satiety; none was hungry after any of the three types of meal.

Subjective evaluation of fast [Figure 1, Table 1]

The scores given by each subject to the fast following each experimental meal as compared with previous religious fasts was significantly higher (i.e., signifying more difficult fasting) after the protein-rich meal (mean score +1.0). Fasting was easier

than usual after the carbohydrate-rich meal (mean -0.8 , $P < 0.01$ vs. the protein meal) and also after the fat-rich meal (mean -0.2 , $P < 0.05$ vs. protein). The most instances of side effects (11 vs. 9 after carbohydrate and 3 after fat meals) and the most subjects with 1 or more side effects (8 vs. 7 after carbohydrate and 3 after fat meals) were reported after the protein meal, but these differences did not reach statistical significance.

The score for degree of thirst after the protein meal was higher than after the carbohydrate or fat meal (not significant), while scores for hunger were very similar after all the meal types. Overall, there was a correlation of 0.4 ($P < 0.01$) between scores for discomfort and thirst.

Physical measurements [Table 2]

Post-fasting weight loss was significant after each of the meal types, with no significant differences between them; the mean loss for all groups taken together was 1.5 kg ($P < 0.05$).

Heart rate increased significantly after the carbohydrate (by 22%, $P < 0.005$) and slightly after the fat meal but decreased minimally after the protein meal; the difference between heart rate response at the end of the fast following the carbohydrate and protein meals was significant ($P < 0.001$).

Post-fasting systolic blood pressures decreased after all the meal types, but significantly so only after the fat meal (from a mean of 112 to 98 mmHg, $P < 0.05$). This decrease after the fat-rich meal was significantly greater compared to the changes in systolic blood pressure measured post-fasting after the carbohydrate and protein meals. Post-fasting diastolic blood pressures decreased significantly after the fat meal only.

Blood chemistry [Table 2]

Sodium and potassium concentrations were similar in all groups at baseline and did not change significantly by the

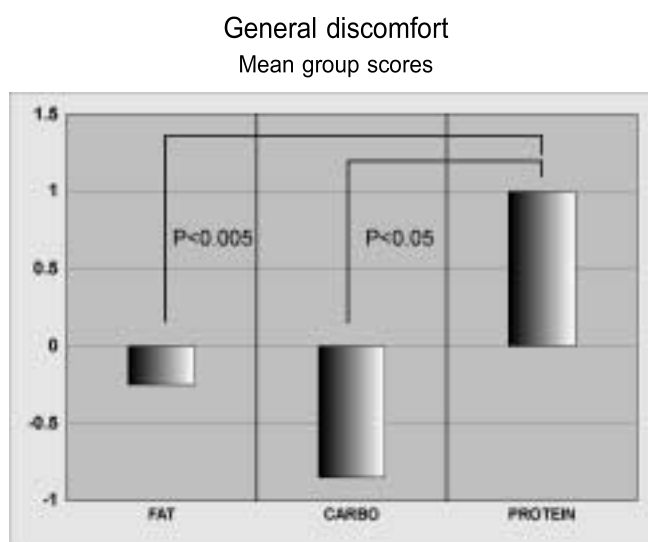


Figure 1. Subjective evaluation of fasts. For each fast, average score for overall discomfort compared to other fasts. Scoring was from -3 (much less discomfort) to +3 (much more discomfort)

Table 1. Effect of fasts on subjective evaluation of hunger, thirst, overall discomfort and side effects

Subject	High protein diet			High carbohydrate diet				High fat diet				
	Side effects	Hunger	Thirst	Dis-comfort	Side effects*	Hunger	Thirst	Dis-comfort	Side effects	Hunger	Thirst	Dis-comfort
1		0	0	0		0	0	0		1	0	0
2		0	0	0		1	0	0		1	0	0
3	V/H	0	6	2	V	0	5	0		3	5	-1
4		1	3	-1		1	4	-1		4	5	-1
5	W	3	4	1	W	4	3	0		4	4	-2
6	H/W	0	8	3	H	1	1	-3	H/W	0	2	3
7		2	1	0		2	1	-1		3	2	0
8	H	4	1	1	H	3	2	1		1	2	-1
9	N/W	8	8	1	N/H	8	2	-1		1	1	-3
10	H	3	7	3		1	1	-3		1	1	-2
11	H	1	7	0	H	1	7	0	H	1	7	2
12	W	3	7	2	V/N	5	7	-2	H/V	3	7	2
13		1	1	1		1	0	1		1	1	0
Sum	11	26	53	13	9	20	34	-10	5	24	37	-3
Mean	0.9	2.0	4.1	1.0*	0.7	2.2	2.6	-0.8	0.38	1.9	2.8	-0.2
SD	–	2.3	3.2	1.2	–	2.3	2.4	1.2	–	1.3	2.5	1.7

Score for hunger and thirst: scale of increasing intensity: minimal = 1, maximal = 10.

Score for intensity of discomfort (compared to preceding religious fasts): from “much less discomfort”(-3), “no difference”(0), to “much more discomfort”(+3).

Sum = total number of side effects or sum of individual scores.

* Significantly greater discomfort after high protein than after high carbohydrate ($P < 0.01$) and high fat diet ($P < 0.05$).

H = headache, V = vertigo, N = nausea, W = weakness

end of the fast. Blood urea nitrogen increased by 40% after fasting following the protein meal (from 14.6 to 20.3 mg/dl, $P < 0.01$), but was virtually unchanged after the other meal types. Thus, BUN at the end of the fasts was significantly higher after the protein than after the carbohydrate or fat pre-fast meals ($P < 0.005$ for both).

Triglyceride levels decreased post-fasting by about one-third after each meal type ($P < 0.05$ – 0.005). Cholesterol increased after the fat meal by 8% ($P < 0.05$). Glucose was unchanged post-fasting after the protein meal, increased slightly after the carbohydrate meal and decreased slightly after the fat meal, resulting in a significant difference between post-fasting concentrations with these two meal types ($P < 0.03$).

Hematological data [Table 2]

Hemoglobin concentration and hematocrit increased slightly post-fasting only after the carbohydrate meal (by 2.2 and 2.8% respectively, $P < 0.05$). Mean red cell volume decreased after the protein meal ($P < 0.001$), but increased slightly after the fat meal ($P < 0.05$). Post-fasting red cell volume was significantly lower after the protein than after the fat or carbohydrate meal ($P < 0.001$ and < 0.005 , respectively).

Total leukocyte and lymphocyte counts decreased and granulocytes increased post-fasting after each of the meal types; however, only when the values after all three types of

meal were taken together were the changes significant ($P < 0.05$ for all). Post-fasting platelet count decreased after all three types of meal, but significantly so only after the carbohydrate meal ($P < 0.01$) when it was significantly lower than after the fat meal ($P < 0.03$).

Urine analysis [Table 2]

The total volume of urine excreted during fasting after each meal type did not exceed one liter, and did not differ significantly from each other. There were significant, weak, negative correlations between urine volume and degree of thirst ($r = -0.40$, $P < 0.01$) and degree of hunger ($r = -0.53$, $P < 0.001$).

Mean osmolarity of urine collected during the fast was 63% higher after the protein than after the carbohydrate meal ($P < 0.001$), and 24% higher than after the fat meal ($P < 0.002$). Osmolarity of the last specimens passed just before ending the fast was highest after the protein meal (881 mosm/L), but differences between meal types were not significant.

Excretion of creatinine and sodium was the greatest after the fat meal, and least after the carbohydrate meal ($P < 0.05$ for both). Potassium was excreted to a greater extent after the protein than after the carbohydrate meal ($P < 0.05$); excretion after the fat meal was intermediate.

Discussion

The major finding of this study was that subjects undergoing a 24 hour food and water fast experienced more discomfort after an experimental protein-rich meal and less discomfort after

BUN = blood urea nitrogen

Table 2. Effects induced by different pre-fast meals on laboratory values

Experimental meal	High protein diet			High carbohydrate diet			High fat diet			P vs. C	P vs. F	C vs. F
	Pre	Post	P <	Pre	Post	P <	Pre	Post	P <	Pre	Post	P <
Physiological												
Weight (kg)	65.6±4.4	64.5±4.4	0.05	67.0±4.5	66.0±4.5	0.01	64.5± 4.9	62.5±6.0	0.01	NS	NS	NS
Heart rate/min	63.4±3.5	62.2±5.3	NS	61.8± 5.6	74.6±13.0	0.01	59.0±2.6	63.5±8.6	NS	0.02	NS	NS
Systolic BP (mmHg)	115.9±18.4	113.5±10.6	NS	116.2±16.0	109.6±20.3	NS	111.9±20.7	98.1±12.0	0.05	NS	0.05	0.05
Diastolic BP (mmHg)	73.5±11.0	70.8±8.7	NS	72.3± 9.1	76.2±14.7	NS	73.5±11.7	65.4±9.9	0.05	NS	NS	NS
Biochemical (mg/dl)												
Glucose	76.3± 6.9	76.8±5.3	NS	77.2± 8.0	81.8±5.9	NS	82.9±7.6	78.8±5.2	NS	NS	NS	0.03
Urea	14.6± 6.2	20.3±5.7	0.01	13.3±4.8	13.3±3.3	NS	14.9± 3.0	14.8±3.7	NS	0.005	0.005	NS
Cholesterol	170.5±36.7	171.8±34.9	NS	173.7±33.7	179.6±36.3	NS	174.0±34.5	187.9±36.6	0.05	NS	NS	NS
Triglycerides	120.7±52.1	85.1±33.0	0.05	128.5±57	91.5±46.5	0.001	155.1±59.6	95.0±36.5	0.001	NS	NS	NS
Hematological												
Hemoglobin (g/dl)	14.4±1.0	14.6± 1.0	NS	14.6±1.0	14.9±0.9	0.05	14.6±0.8	14.5±1.1	NS	NS	NS	NS
Hematocrit (%)	42.0±2.7	42.4±2.5	NS	42.1±2.7	43.3±2.3	0.01	43.1±2.0	43.3±2.8	NS	0.05	NS	NS
MCV (µl)	89.2±2.6	88.3±2.5	0.001	88.2±2.3	88.6±2.3	NS	87.8±2.7	88.9±2.3	0.05	0.005	0.001	NS
Leukocytes (10 ³ /mm ³)	7.2±1.3	6.9±1.0	NS	7.1±0.9	6.8±0.7	NS	7.4±1.8	6.9±1.5	NS	NS	NS	NS
Platelets (10 ³ /mm ³)	247±37	242±45	NS	255±42	233±36	0.01	252±44	249±39	NS	NS	NS	0.03
Urinary/day												
Volume (ml)		943±363			993±429			808±302		NS	NS	NS
Osmolarity (mOsm)		764±131			468±167			614±160		0.0001	0.002	0.04
Creatinine (mg)		1004±268			927±321			1097±348		NS	NS	NS
Sodium (mmol)		113±59			95±41			119±43		NS	NS	NS
Potassium (mmol)		75±21			62±22			71±26		0.03	NS	NS
Chloride (mmol)		106±54			97±43			102±41		NS	NS	NS
Phosphates (mg)		152±59			170±73			134±50		0.005	NS	NS
Uric acid (mg)		231±166			149±83			199±128		NS	NS	NS
Calcium (mg)		87±49			69±38			71±32		NS	NS	NS

P = protein, C = carbohydrate, F = fat, MCV = mean corpuscular volume

both fat- and carbohydrate-rich meals than they had during previous religious fasts. In addition, after the protein-rich meal there were slightly more specific side effects and more side effects per subject; the thirst score also tended to be higher. These findings therefore suggest that it might be possible to alleviate the discomfort of fasting by eating low protein pre-fast meals.

Reasons for greater discomfort following the high protein pre-fast meal

We suggest three possible mechanisms whereby the pre-fast protein-rich meal might adversely affect fasting. The first is that water conservation, already compromised by water restriction during hot weather, is affected by nutritional factors. All three basic foodstuffs affect water balance, each in a different way. An increase in carbohydrate intake results in water retention and a concomitant decrease in water loss [1], while metabolic use of fat results in the production of about 200 ml of water of oxidation per day [2]. On the other hand, protein catabolism involves the obligatory excretion of urinary water to eliminate nitrogenous metabolic products [2]. Thus theoretically, carbohydrate and fat both contribute towards positive water balance, whereas protein promotes water loss.

Contrary to what we expected, the average volume of urine excreted during fasting was virtually the same after each of the three meal types. Possibly, the above effects of the major nutrients are maintained for only the first few hours after their ingestion. However, during a long fast, the limited amount of water available for urinary excretion has a dominant effect on the final urine volume, rendering any differences induced by the three meal types negligible.

We have previously presented corroboratory evidence for significant overall water loss during the *Tisha B'Av* religious fast (which falls at the height of summer). We found significantly increased blood viscosity as a result of the fast, and suggested that those with increased hematocrit be wary of fasting, to avoid possible thrombotic events [3]. Recent reports on the incidence of acute cerebrovascular and cardiovascular events during the Islamic Ramadan fast did not show any increase [4,5], possibly because of the short duration of the daily fasts. Also, a trend toward a decrease in platelet count was observed during the Ramadan fast [6]. The reported increase in bleeding and coagulation times during the Ramadan fast [7] may counteract the prothrombotic effects of increased viscosity.

A second explanation for poorer fasting after a protein meal might be related to blood retention of part of the increased load

of protein degradation products. We found a significant increase in urea after the protein meal, resulting in a relative azotemia, with BUN almost doubling and reaching the upper limit of normal during the 24 hours of fasting. In contrast, there was no increase whatsoever in BUN after the carbohydrate and fat meals. Moreover, urine osmolality was highest after the protein meal, presumably due to increased urea and other nitrogenous products (which were not measured in the urine). Greater urinary losses of potassium may have also added to muscle weakness and contributed to poorer tolerance of fasting after the protein meal.

A third possible explanation for greater discomfort after the protein meal could be poorer hemodynamic adaptation. Unlike the response to the carbohydrate and fat meals, there was no compensatory increase in heart rate accompanying the decrease in systolic blood pressure that followed all meal types.

Other responses to fasts

The marked decrease in triglycerides that we found after all meal types is in accord with our previous report on biochemical changes induced by fasting [8]. A study of the food and water fast during daylight hours in the Islamic month of Ramadan also showed a marked decrease in triglycerides during the first days of the fast [9]. However, total cholesterol tended to increase in our study, as it does during prolonged starvation [10], but to decrease during the Ramadan fast [11] – the difference probably being due to the short duration of the daily Ramadan fasts.

Other significant changes that we reported previously [8] (in blood uric acid, sodium, glucose, total protein and albumin) did not occur to significant degrees in the present study, even when the data of all three fasts were grouped together. This may be due to the much smaller number of subjects in the current study (13 vs. 38).

Limitations of the study

There were four main limitations to this study. Firstly, our subjects were all volunteers who usually fasted at least fairly well and whose physiological responses apparently could cope well with the challenge of fasting. Those who usually fast poorly would have been more appropriate for this study, as subjectively they might have benefited even more from the low protein meal. Also, their fasting-induced hemodynamic and/or biochemical blood and urine responses to fasting might have been more pronounced, such that the noxious effects of the protein-rich pre-fast meal might have been more marked. The second limitation was the small number of subjects, which was not conducive to the detection of small but significant differences in objective responses to fasting. Thirdly, some climatic parameters differed on the experimental days. However, subjects spent most of the fast day indoors at their usual sedentary activities, mostly in air-conditioned rooms. Thus the outdoor climate was unlikely to have had a major effect on fasting. Also, the all important heat load [12] was similar on all days. Prolonged exposure to more extreme weather conditions might have made the observed differences between the three types of

fast more pronounced. Finally, although subjects were highly motivated to comply with the protocol, they were not observed throughout the fast and some might have tasted food or drink on some of the fast days. The blood chemistry of the subjects did not disclose any obvious violations of this kind.

Clinical implications

Based on the differences in subjective evaluations of fasting in relation to the composition of the pre-fast meals, we suggest that a protein-poor meal may ease the discomforts of fasting. This might apply not only to 24 hour food and water fasts required by Judaism, but also to the Moslem daylight fasts, particularly when the month of Ramadan falls in the summer. It also might be helpful before prolonged military or other missions, and before elective surgery should fasting be necessary. Studies on the effects of other pre-fast meal parameters (such as meal volume and number of calories) might bring us closer to defining the ideal pre-fast meal.

Appendix 1. Characteristics of diets

A. Composition of meals

	Fat meal	Carbohydrate meal	Protein meal
Weight (g)	148	225	206
Protein (%)	10	10	49
Carbohydrate (%)	21	86	30
Fat (%)	69	4	21
Kcal	954	920	934
Na (mEq/L)	748	810	732
H ₂ O (ml)	659	674	684

B. Ingredients of meals

Protein meal

Bread 60 g, cooked chicken breast 200 g, cooked fish fillet 200 g, canned peas 100 g, chicken soup mix 20 g in 200 ml water, peanuts 20 g, melon 100 g.

Carbohydrate meal

Bread 60 g, pasta 300 g, sauce (tomato sauce 100g, onion 50 g, green pepper 50 g), salt 1.5 g, apple 150 g, grape juice 200 ml.

Fat meal

Bread 60 g, avocado 100 g, salad 100 g, sour cream 150 g, soup mix 20 g in 200 ml water, salt 0.75g, water 200 ml.

Acknowledgements. We thank Laurie Duitsch RD for her assistance

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