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Changes in Metabolism during a Fasting Period and a Subsequent Vegetarian Diet with Particular Reference to Glucose Metabolism

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ABSTRACT

During an investigation on the effect of fasting and a vegetarian diet on the symptoms and signs in chronic cutaneous and arthritic diseases studies were made of glucose metabolism, liver function and the plasma concentration and urine excretion of some minerals. The study was performed on 27 patients who stayed as in-patients on a metabolic ward for five weeks. After the fasting period the blood glucose and serum insulin concentrations were lower ($p < 0.01$) than before the fast. At the end of the period on the vegetarian (vegan) diet (three weeks) the insulin/glucose ratio was lower than at the start of the fast. Serum enzyme concentrations reflecting liver function increased during the fast, but normalized during the vegan diet. The intake of vitamin B_{12} and of selenium due to the vegan diets was very low, which may give reason for some concern during long-term use of this type of vegetarian diet.

INTRODUCTION

Today, fasting is tried by many Swedish adults for alleged therapeutic purposes. Vegetarian diets are claimed to improve the clinical condition in various diseases, e.g. rheumatoid arthritis and different intestinal and cutaneous disorders. However, very few investigations have been made under controlled conditions to confirm these claims.

The clinical effects of two weeks of modified fasting followed by a period on a vegan diet were studied in a group of subjects with different diseases. The findings regarding the effects on the clinical status and on laboratory values related to inflammatory processes, have been described elsewhere (7). In this paper we describe the changes that occurred during a five-week period comprising two weeks of fasting followed by three weeks on a vegetarian (vegan) diet, with regard to blood glucose and serum insulin concentrations, liver function tests, serum electrolyte concentrations and the excretion of electrolytes in the urine.

MATERIALS AND METHODS

Subjects

The study was performed on 27 patients - 21 women and 6 men, with mean ages (± SD) of 46 ± 12 and 41 ± 13 years, respectively. The clinical diagnoses and the clinical course during the treatment have been described elsewhere (7). All patients had had their diseases for several years and were in a stable condition on admission.

Experimental procedure

During the first day the ordinary hospital diet was given. After the second day's tests the patients were given the vegan diet at a low energy level (5.0 MJ/day) for two days. They then fasted for 11 days, during which time only vegetarian broths were given (0.8 - 0.9 MJ/day). After breaking the fast, the energy intake was gradually increased during the first three days. Thereafter the daily energy intake was adjusted according to the patients' body weight, aiming at a stable body weight during the last two weeks of treatment.

On admission, clinical examinations and laboratory tests were performed on the first and second days. All studies carried out on admission were repeated at the end of the fast and at the end of the vegan-diet period. All tests were made in the morning after an overnight fast.

Diets

During the fasting period, vegetarian broths, vegetable and berry juice drinks and herbal teas were given every two to three hours. The beverages were made from different root vegetables such as beetroot, carrots and potatoes, and from bilberries and strawberries.

Table 1. Contents of protein, fat and carbohydrates calculated per 4.2 MJ (1000 kcal), in grams and as per cent of total energy (E%), in the vegan diet and a recommended Swedish diet. The average contents of calcium, carbohydrates and iron, and of some vitamins are given.

	Ordinary vegan diet		Ordinary Swedish diet*		Recommended** nutrients
	content	E%	content	E%	content
Protein	23±2 g	9	32 g	13	10-15 E%
Fat	45±2 g	42	43 g	40	35 E% (maximum)
Carbohydrate	125±5 g		115 g		50-60 E%
Calcium	370±68 mg		415 mg		350 mg
Phosphorus	610±125 mg		560 mg		
Iron	10±0.8 mg		6.9 mg		9.0 mg
Retinolequiv.	2.9±0.3 mg		0.6 mg		0.4 mg
Thiamin	1.01±0.25 mg		0.67 mg		0.5 mg
Riboflavin	0.56±0.06 mg		0.75 mg		0.7 mg
Niacinequiv.	10.4±0.7 mg		6.2 mg		7.0 mg
Ascorbic acid	76±16 mg		36 mg		33 mg
Sodium***	1090±234 mg				-
Potassium***	1850±70 mg				-
Zinc***	4.2±0.7 mg				

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**Statens livsmedelsverks meddelanden (ISSN 0347-1977) M 4/81.

***Analysis

A seven-day menu was used throughout the vegan diet period. The composition of the food (Table 1) was calculated from food tables. The vegetarian diet was based on fresh vegetables, root vegetables, millets, lentils and buckwheat. Sunflower oil (with a high content of polyunsaturated fatty acids) was used in dressings etc. The average ratio of polyunsaturated to saturated fatty acids was 4.4 ± 0.3 (mean ± SD). All animal protein (meat, fish, egg, milk) was excluded, which made the protein content of the diet low (Table 1). No extra salt or sugar was allowed. The simple carbohydrates included in restricted amounts were derived from berries and fruits. The average fibre content was 21.2 ± 1.9 g/4.2 MJ. One week's food was analysed for its content of some minerals. The average intake (per 4.2 MJ) of sodium was 1090 ± 234 mg, potassium 1850 ± 70 mg, zinc 4.2 ± 0.7 and selenium 8.1 ± 2.1 µg. The concentration of B_{12} was below the detection limit of the method (< 0.2 ng/g).

Statistics

A three-way analysis of variance was applied when separating effects of therapy, patient and sex, using the Statistical Analyses System (SAS) package for statistical analyses.

Biochemical methods

Blood glucose was determined by a glucose oxidase method (8). Serum insulin concentrations were measured with a Phadebas insulin kit (Pharmacia, Uppsala, Sweden). All other analyses were made at the Central Chemical Laboratory at the University Hospital, following standard procedures. Sodium and potassium in the diet were determined by spectrophotometry after ashing, and zinc and selenium by atomic absorption analysis after ashing and digestion with acids, respectively. B_{12} was extracted by a phosphate buffer at pH 8.9 and added to a Lactobacillus leichmanni culture, and the lactic acid formation was measured. These analyses were made at the Laboratory of the National Food Administration, Uppsala.

RESULTS

The body weight decreased significantly by about 10 % during the two-week fast in both sexes. During the consecutive vegan diet period it did not change significantly (Fig 1).

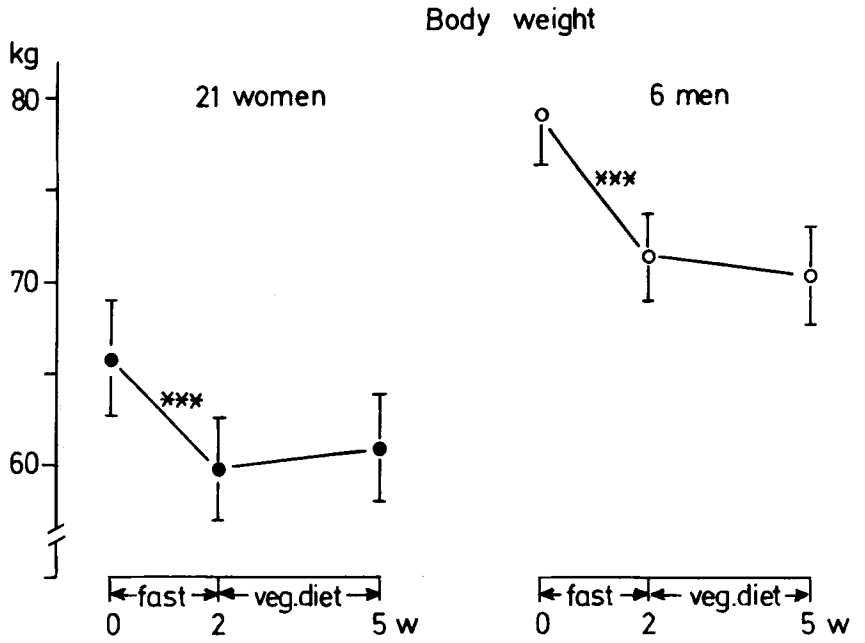

Fig. 1. Body weight in women and men on admission, after a two week vegetarian fast and after a three week vegetarian diet. Mean ± SEM. Significant changes are indicated by *** = $p<0.001$.

The blood glucose concentration fell during the fast and increased again during the vegan diet to values similar to those on admission, in both sexes (Fig. 2).

The serum insulin concentration decreased significantly during the fast in both women and men, and remained at a low level during the following vegan-diet period (Fig. 2).

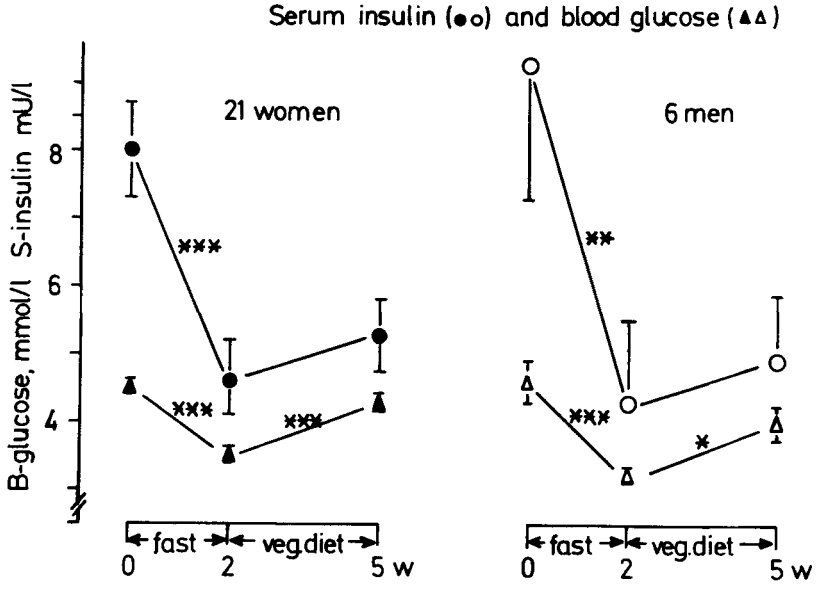

Fig. 2. Serum insulin and blood glucose concentrations. * = $p<0.05$, ** = $p<0.01$, *** = $p<0.001$.

Liver function tests. The serum-bilirubin concentration changed in a similar way in women and men (Fig. 3). There was an increase during the fast, followed by a decrease during the vegan-diet period. The final concentration was similar to the pretreatment value. Serum alkaline phosphatases did not change significantly in either sex (Fig. 3). In women, serum ASAT and ALAT increased significantly during the fast and then tended to decrease during the vegan-diet period (Fig. 4); in contrast, the serum gamma-glutamyltransferase (GT) concentration decreased significantly during the fast and then remained unchanged during the vegan diet (Fig. 4). This latter enzyme behaved in a similar way in the group of six men, whereas the changes of aspartate-aminotransferase (ASAT) and alanine-aminotransferase (ALAT) were less distinct than in the female group.

Serum creatinine increased significantly in both sexes during the fasting period and then decreased again to values similar to those on admission (Fig. 5).

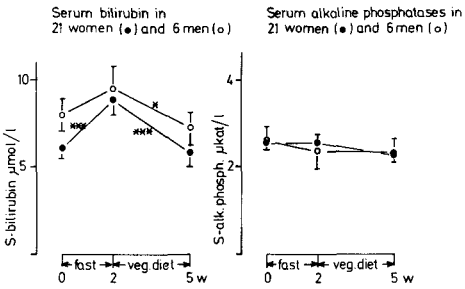

Fig. 3. Serum bilrubin concentrations and serum alkaline phosphatase activity. Statistical details as in Fig. 2.

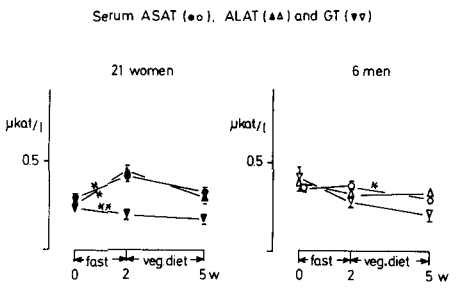

Fig. 4. Serum ASAT, ALAT and GT activity. Statistical details as in Fig. 2.

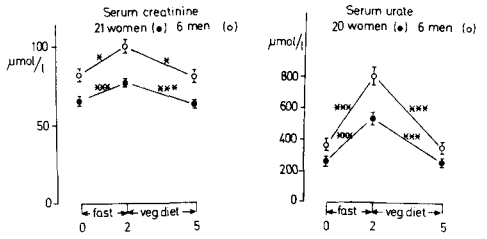

Fig. 5. Serum creatinine and urate concentrations. Statistical details as in Fig. 2.

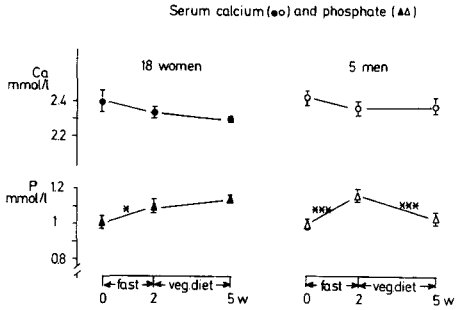

Fig. 6. Serum calcium and phosphate concentrations. Statistical details as in Fig. 2.

Serum urate increased during the fasting period and decreased during the vegan-diet period in both sexes (Fig. 5).

Serum electrolytes. The calcium concentration did not change significantly either in women or in men (Fig. 6). In contrast, the phosphate concentration increased significantly in both sexes during the fasting period and then decreased significantly among the men but not among the women.

Serum sodium and potassium both decreased in women during the fast and then increased again during the vegan-diet period. The trend was similar among men (Fig. 7).

Serum zinc and copper concentrations. The zinc concentration in serum increased during the fast and decreased during the vegan-diet period in both women and men, whereas the copper concentration did not change significantly during either treatment period in either sex (Fig. 8).

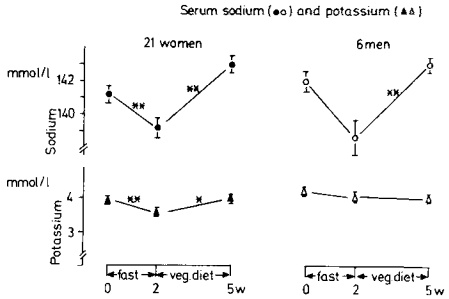

Fig. 7. Serum sodium and potassium concentrations. Statistical details as in Fig. 2.

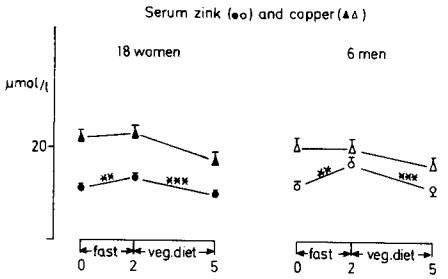

Fig. 8. Serum zinc and copper concentrations. Statistical details as in Fig. 2.

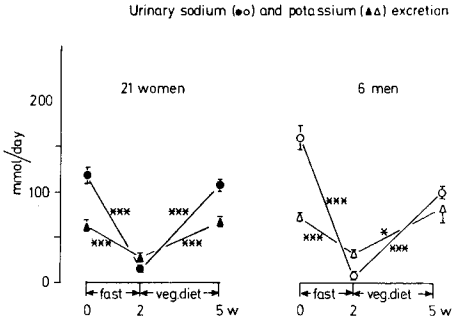

Fig. 9. Urinary sodium and potassium excretion. Statistical details as in Fig. 2.

Urine sodium and potassium excretion. There was a dramatic decrease in the daily urinary excretion of both sodium and potassium during the fasting period in both sexes (Fig. 9). During the vegan-diet period the excretion increased again; in women, the final values were not significantly different from those on admission, whereas in men, the daily excretion of sodium was significantly lower at the end of the vegan-diet period than at admission.

DISCUSSION

At the end of the vegan-diet period only a few of the biochemical variables studied were significantly altered compared with their values on admission. The most striking change was the decrease in fasting serum insulin to values below 5 mU/l, from a mean value of above 8 mU/l on admission. At the same time only minor and insignificant changes in the blood glucose concentration had

occurred, indicating a lowered insulin/glucose ratio. This may be regarded as "favourable", as low ratios are usually associated with a normal peripheral insulin sensitivity. Based on this premise, an improvement of this sensitivity may have been achieved during the treatment.

Several factors may have contributed to this. Firstly, the type of carbohydrates with a low intake of simple sugars may have affected glucose turnover, though probably only to a minor degree. Secondly, the decrease in body weight by about 10% from the pretreatment value is likely to have affected the peripheral insulin sensitivity. Earlier studies have also shown a more marked decrease of insulin values than of glucose values in the refed state after a fasting period (3,8).

In a study by Sörbris et al. (9) a similar type of fast as in our study was used. Their subjects, however, included obese persons who fasted for five weeks. This may explain some of the differences in the results regarding the liver function tests. For example in our study, bilirubin, ASAT and ALAT increased significantly, whereas in their study the only significant increase was in ASAT. It is of interest that in both studies serum GT decreased during fasting. The reason for the different effects on ASAT and GT are unclear. The moderate increases of ASAT and ALAT during the supplemented fast in our study as compared with the pronounced increases during a total fast (1) may be due to a protective effect of small amounts of glucose on liver function (4).

There was a significant but minor increase in serum phosphate during fasting. This may reflect the dissolution of minerals due to the acidosis during the fast. It may therefore be advisable for individuals prone to osteoporosis not to use even a modified fast for weight-reduction (4). Both sodium and potassium in serum decreased in females, but the values remained within reference ranges for all subjects. The lower sodium and potassium intake during the fast is reflected in the very low daily excretion of these minerals during this period. It is somewhat surprising that in women, during the vegan

diet the excretion of sodium and potassium was almost as high as on admission, despite the reduced intake of sodium during the vegan-diet period.

There has been some concern in the literature about the low intake of zinc (5), selenium (10) and vitamin B_{12} with vegan diets. In our study the serum concentration of zinc was significantly lower during the vegan-diet period than on admission, but was within reference limits. Normal values have also been found in women following vegetarian diets for many years (2). The contents of selenium and B_{12} in the vegan diet were low and there may be a need for supplementation when this type of diet is used for year-long periods (5). The daily recommended intake of selenium is 50-200 μg/day; the vegan diet used in our study does not even fulfil the requirements for a minimum intake of 20-30 μg/day (10).

In summary, the present study indicated that the peripheral insulin sensitivity was improved at the end of the vegan-diet period. This was regarded mainly as an effect of the proceeding weight decrease. Changes in liver function tests during the fast were only moderate and were reversible.

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