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CORRELATION OF GASTROINTESTINAL TRANSIT TIME TO FECAL WEIGHT IN ADULT HUMANS AT TWO LEVELS OF FIBER INTAKE

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ABSTRACT

Twenty-two healthy male and female adults were placed on a low-fiber diet for the duration of the study (28 days). Fecal wet weight (FW) and transit time (TT) were measured on days 10-14. After the subjects were distributed in two groups similar in FWs and TTs, they were placed on treatments supplying either 11 (PF11) or 2 (PF2) g/day water-insoluble fiber (WIF). After adaptation to the treatments, FWs and TTs were measured again on days 24-28. Non-significant changes were found for PF2 ($p>0.05$). For PF11, FW increased by 46.7% from baseline, but when the 2 subjects with the highest and the 2 with the lowest FWs were eliminated, the increase was 65.6%. Similarly, the TT change was non-significant ($p>0.05$) when all subjects were taken into account, but it became significant at $p<0.05$ when the 3 subjects with TTs $\geq$ 5 days were eliminated from the calculations (TT=-0.6 days). All subjects with TTs $\geq$ 5 days had a FW $\leq$ 90 g/day while all subjects with TT $\leq$ 2 days had FWs $\geq$ 120 g/day. Eleven g/day of WIF appears sufficient to make a significant ($p<0.05$) change in TTs and FWs in the majority of the population in this study, but a greater intake is probably needed for subjects with very low TTs and FWs. While the need to collect more data from a large population is evident, these results confirm previous observations that 120 g/day might be the minimal fecal weight to insure TTs $\leq$ 2 days.

INTRODUCTION

Dietary fiber has been the object of extensive research in the 1970s, after many years of minimal interest on the part of nutritionists and clinicians (1-2). In spite of the large number of publications on this subject there is lack of agreement as to what might be a desirable daily fiber intake in humans (3) as well as the kind of fiber pattern that would be ideal in human diets (2). Part of this lack of agreement is because dietary fiber can have both metabolic effects, e.g. on carbohydrate absorption, and effects on colon function.

Despite various disagreements and controversies on the quantitative need for plant fibers in the diet, it appears logical that the ability to expel feces without undue strain and pain is a desirable goal, no matter whether there is agreement or not on the

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long-term consequences of chronic constipation. This ability requires feces that are moist and formed but still soft and of sufficient fecal weight and bulk.

It has been previously shown by Spiller et al (4), Connell (5) and Burkitt et al (6) that gastrointestinal transit time (TT) decreases rapidly when the fecal weight is increased from a low of 20-30 g/day to about 120-200 g/day. Beyond this point further increases in fecal weight cause little or no decrease in transit time. The suggestion has been made (7) that 120-150 g/day is a critical fecal weight (CFW) and that this should be used as a guide to the minimum amount of dietary fiber to be consumed per day should a TT $\leq$ 2 days be desired. There is no consensus at this time whether or not CFW has implications on human health. It is presently a scientific fact that can be used as a tool in physiological and epidemiological studies.

In a typical western diet, the plant cell wall polymers that induce fecal bulk are the water-insoluble polymers that are probably equal to the neutral detergent fiber fraction. These polymers are cellulose, lignin and a fraction of the hemicelluloses. The types of hemicelluloses and their ratios to cellulose and lignin show wide variation in different foods. Plant fiber terminology in nutrition is confused (8), but the term water-insoluble fiber will be used in this text. Many water-soluble polymers such as pectin and some gums do not affect fecal weight. Some unusual plant products, such as psyllium seed and karaya gum are an exception as the water-soluble fraction (e.g. the mucilage or gum) is used as a bulking agent, but these products are not part of common foods.

In this study we attempted to further clarify: 1) what is the effect of each gram of water-insoluble fiber in increasing fecal weight, and 2) the concept of a critical fecal weight in relation to transit time. We supplemented the diet with a mixture of plant fibers rather than with a single source, to simulate more closely the way a western diet may be supplemented with high-fiber foods.

MATERIALS AND METHODS

Subjects and diets. Twenty-two healthy male and female adults, all residents of the San Francisco (Calif.) Bay region, aged 24 to 57 years (mean age = 31) were selected for this study. They were chosen after they had undergone a physical examination that excluded anyone who was pregnant or had a history of gastrointestinal disease. Each subject was carefully informed of the design of the study and of the type of treatment and diet they would have to consume, and all signed a consent form.

Subjects were not allowed to take any medication that could affect gastrointestinal function for the duration of the study and were placed on a modified low-residue diet for the entire period of the study. This diet limited the crude fiber intake to approximately three grams per day and a nutritionist discussed the diets in detail

with each of the subjects daily to insure compliance. Subjects were specifically instructed in the estimation of portion size and were required to keep a daily diet record so that compliance could be monitored. Each subject acted as his/her own control and was instructed to eat his/her normal diet throughout the study period with no change as to the basic pattern throughout the study, to minimize the effects of different non-fibrous dietary components on fecal output and transit time. All fluid intake was recorded and subjects asked to maintain it as constant as possible for the duration of the study. Subjects drinking alcohol were asked not to exceed two drinks per day. The crude fiber values were used in absence of the preferable values for dietary fiber or water-insoluble fiber, as these values are not yet widely available for foods in the United States. Legumes and products high in cereal bran were not allowed and the "allowed" fiber was derived from controlled portions of fruits, vegetables and grain products.

Study design. The subjects adhered to the restricted diet for the entire study period (28 days). Days 1-19 were a baseline period without any treatment. Feces were collected daily for 5 days (days 10-14). Treatment assignment was made on days 15-18. The treatment period started on day 19 and subjects were assigned to one of two treatment groups so that mean fecal wet weight and transit time were similar for both groups. The treatment period consisted of days 19-29 with daily fecal collections for 5 days (days 24-28).

Physiological measurements. Fecal specimens were collected by the subjects using a commode specimen system (Sage Products Inc., Elkgrove Village, IL), kept in an enclosed styrofoam container, cooled with packaged ice. Time of elimination was noted on each container. Intestinal transit time was measured according to the method of Hinton et al (9). Transit markers, in the form of radioopaque barium-impregnated pellets were administered to the subjects on days 10 and 24. The fecal containers were x-rayed daily and the appearance of 80% of the markers taken as the transit time. The feces were visually inspected, then frozen and at the end of the collection periods homogenized and an aliquot stored for possible future studies. Mean fecal wet weight per day for the five day period was used in the calculations.

Treatments. During the treatment period subjects ingested one of two types of food bars: treatment one, supplied 11 g/day of water-insoluble fiber, in the form of a mixture of soy and corn bran, peanut butter, rolled oats, carrot flakes and prune powder[2,3].

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[2] This was a commercial product (Bran 'N Oats™ Bar) manufactured by Shaklee Corporation, San Francisco, CA

[3] As some fruits in the diet may have a mild laxative effect, it was felt that the addition of a small amount of prune powder (3 g/day) would make the study more representative of an actual diet high in fruits, vegetables and seeds, while the plant fiber remained the fecal bulking agent.

Other ingredients in this food bar were fructose, crisped rice, wheat germ, soy protein, acacia gum, pectin and lecithin. This treatment will be referred to as PF11. The second treatment supplied 2.1 g/day water-insoluble fiber (PF2). To lower the fiber in PF2, these ingredients were removed or reduced: soy and corn bran, peanut butter, carrot flakes, prune powder, wheat germ, pectin and acacia gum. To simulate consistency and flavor, in an attempt to keep the study as blind to the subjects as possible, the oats and crisped rice were increased in PF2, but their minimal content of water-insoluble fiber allowed to keep this as a "low" fiber product. The two treatments were isocaloric to equalize any possible effect on food intake by the addition of the treatments to the baseline diet. Fiber analyses of the treatments are given in Table 1.

TABLE 1

Water-Insoluble Fiber Analyses of Treatments*

	Water-insoluble fiber %	Cellulose %	Hemi-cellulose %	Lignin (H_2SO_4) %
High-fiber treatment (PF11)	10.1	3.7	5.1	1.3
Low-fiber treatment (PF2)	1.9	1.0	0.5	0.4

*Analyzed by J.B. Robertson. Cornell University, Ithaca, NY, by the neutral-detergent and acid-detergent fiber methods (8)

RESULTS

Total fecal wet weight. Total fecal wet weight increased from baseline to treatment for PF11 (high-fiber treatment) by 46.6 g corresponding to 4.2 g/g of water-insoluble fiber ($p<0.05$), Table 2. For the low-fiber treatment (PF2) the increase was not statistically significant. The subjects with the highest fecal output (156 and 194 g/day for PF2 and 181 and 189 g/day for PF11) and the two with the lowest (25 and 27 g/day for PF2 and 22 and 30 g/day for PF11) were eliminated from the calculations for the respective groups. The results did not change for the PF2 but the increase in total fecal wet weight for PF11 was greater, 62.4 g corresponding to 5.7 g/g of water-insoluble fiber.

Gastrointestinal transit time. When all subjects were included in the calculations either on the PF2 or PF11, there was no statistically significant change at the $p<0.05$ level. When the subjects with transit time of 5 days or greater were excluded (3 subjects in each group), the change in transit time for PF11 group was 0.6 days, significant at the $p<0.05$ level, while it remained unchanged for PF2 (Table 2).

Frequency of elimination. While the elimination for the PF11 increased slightly (Table 2), this change was not significant. There was no change for the low-fiber group.

DISCUSSION

Some important points become apparent from this study. In regard to fecal wet weight, it is apparent that subjects with the highest and the lowest fecal wet weight for both groups did not respond to the fiber supplementation as well as the subjects with fecal wet weights in the range of 40 to 123 g/day. The reasons for this are hypothesized below.

The increment observed of 4.2 to 5.7 g/g of water-insoluble fiber is in the range reported in studies cited by Eastwood et al in a recent review (10).

The data for gastrointestinal transit time shows that some subjects are hyporesponders. These are the subjects who had a transit time of 5 days or more. Perhaps in these individuals, the long residence time in the colon favors greater digestion of the fiber polymers by bacteria, thus leaving feces that are too small to stimulate defecation.

We had previously shown that all the 40 ingested markers could be counted in the region of the sigmoid colon in an x-ray of a human subject who had a transit time longer than 7 days (7).

All this indicates that fiber supplementation at the moderate level of this study (+11 g/day water-insoluble fiber) is superfluous for individuals with fecal output higher than 156 g/day. Conversely, for people with extremely low fecal wet weight (30 g/day or less), who also have very slow transit time, this fiber supplementation is insufficient to achieve the desired fecal wet weight. For the majority of the population in this study, however, this change produced statistically significant increases in fecal wet weight.

Another important observation is that all subjects with a transit time equal to or greater than 5 days have a fecal wet weight of 90 g/day or less and that all the subjects with a transit time of 2 days or less have a fecal wet weight greater than 120 g/day. This confirms some previously published observations (4,7). Between 90 and 120 g/day there is a gray area of poor correlation of fecal wet weight to transit time (2-4 days). Thus, it appears that 120 g/day is a critical fecal weight (CFW) (7) in relation to transit time.

TABLE 2

Daily fecal wet weights (FW), transit time (TT) and frequency of elimination (FE) per five days for baseline period and high and low fiber treatments.

	TREAT-MENT	SAMPLE SIZE	BASELINE	TREATMENT	ACTUAL CHANGE	% CHANGE
FW (g/day) (all subj)	PF2	11	100.2 ± 15.9	113.9 ± 17.8	+13.7	+13.7%
	PF11	11	99.9 ± 16.3	146.5 ± 24.8	+46.6	+46.7%
FW (g/day) LESS 2 HIGHEST 2 LOWEST[1]	PF2	7	100.0 ± 10.6	114.7 ± 20.1	+14.7	+14.7%
	PF11	7	96.6 ± 9.6	159.0 ± 21.5	+62.4	+65.6%
TT (days) (all subj)	PF2	11	3.2 ± 0.5	2.9 ± 0.5	-0.3	-9.4%
	PF11	11	3.4 ± 0.6	2.9 ± 0.6	-0.5	-14.7%
TT (days) ≤5 days[2]	PF2	8	2.4 ± 0.3	2.3 ± 0.5	-0.1	-4.2%
	PF11	8	2.4 ± 0.3	1.8 ± 0.2	-0.6	-25.0%
FE (per 5 days)	PF2	11	5.1 ± 0.5	5.0 ± 0.5	-0.1	-2.0%
	PF11	11	5.2 ± 0.6	6.2 ± 0.9	+1.0	+19.2%

1 the two subjects with the highest and two with lowest FW were eliminated from the calculations for both groups.

2 the three subjects with TT equal to or greater than 5 days were eliminated from the calculations for both groups.

It appears important to accumulate more data on the plant fiber content of foods in the United States and it appears important that these analyses contain not only the total dietary fiber but also the water-insoluble fiber values, which are most likely more closely related to the amount of fecal output beyond the endogenous levels.

Presently there is no consensus as to the advantages of a certain transit time or of a regular daily fecal elimination. As more evidence accumulates relating dietary fiber intake to human health the physiological concept of a critical fecal weight to insure a transit time of two days or less may be come clinically important and may lead to recommendations for a desirable level of dietary fiber intake, perhaps in the range of 20-30 g/day of water-insoluble fiber.

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