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Dietary Fiber and Weight Regulation

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The influence of dietary fiber on energy regulation remains controversial. This review summarizes published studies on the effects of dietary fiber on hunger, satiety, energy intake, and body composition in healthy individuals. Under conditions of fixed energy intake, the majority of studies indicate that an increase in either soluble or insoluble fiber intake increases postmeal satiety and decreases subsequent hunger. When energy intake is ad libitum, mean values for published studies indicate that consumption of an additional 14 g/day fiber for >2 days is associated with a 10% decrease in energy intake and body weight loss of 1.9 kg over 3.8 months. Furthermore, obese individuals may exhibit a greater suppression of energy intake and body weight loss (mean energy intake in all studies was reduced to 82% by higher fiber intake in overweight/obese people versus 94% in lean people; body weight loss was 2.4 kg versus 0.8 kg). These amounts are very similar to the mean changes in energy intake and body weight changes observed when dietary fat content is lowered from 38% to 24% of energy intake in controlled studies of nonobese and obese subjects. The observed changes in energy intake and body weight occur both when the fiber is from naturally high-fiber foods and when it is from a fiber supplement. In view of the fact that mean dietary fiber intake in the United States is currently only 15 g/day (i.e., approximately half the American Heart Association recommendation of 25–30 g/day), efforts to increase dietary fiber in individuals consuming <25 g/day may help to decrease the currently high national prevalence of obesity.

Introduction

The prevalence of overweight and obesity are increasing nationally and worldwide. In the United States, 59% of adult men and women are now considered overweight (body mass index [BMI, kg/m^2] 25–29.9) or obese (BMI >30).[1] Although consumption of a western diet is thought to be one of the causes of this high prevalence of obesity, the precise roles of specific dietary components remain uncertain. This review is the second in a series[2] from our laboratory examining the effects of individual dietary components on energy regulation, and expands on previous reviews in this area.[3–7]

What Is Dietary Fiber?

There is no single accepted definition of dietary fiber, but a physiologically based description is dietary constituents that are not enzymatically degraded to absorbable subunits in the stomach and small intestine. This definition is based on previously suggested terms[8,9] and broadened to include dietary constituents of nonplant origin (e.g., animal, fungal) as was recently suggested.[10] There are a wide range of plant constituents that fall within this definition as summarized in Table 1, and they can be broadly classified as soluble or insoluble and fermentable or nonfermentable. Solubility depends on the extent to which the fiber dissolves in water or forms a gel. Fermentability relates to whether the undigested fibers that reach the large intestine are fermented by anaerobic bacteria to yield short-chain fatty acids (which are absorbed and used as an energy source) and gases such as methane and hydrogen.[11–13] All fibers except lignin are nonstarch polysaccharides, and lignin is an alcohol derivative. The soluble fibers are typically fermented to a greater extent than insoluble cellulose but all nonstarch polysaccharides are at least partially fermented in the large intestine.

Theoretic Roles of Fiber in Energy Regulation

There are several physiologic effects of fiber that can be predicted to influence energy regulation[14,15] as summarized below and illustrated in Figure 1.

Energy Dilution

By definition, fiber is not enzymatically digested into absorbable subunits. Most fibers, especially soluble ones, are fermented to a greater or lesser degree in the large intestine, and the resultant short-chain free fatty acids are

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Table 1. Types of Fiber Found in Foods[11,12]

Name	Food Source	Solubility	Fermentability	Structure
Lignin	All woody plant tissues	Insoluble	Not degraded	Polymers of phenylpropane (noncarbohydrate)
Cellulose	All plant cell walls	Insoluble	Slowly degraded	Glucans
Hemicelluloses	Matrix of all plant cell walls	Insoluble/soluble	Degraded more quickly than cellulose	Arabinozylans, galactomannans, xyloglucans
Pectins	Ripe fruit (e.g., apples, oranges)	Soluble	Rapidly degraded	Galactouronans, arabinogalactans, α-glucans Arabinozylans
Gums	Guar, locust bean	Soluble/dispersable	Rapidly degraded	Galactomannans, arabinogalactans
Mucilages	Seeds	Soluble/dispersable	Rapidly degraded	Branched galactans

absorbed and used as energy. On average, however, only 40% of fiber is fermented,[16] which causes the energy content of fiber per unit weight to be low such that including fiber in a diet effectively lowers energy density. Furthermore, the capacity of both soluble and insoluble fibers to bind water leads to an additional lowering of the energy-to-weight ratio in foods.[14] Eating the same weight of a less energy-dense food has been reported to increase satiety and decrease energy intake in several short-term studies.[17–21] Thus, by virtue of its ability to reduce energy density fiber may reduce voluntary energy intake.

Chewing

Foods that are naturally rich in fiber require greater mastication in terms of effort and/or time. This is hypothesized to promote satiation by reducing the rate of ingestion.[22]

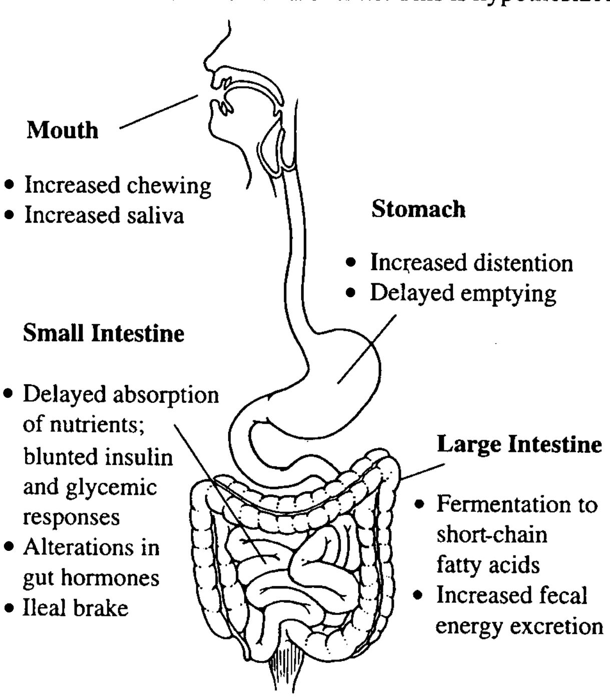

Figure 1. The effects of fiber in the gastrointestinal tract on parameters related to energy regulation.

Gastric Distention

The increased chewing necessitated by fiber may promote gastric distention through the additional production of saliva and gastric acid.[14,23,24] In addition, because some of the soluble fibers absorb large quantities of water and form gels, they may further increase stomach distention. Stomach distension is suggested to trigger afferent vagal signals of fullness and hence contribute to satiety during meals and satiation in the postmeal period.[14,15,25]

Gastric Emptying and Rate of Nutrient Absorption

Soluble fibers delay gastric emptying by forming a viscous gel matrix that traps nutrients and retards their exit from the stomach and retards digestion.[15,23,26–28] Thus, nutrient absorption occurs over an extended period during consumption of diets higher in soluble fiber. Friedman's[29] energy regulation model postulates that availability of circulating nutrient substrates may signal hunger and/or satiety, and thus the ability of fiber to extend the period during which nutrients are absorbed may reduce hunger and/or increase satiety. In the small intestine, soluble fiber may blunt postprandial glycemic and insulinemic responses,[30,31] which are linked to reductions in the rate of return of hunger and subsequent energy intake in several previous studies.[2] Furthermore, the observation that levels of glycemia at a test meal influence glycemic responses to a subsequent test meal (the "second meal effect")[30,32,33] provides a potential link between glycemic response and subsequent food ingestion.

Gastrointestinal Hormones

Dietary fiber may also influence energy intake and body weight through its effects on gut hormones, although most of the proposed mechanisms remain speculative. Delaying the absorption of macronutrients in the proximal small intestine results in a relative increase in the contact of macronutrients with the distal small bowel absorptive surfaces. The presence of these unabsorbed macronutrients in the distal small bowel has been associated with delayed gastric emptying and slowing of small bowel transit time, termed the "ileal brake."[15,32,34] There exist several candidate gut hormones that may mediate the ileal brake, including glucagon-like peptide-1 (GLP-1), peptide YY, and neurotensin.[15] GLP-1 is a hormone secreted along the length of the gastrointestinal tract in response to glucose and fat, as well as fermentable fibers and other stimuli, and has been shown to slow gastric emptying, reduce hunger, and promote weight loss when provided exogenously.[35] GLP-1 secretion is reduced in obese individuals,[36,37] although cause-effect relationships remain unclear. In animal studies, ingestion of fermentable fiber promotes increased GLP-1 secretion.[38,39] Because GLP-1-producing cells are abundant in the ileum and colon, it is possible that soluble fiber intake increases GLP-1 secretion by facilitating increased macronutrient delivery to the ileum, as well as through the action of fermented short-chain fatty acids in the colon.

Caloric Excretion

Some fibers, in particular the more soluble, fermentable fibers from fruits and vegetables,[40] reduce the overall absorption of fat and protein. This may be because their presence in the gastrointestinal tract restricts the physical contact between nutrients and intestinal villi necessary for absorption.[41] As a consequence, there is an inverse relationship between fiber intake and both fat and protein digestibility.[41,42] Thus, higher-fiber diets may directly reduce digestible energy intake and in this way may contribute to long-term weight management.[14,15] It should also be noted that the amount of energy lost owing to reduced digestion of fat and protein in the small intestine is partly offset by the energy available from fermentation of both fiber and trapped nutrients in the large intestine. For this reason, although there remains controversy regarding the precise relationship between fiber and fecal energy loss, net availability of energy from fiber is usually considered to be zero and a small additional loss of energy in subjects consuming higher-fiber diets is generally recognized.[25] In one study with large differences in fiber intake between control and fiber-supplemented groups, subjects eating the low-fiber (20 g/day) diet had an 8% higher absorption of energy from food than subjects consuming a high-fiber diet (48 g/day).[42]

Historic and Epidemiologic Data

Fiber intakes during human evolution were considerably greater than they are today. Eaton et al.[43] estimated that Paleolithic man ate 77–120 grams fiber/day, an amount five to eight times greater than current adult intakes in the United States.[44] Modern-day subsistence farmers and other groups continuing to eat a traditional diet consume ≈50 g fiber/day,[45] which is lower than the Paleolithic intake but still more than triple current mean intakes.

These numbers alone do not, of course, suggest that fiber is protective against obesity, but obesity is reported to be rare in populations that consume a high-fiber diet and prevalent in populations that consume a low-fiber diet.[23] For example, the mean daily intake of dietary fiber in the United States, where 59% of adults are now overweight or obese,[1] is estimated to be 15 g/day,[44] but is 60–80 g/day in Kenya, Uganda, and Malawi,[46] where <15% of adults are overweight or obese.[47,48] Similarly, within population groups, individuals with higher fiber intake tend to be leaner than individuals with lower fiber intake,[49,50] and case-control studies have documented that obese individuals typically consume less fiber than normal-weight individuals.[51,52] Migrant population studies also show consistent results. For example, Pima Indians living their traditional life in Mexico consume an average of 50 g fiber/day and have a mean adult BMI of 24.9, whereas Pima Indians living on reservations in Arizona consume an average of 19 g/day and have a mean BMI of 34.2. Similar results were reported by Gittelsohn et al.[53] for a native population living in Canada.

One problem with these epidemiologic approaches is that fiber usually covaries with other nutrients that have a potential impact on energy regulation; for example, diets low in fiber are typically high in fat and energy density. Some epidemiologic studies have used statistical approaches to separate the association of fiber with body weight from other potentially active dietary variables. In a prospective study of the changes in cardiovascular disease risk factors over 10 years in young adults (the CARDIA study), Ludwig et al.[54] reported that at all levels of fat intake, people eating the most fiber gained less weight over a 10-year period than those eating the least fiber. Fiber was also significantly inversely associated with change in waist-to-hip ratio, whereas dietary fat was not. Thus, fiber was associated with decreased weight gain and reduced risk of obesity after accounting statistically for the possible confounding influence of dietary fat intake. Other potential factors such as food form, diet palatability and variety, and physical activity were not taken into account although other studies have suggested potential roles for these factors in energy regulation.[55–59]

Combined, the data from epidemiologic studies convincingly suggest an association between low fiber intakes and higher body weight/higher BMI and are consistent with the known physiologic effects of fiber that potentially have an impact on energy regulation. However, the question of whether the epidemiologic associations are primarily driven by fiber or some other dietary variable is not adequately resolved owing to the potential for other nutrients to confound the association.

The Effects of Fiber on Hunger and Satiety

Several of the known physiologic effects of fiber described above suggest a generalized influence of fiber on hunger and satiety. Table 2 summarizes studies directly examining the effects of dietary fiber on hunger and satiety as measured by psychological instruments such as the analog scale.[92] The studies used in the summary were those that investigated healthy nondiabetic subjects, and had a control treatment with equivalent energy and fat contents (studies that had different fat levels between treatment groups, e.g., that of Mickelsen et al.,[17] were excluded). The studies were divided by the type of fibers given and study duration (short term ≤2 days; long term >2 days) to examine whether there were different effects depending on the nature of the fiber and period of consumption. As shown, the majority of studies showed a significant or nonsignificant increase in satiety between meals and/or a decrease in hunger relative to a control group that consumed less fiber, and there was no apparent difference in the efficacy of fiber between short-term and long-term studies. Furthermore, there was no trend toward either soluble or insoluble fiber being more effective. There were no studies that reported significantly reduced satiety or increased hunger with a higher-fiber treatment.

It should be noted that not all of the studies in Table 2 used treatment and control regimens that were precisely comparable (only studies with different levels of energy and fat intake in the control treatment were excluded from the main summary), and thus the results might possibly have been confounded by uncontrolled differences between groups. We therefore differentiated those studies approximately controlled for food form (i.e., raw versus cooked), palatability, energy density, and variety—four factors known to influence energy intake[55–59]—from those that were uncontrolled for these factors by highlighting the relatively more controlled studies in boldface type. Among this subset of more controlled studies, the majority again showed a significant or nonsignificant increase in satiety or decrease in hunger with increased fiber. We further distinguished (using asterisks) those studies that used high-fiber versus low-fiber foods to create differences in fiber between groups from those that used fiber supplements. All the studies that used a fiber supplement reported a significant or nonsignificant increase in satiety or reduction in hunger compared with a control group, whereas only ≈80% of studies creating differences in fiber with food found beneficial effects of fiber. This suggestion of greater fiber efficacy from fiber supplements compared with foods was not statistically significant but may merit further investigation.

The Effects of Fiber on Energy Intake and Body Weight

The studies described above strongly suggest that an increased fiber intake, whether given as higher-fiber foods or as a fiber supplement, results in increased satiety and/or decreased hunger. However, a further important question is whether these changes in hunger and satiety induce or facilitate changes in energy intake that ultimately lead to weight loss or prevent weight gain under conditions of ad libitum intake or a fixed low-energy regimen.

Tables 3 and 4 summarize studies in healthy subjects

Table 2. Does Dietary Fiber Increase Satiety or Reduce Hunger Relative to a Low-fiber Control/Placebo Treatment?

Studies ≤2 Days	Yes	No
Mixed Fibers		
Haber et al., 1977[55]	x	
Bolton et al., 1981[60]	x	
Porikos & Hagamen, 1986[61]	x	
Burley et al., 1987[62]	x	
Leathwood & Pollet, 1998[63]	x	
Burley et al., 1993[64]		x
Gustafsson et al., 1993[65]		x
Raben et al., 1994[66]	x	
Delargy et al., 1995[67]	NS	
Gustafsson et al., 1995[68]	x	
Soluble Fibers		
Wilmshurst & Crawley, 1980[69]	x	
Ellis et al., 1985[70]	x	
French & Read, 1994[71]	x (high fat)	x (low fat)
Van De Ven et al., 1994[72]*	x	
Tomlin, 1995[73]*	NS	
Delargy et al., 1997[74]		x
Tiwary et al., 1997[75]*	x	
Insoluble Fibers		
Burley et al., 1993[76]	x	
Turnbull et al., 1993[77]	x	
Delargy et al., 1997[74]		x
Studies >2 Days		
Mixed Fibers		
Anderson & Sieling, 1980[78]	NS	
Rigaud et al., 1987[79]*	x	
Rossner et al., 1987[80]*	NS	
Astrup et al., 1990[81]	x	
Effertz et al., 1991[82]*	x	
Soluble Fibers		
Shearer, 1976[83]*	x	
Hylander & Rossner, 1983[84]	x	
Krotkiewski (Study I), 1985[85]	NS	
Krotkiewski (Study II), 1985[85]	x	
Krotkiewski (Study III), 1985[85]	x	
Rigaud et al., 1990[86]*	x	
Pasman et al., 1997[87]	x	
Heini et al., 1998[88]		x
Insoluble Fibers		
Hylander & Rossner, 1983[84]*	x	
Krotkiewski (Study IV), 1985[85]	NS	
Ryttig et al., 1985[89]*	x	
Ryttig et al., 1989[90]*	x	
Turconi et al., 1995[91]*	x	

Note: Within studies, treatment and control diets had similar fat contents and energy density. Studies approximately controlled for food form, palatability, energy density, and variety are shown in bold font.

* Studies in which fiber was given as a supplement rather than as high-fiber foods.

Table 3. Percentage Decrease in Energy Intake During Consumption of Higher-fiber Diets Compared with a Lower-fiber Control Diet

Studies ≤2 Days		Fiber Amount (g/day)	% Decrease in Energy Intake: Fiber/Control
Mixed Fibers			
Grimes & Gordon, 1978[93]		—	78+
Bryson et al., 1980[94]		8	94
Porikos & Hagamen, 1986[61]	(obese)	6	105
	(nonobese)†	6	59+
Burley et al., 1987[62]		9.5	99
Levine et al., 1989[95]		39	89+
Burley et al., 1993[64]		29	96+
Delargy et al. (Study I), 1995[67]		17	91+
Mean			89
Soluble Fibers			
Van De Ven et al., 1994[72]*†		5	98+
Tomlin, 1995[73]*		9	80
Delargy et al., 1997[74]		19	98
Mean			92
Insoluble Fibers			
Burley et al., 1993[76]		8	82+
Turnbull et al., 1993[77]		7	76+
Delargy et al., 1997[74]		19	107
Mean			88
Studies >2 Days			
Mixed Fibers			
Heaton et al. (nondiabetics), 1983[96]†		14	78+
Rigaud et al., 1987[79]*		7.3	99
Stevens et al., 1987[97]*		19	95+
Effertz et al., 1981[82]*†		20	87
Mean			90
Soluble Fibers			
Evans & Miller, 1975[98]*		10	90
Stevens et al., 1987[97]*		19	93+
Pasman et al. (Study I), 1997[87]*†		40	81+
Mean			88
Insoluble Fibers			
Evans & Miller, 1975[98]*		10	90
Stevens et al., 1987[97]*		19	97+
Mean			94

Note: All studies had similar levels of dietary fat (percentage of energy) and energy density in control and treatment diets. Studies approximately controlled for food form, palatability, energy density, and variety are shown in bold.
* Studies in which the fiber was given as a supplement versus higher-fiber foods.
+ Results statistically significant (p <.05).
† Subjects were obese or overweight (in studies with some overweight/obese and some normal-weight subjects, + is used when the mean body mass index [BMI, kg/m^2] was >25).

in which energy intake and/or body weight change were compared between higher-fiber and lower-fiber treatments approximately matched for the proportion of dietary energy provided by fat. Some of the studies used different groups to study the effects of high versus low fiber, whereas others used each subject as his/her own control. We excluded studies without a control group,[113,114] studies that had differences in dietary fat content or energy density between groups,[17,18,115–117] and specific groups within studies that combined changes in fiber with exercise.[106] As in Table 2, studies highlighted in boldface type denote those approximately controlled for energy density, palatability, food form, and variety, and those with an asterisk used a fiber supplement rather than foods naturally high in fiber to create differences between treatments.

The majority of the investigators examining energy intake observed a decrease in intake during consumption of a higher-fiber regimen, and there was no apparent difference between those studies that were controlled for food form, variety, and palatability versus those that were not (Table 3). Similarly, the effects of soluble versus insoluble fibers and fiber from high-fiber foods versus supplements appeared to be comparable, although further studies are needed to confirm these tentative conclu-

Table 4. Weight Loss in Studies Comparing Higher-fiber Diets with a Lower-fiber Control Diet in Studies ≥4 Weeks Duration

Fixed Intake	Fiber Type	Fiber (g/day)	Duration (months)	Δ Weight (kg/study)	Δ Weight (g/day)
Duncan et al., 1960[99]*†	I	4–5	2	–0.27	–4
Valle-Jones, 1980[100]*†	S	18	1.5	–1.8	–43+
Rossner et al., 1985[101]*†	M	5	2	–1.4	–23
Ryttig et al., 1985[89]*†	M	8.5	2.8	–2.1	–27+
Kaul et al., 1987[102]†	M	30	2.5	–1.8	–41+
Rossner et al., 1987[80]*†	M	5	2	–1.0	–18+
Solum et al., 1987[103]*†	M	5	3	–1.8	–21+
Rossner et al., 1988[104]*†	M	6.5	3	0.3	4
Pena et al., 1989[105]†	M	15	1	–0.7	–25+
Ryttig et al., 1989[90]*†	I	6–7	6	–1.3	–7+
Rigaud et al., 1990[86]*†	M	7	6	–2.5	–14+
Mean		10	2.9	–1.3	20
Ad libitum Intake					
Yudkin, 1959[106]*†	I	10	1.5	–1.7	–40+
Weinreich et al., 1977[107]*	I	25	1.1	–0.4	–11+
Henry et al., 1978[108]	M	20	1	0	0
Tuomilehto et al., 1980[109]*	S	12	4	–2.0	16+
Heaton et al. (nondiabetic), 1983[96]†	M	14	1.5	–3.2	–76+
Walsh et al., 1984[110]*†	S	3	2	–3.2	–57+
Krotkiewski					
(Study II), 1985[85]*†	M	8	12	–5.8	–17+
(Study III), 1985[85]*†	M	8	13	–1.8	–5
Gropper & Acosta, 1987[111]*†	M	15	1	–0.3	–4
Effertz et al., 1991[82]*†	M	20	3.2	–0.8	–8
Vido et al., 1993[112]*†	S	1	2	–2.1	–35
Mean		12	3.8	–1.9	–24

Note: All studies had similar levels of dietary fat (percentage of energy) and energy density in control and treatment diets. Studies approximately controlled for food form, palatability, energy density, and variety are shown in bold.

* Studies in which the fiber was given as a supplement versus higher-fiber foods.

\+ Results statistically significant (p <.05).

† Subjects were obese or overweight (in studies with some overweight/obese and some normal-weight subjects, † is used when the mean body mass index [BMI, kg/m^2] was >25).

M = mixed fibers, S = soluble fiber, I = insoluble fiber.

sions. Overweight/obese subjects tended to reduce energy intake to a greater extent on the higher-fiber diets (mean 82% versus 94%), suggesting an enhanced effect of fiber in individuals with typically low intakes. Because several studies showed trends toward lower energy intake with higher fiber intakes that were not significant, we further analyzed the effects of fiber on energy intake by combining the different studies that quantified the effect of fiber intake. As shown in Figure 2, mean energy intake on the higher-fiber diets in studies >2 days was 90% of that on the control diets, and a paired t-test showed that energy intake on the higher-fiber treatments was significantly lower than on the lower-fiber treatments (p = 0.003).

A summary of the effects of high-fiber versus low-fiber diets on body weight under fixed energy and ad libitum conditions is shown in Table 4. Almost all studies reported weight loss in the high-fiber group relative to the lower-fiber group irrespective of whether energy intake was fixed or ad libitum. There was no apparent difference between different types of fibers (soluble versus insoluble versus mixed, and fiber supplements versus high-fiber foods), and no difference between longer versus shorter studies. Total weight loss was relatively higher in the ad libitum–fed subjects who consumed higher amounts of fiber (averaging 1.9 kg over a mean study duration of 3.8 months), suggesting that the effects of fiber on reduced hunger and increased satiety do in fact translate into changes in body weight. The mean rate of weight loss in the 12 ad libitum studies for which weight loss data was available is shown in Figure 3, and there was a significant difference between lower-fiber and higher-fiber groups (p = 0.003). Furthermore, weight loss was more pronounced in those studies that used obese or overweight individuals as subjects (2.4 kg versus 0.8 kg). These amounts of overall weight loss in nonoverweight and overweight subjects were very similar to the means for similar subjects changing from a high-fat (38% of energy) to a low-fat (24% of energy) diet.[118] It is also important to note that subjects

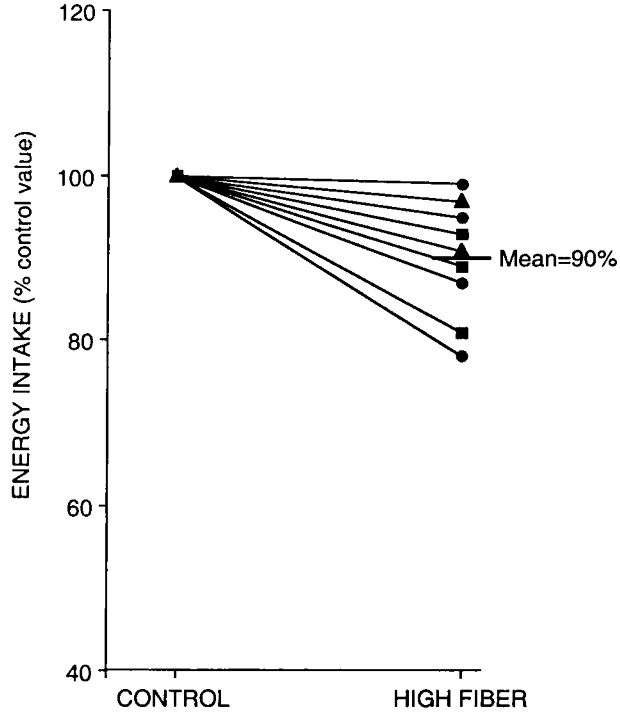

Figure 2. Percentage reduction in voluntary energy intake in studies examining the effects of high-fiber versus low-fiber diets. Values are means of treatment groups for each of the studies >2 days duration in Table 3, with control group values set to 100. In a paired t-test analysis of the group means from individual studies, treatments averaged 90% of controls and were significantly different ($P = 0.003$).

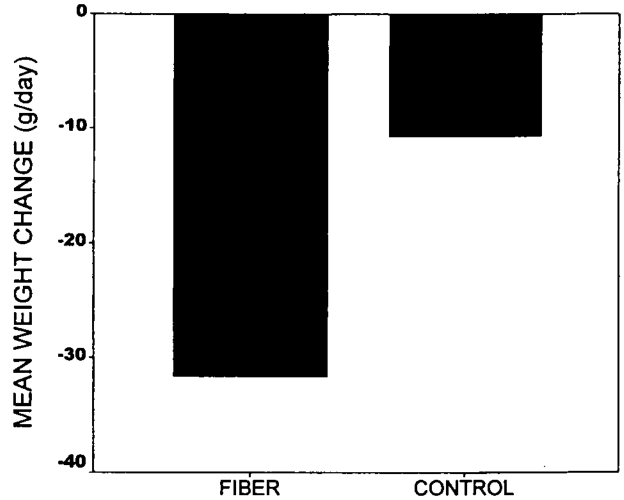

Figure 3. Rate of weight loss in lower- and higher-fiber treatments. Values are the means of treatment means from the ad libitum studies described in Table 4. Differences between the treatments were significantly different by paired t-test ($P = 0.003$).

consuming higher-fiber diets lost weight even when energy intake was fixed (Table 4). This is surprising because the expected increase in fecal energy excretion owing to fiber is small and unlikely to be measurable as a change in body weight. The difference may be due in part to increased compliance with the fixed calorie regimens (many of which were hypocaloric) owing to increased satiety and decreased hunger.

Another role for fiber may be in prevention of weight regain following weight loss. Ryttig et al.[90] reported that overweight subjects given fiber supplements for the weight maintenance phase of a weight-reduction program were better able to sustain their weight loss than subjects given a placebo. Similarly, Cairella et al.[119] gave subjects either a placebo or 6 g/day of a mixed fiber supplement after they had achieved weight loss with a very low–calorie diet, and the supplemented group had a significantly greater additional drop in BMI after a further 2-month measurement period.

Conclusions

Consistent with the known physiologic effects of fiber, the majority of studies in healthy adult subjects have demonstrated increased satiety, reduced hunger, reduced energy intake, and body weight loss during consumption of higher-fiber diets. The changes in body weight when higher-fiber diets are consumed ad libitum are relatively modest for all studies taken together, averaging 1.9 kg over 3.8 months, but are similar in magnitude to those obtained in studies comparing high-fat and low-fat diets consumed ad libitum. Moreover, more pronounced effects of higher-fiber diets tend to be seen in studies of obese/overweight subjects (energy intake reduced to 82% of control intake and weight loss of 2.4 kg), suggesting that the ability of fiber to promote negative energy balance may be most pronounced in individuals who need to lose weight most.

The beneficial effects of fiber on energy regulation were seen with both soluble and insoluble fibers, when using foods naturally high in fiber and fiber supplements. There is relatively little information directly comparing different fiber types and modes of administration, however, and further studies are needed in this area. Pending the outcome of these investigations, a focus on increasing the mean population fiber intake from its current U.S. level of 15 g/day up to the recommended level of 25–30 g/day mixed fiber,[120] by substituting whole grain products for refined ones and increasing fruit and vegetable consumption, is likely to be beneficial and may help reduce the high national prevalence of obesity.

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