What Do We Know about Dietary Fiber Intake in Children and Health? The Effects of Fiber Intake on Constipation, Obesity, and Diabetes in Children[1]

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ABSTRACT

The effect of dietary fiber intake on chronic diseases has been explored in adults but is largely unknown in children. This paper summarizes the currently existing evidence on the implications of dietary fiber intake on constipation, obesity, and diabetes in children. Current intake studies suggest that all efforts to increase children's dietary fiber consumption should be encouraged. Available data, predominantly from adult studies, indicate significantly lower risks for obesity, diabetes, and constipation could be expected with higher dietary fiber consumption. However, there is a lack of data from clinical studies in children of various ages consuming different levels of dietary fiber to support such assumptions. The existing fiber recommendations for children are conflicting, a surprising situation, because the health benefits associated with higher dietary fiber intake are well established in adults. Data providing conclusive evidence to either support or refute some, if not all, of the current pediatric fiber intake recommendations are lacking. The opportunity to improve children's health should be a priority, because it also relates to their health later in life. The known health benefits of dietary fiber intake, as summarized in this paper, call for increased awareness of the need to examine the potential benefits to children's health through increased dietary fiber. *Adv. Nutr. 3: 47–53, 2012.*

Introduction

Childhood obesity and other diet-related chronic diseases and conditions affect many children in the US. Due to the healthcare costs and lower quality of life associated with these, effective means to help children stay healthy are needed. The effects of fiber on chronic diseases are well documented in adults, but tremendous gaps remain concerning the relationship of fiber and childhood health. Obesity and diabetes are recognized as serious public health issues in children; however, another condition associated with fiber intake, constipation, affects many children in Western countries and may have a significant effect on a child's well-being and scholarly performance. Children with chronic constipation reportedly have lower quality of life scores even than children with inflammatory bowel disease or gastric reflux (1). We examined the existing scientific literature to address the question "What are the health benefits of dietary fiber intake on body weight status, diabetes, and constipation in children?"

Dietary fiber is defined by the IOM[5] as nondigestible carbohydrates and lignin that are intrinsic and intact in plants, including the "plant nonstarch polysaccharides (e.g., cellulose, pectin, gums, hemicelluloses, β-glucans, and fibers contained in oat and wheat bran), plant carbohydrates that are not recovered by alcohol precipitation (e.g., inulin, oligosaccharides, and fructans), lignin, and some resistant starch." Functional fibers, on the other hand, include fibers that are added to foods (or provided as supplements) and that have been shown to have health benefits. They include, but are not limited to, "isolated, nondigestible plant (e.g., resistant starch, pectin, and gums), animal (e.g., chitin and chitosan), or commercially produced (e.g., resistant starch, polydextrose, inulin, and indigestible dextrins) carbohydrates" (2). The variety of fibers used in the food supply, especially the consistently increasing number of foods with added fibers, renders the examination of total fiber consumption in the U.S. population difficult. Whereas dietary fibers are included in nutrient composition databases,

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[5] Abbreviations used: AAP, American Academy of Pediatrics; DRI, Dietary Reference Intake; IOM, Institute of Medicine; T2DM, type 2 diabetes mellitus.

functional fibers are not. Thus, the consumption level of functional fiber in adults or children cannot be estimated. The analytical methods commonly used in the past to identify fibers in foods are not meeting the challenges of identifying and quantifying the fibers in the modern food supply. As a result, not all of the functional fibers are included in national nutrient databases (3). Furthermore, not all added fibers are functional fibers. For example, bran is frequently added to foods, such as cereals, rendering it by definition to be an added fiber; however, bran is a source of fiber that is reported in national nutrient databases as a dietary fiber.

Dietary fiber intake recommendations are a complex issue that remains to be consolidated and examined for their physiological impact. The DRI (2) pay considerable attention to different sources of fiber and their effects on health. However, those considerations only include adults. It has been acknowledged that the fiber intake recommendation for children is in fact extrapolated from adult data. The age-based fiber recommendations for children do not specify the type or properties of the fibers included, i.e., functional or dietary fiber, which may be necessary to support specific health benefits at the suggested amount of intake. It is noteworthy to point out that in addition to the lack of coherence between intake recommendations, the usual fiber intakes in the American pediatric population fail to meet the fiber recommendations. National intake data show that dietary fiber intakes are inadequate in most U.S. children, especially from low-income and minority backgrounds (4). In fact, 9 in 10 children fail to achieve the IOM's recommendation for fiber intake (5), which is admittedly the higher of the 2 fiber intake recommendations, but these data show that one of the main issues in child nutrition and diet quality is not necessarily centered around the types of fiber but the amount of foods consumed that contribute any fiber. Although the Dietary Guidelines for Americans has consistently identified fiber as an important nutrient for children and adults alike, the most recent survey of usual nutrient intakes in the U.S. population indicated that children and adolescents consume approximately one-half of the current DRI intake recommendation. Teenagers are even less likely to meet their recommendation than younger children, as reflected by the small increase in intakes compared to recommendations (**Table 1**).

Table 1. Fiber intakes by age and gender for children and adolescents in the US[1]

Consumer gender and age	Fiber intake
	g/d
Males	
2–5 y	11.3
6–11 y	13.7
12–19 y	14.9
Females	
2–5 y	10.5
6–11 y	12.0
12–19 y	13.3

[1] Adapted from (5).

The importance of fiber intake in children and adults is likely based on the chemical structure of fiber, which varies in chain length, branching, side chains, type of binding, and composition, all of which may alter function in the human gut and effects on disease (6). Some studies suggest that the type of fiber may have an effect on an individual's response and potential for discomfort induced by fermentation (7,8). Furthermore, the fiber's particle size contributes to this relationship (9). As mentioned earlier, fiber comes from a variety of sources and may be naturally present in the foods consumed or could be added during manufacturing.

On the Nutrition Facts label, the food industry chooses to divide fiber into insoluble and soluble fiber (10). Until the early 2000s, each of these 2 types of fiber was assumed to have distinct functions. However, with the addition of fibers that carry a large variety of properties and functions to the food supply, the quantification of the fiber type has become challenging. Currently, the national data composition databases [e.g., Food and Nutrient Database for Dietary Studies (11)] only include total dietary fiber.

One potentially rich source of dietary fibers are whole grain products, and whole grain intakes have been shown to be positively linked to health outcomes (12). The intake of grains with a high fiber content, including wheat and barley, increases dietary fiber consumption levels in children. However, many foods based on high-fiber grains are not well accepted by children for a number of yet to be examined reasons. Depending on the specific grain, whole grains may also have relatively low fiber density and therefore do not effectively increase children's fiber intake levels. Children actually consume much of their dietary fiber from foods that are low in fiber density (13,14), but they consume large amounts of those foods. Hence, it is advisable to identify foods that are high in fiber density and acceptable for consumption to improve children's diet quality. Although breakfast cereals are frequently referenced as a main source of dietary fiber in children's diets, consumption data collected between 1999 and 2006 indicate that cereal eaters consumed only 1 g of fiber more than children and adolescents who skip breakfast or consumed other breakfast foods (15,16).

Current status of knowledge

Childhood constipation

The American Gastroenterological Association describes constipation as a "symptom-based disorder defined as unsatisfactory defecation and characterized by infrequent bowel movement, difficult stool passage, or both. Difficult stool passage includes straining, sense of incomplete evacuation, hard/lumpy stool, prolonged time to defecate or pass stool, or need for manual maneuvers to pass stool" (17).

Clinicians often use the Rome II or Rome III criteria (18) for the diagnosis of constipation in children (18,19). Constipation is reportedly the cause for almost 5% of all pediatric outpatient visits and >25% of referrals to gastroenterology specialists in the US (20,21). In 2009, it was noted that functional constipation had a worldwide prevalence of between 7

and 30% and up to 10% of children in the US suffer from chronic constipation.

Over the past decade, more research has been published on the topic of fiber and constipation in children. A community-based survey on the prevalence of constipation in children 3–5 y old in Hong Kong found that almost 30% had constipation based on the Rome II pediatric criteria. Mean dietary fiber intake of these children was low (4.1 g/d), less than one-half of the dietary fiber intake recommended by the AAP (22). Similarly, one-third of children in the United Kingdom (mean age of 10 y) were constipated (23). In both studies, children who were not constipated had higher fiber consumption (24). In a sample of Irish children ages 5–8 y old, the incidence of constipation was twice as high in children with inadequate fiber intake than in children with adequate fiber consumption levels (13.6 vs. 6%) (23). Thus, evidence supports an association between low intakes of fiber and the high prevalence of childhood constipation (25).

Several studies showed a positive effect of dietary fiber intake in the treatment for constipation in children (22,26–29) and increasing the fiber consumption is the first treatment option for chronic constipation in healthy children (29,30). Only if dietary and lifestyle changes are not successful are laxatives prescribed (31). Laxatives are highly effective (32,33). It is noteworthy to point out one major challenge associated with a dietary intervention to resolve constipation: many children are not able to meet their fiber recommendations even after nutrition education (34).

Not all research indicates a positive correlation between low fiber intake and constipation. Constipated children may have lower, the same, or higher intakes of dietary fiber than nonconstipated children (35–38). However, the inconsistencies in the current body of knowledge highlight the importance of the question: What are appropriate recommendations for fiber intake in children? Many confounding factors in the etiology of childhood constipation, including dehydration and psychosomatic problems, need to be taken into account. To date, the majority of the evidence supports fiber intake as an important factor in the development of constipation in children.

The AAP suggests that the current research is too weak to support a definitive recommendation for fiber supplementation in the treatment of constipation. However, the AAP continues to recommend a balanced diet that includes whole grains, fruits, and vegetables, which are associated with higher fiber intake and are part of the dietary treatment to alleviate constipation in children. The current actual intake level of these food groups in the population, however, indicates that this approach is not effective. Parents, caregivers, and schools need to dramatically increase the amount of fiber-dense foods that are offered to children to enable them to consume fiber at a level that meets the recommendations. It is noteworthy to point out the importance of the difference between the fiber content of the total diet consumed by a child compared to the total energy consumed (39).

Despite the lack of agreement on the recommended amount of fiber and the type of fiber that may be most beneficial for children, evidence supports that fiber contributes to the maintenance of a healthy gastro-intestinal function and prevents and treats childhood constipation. Many guidelines to treat childhood constipation include multiple phases to slowly increase the dietary fiber consumption.

Although dietary fiber most certainly contributes to children's digestive function, the evaluation of fiber on constipation in children is most easily accomplished through the examination of the effect of isolated fibers, because different fibers have different effects in the body. A study in constipated children who were given bran fiber (median intake of 20 g fiber/d) indicated that children with improved constipation had higher fiber and bran intake than the children whose constipation did not improve or even worsened. The authors concluded that fiber intake of at least age + 10 g/d was associated with recovery or improvement of constipation (27). In children ages 3–10 y old with chronic idiopathic constipation, intake of cocoa husk resulted in less hard stools (41.7 and 75.0%) compared to children who received a placebo (40). The effect of fiber on constipation was also examined in developmentally disabled children. The children's baseline fiber intake was 2 g/d and they used laxatives to control their constipation. During the 2 stages of the dietary fiber intervention, fiber intake was increased from 2 to 17 g/d in stage 1 and then to 21 g/d in stage 2. Results showed that laxative use was reduced during stage 1 and was further reduced in stage 2 (41).

The effect of one specific fiber, glucomannan, was evaluated in children with chronic functional constipation. An improvement in stool consistency was reported by parents and children in both the glucomannan (62%) and placebo (23%) groups. Also, fewer children in the glucomannan group had infrequent bowel movements and complaints of abdominal pain. The authors concluded that treatment with fiber resulted in higher proportions of children (42 vs. 13%) and parents rating their children's constipation as improved (68 vs. 13%) (30).

The most common benefit associated with dietary fiber is general gastrointestinal health, including laxation. However, other benefits of fiber are ill-defined in children. Coccorullo et al. (42) reported conflicting results on the role of dietary fiber, because evidence showed that constipated children have a lower, equivalent, or higher intake of dietary fiber. The lack of consensus in the current research underscores the difficulty of assessing the effect of dietary fiber, mainly because the majority of studies were underpowered, used inappropriate doses of fiber in the diet, or included only isolated fiber as a supplement. More research is needed to better understand how much fiber is appropriate for children overall, not only in constipated children. To develop science-based dietary fiber recommendations for children, the current body of evidence available in the literature must be improved. However, until well-substantiated recommendations for defined benefits can be developed, it is important to continue to promote an increase of fiber intakes to help children develop diet patterns that are aligned with current fiber intake recommendations from the IOM.

Body weight

Increasing dietary fiber intake has been suggested to help reduce body weight in adults (43) and data from nationally representative samples and large European populations confirm a beneficial effect (44,45). Interestingly, dietary fibers from grains but not fruit or vegetable intake were associated with significantly lower body weight (45). In children, analysis of NHANES data showed that the reduced risk for overweight/obesity associated with whole grain intake was driven by the dietary fiber content of the grains (45,46). Lack of dietary fiber was associated with higher body fatness in a sample of British children (47) and 15 g of supplemental fiber along with a energy-restricted diet was found to result in a 2 kg higher weight loss (48). Others found no association between dietary fiber and adiposity (49). In a longitudinal study in a sample of German children, greater fiber density was in fact associated with a higher risk for overweight/obesity (50). However, one needs to acknowledge that the German diet is quite different from the U.S. diet and that German children consume on average more dietary fiber than American children.

A 2-y follow-up study in 7- to 11-y-old Latinas living in the US showed that increasing levels of soluble fiber were associated with a small reduction of visceral body fat and that decreasing fiber intakes were associated with a 10% increase of visceral body fat (51). A potential mechanism to explain this phenomenon was not proposed. Retrospective chart reviews showed that obesity was associated with an increased prevalence of constipation, but due to the nature of the study, a causal relationship could not be established (52).

Postprandial glucose concentrations and increased insulin sensitivity are associated with the increased viscosity of soluble fiber intake (43,53), which has been found to be associated with delayed gastric emptying, altering of gastrointestinal myoelectrical activity, decreased glucose diffusion through the water layer, and decreased accessibility of substrates to α-amylase. Insoluble fiber, on the other hand, does not absorb water but is also beneficial in that it increases insulin sensitivity (53). The mechanism or pathway for this phenomenon has not been shown.

Diabetes

Obesity is associated with increased risk for T2DM (54). Dietary fiber may have a preventative effect and may attenuate the symptoms of T2DM in adults, but data are lacking in children. Normoglycemic obese women at risk for insulin resistance who consumed 10 g/d of soluble fiber experienced beneficial effects on postprandial insulin levels (54). In another clinical study, overweight and obese women consumed 3 portions of 10.4 g oat fiber/d and improved insulin sensitivity (55). Kaline et al. (56) suggest that insoluble dietary fiber may be especially valuable for the prevention of T2DM and a review of 7 randomized, controlled, clinical trials indicated that psyllium intake improves postprandial plasma glucose in persons with T2DM (57). Fiber from vegetables was also associated with decreased risk of T2DM (58). Others reported that intake of fiber from grains was beneficial for diabetes risk estimates in men and women, whereas vegetable fiber was protective only for men, and fiber from fruit did not affect diabetes risk in either men nor women (59). A meta-analysis of 7 cohort studies showed that higher cereal fiber and magnesium intakes decreased diabetes risk (60).

Although data consistently indicate a risk reduction for diabetes associated with fiber intake in adults, the examination of the effect of dietary fiber on children's risk for diabetes or its symptoms is dramatically understudied. Few studies show associations of dietary intakes with fasting blood glucose concentrations. Because increasing obesity prevalence is associated with dysregulation of glucose concentrations, the examination of dietary interventions to prevent and/or treat metabolic syndrome (symptoms for diabetes and cardiovascular disease along with obesity) are urgently needed (61). For instance, supplementation with psyllium decreased postprandial glucose in children with T2DM (62). However, in a study conducted in German children, postprandial glucose regulation was not associated with fiber intake (50). In overweight Latino children, soluble dietary fiber intake was significantly higher in children without symptoms of metabolic syndrome compared to those with $\geq$3 symptoms (5.2 vs. 4.1 g fiber/d, respectively) (63). Others found no association between dietary fiber intake and metabolic syndrome prevalence (64).

Data in adults indicate a possible beneficial effect of fiber intake on various health outcomes; nevertheless, the question remains if the current fiber intake recommendations, which were extrapolated from the adult data, are indeed appropriate for children and if they are associated with the same beneficial health effects as in adults.

What are the current recommendations?

Dietary intake recommendations for dietary fiber differ widely between various authoritative bodies. General dietary fiber recommendations for children from the DRI published in 2005 are presented in **Table 2**. The AAP suggests 2 different guidelines for fiber intake: age of the child in years + 5 g; and 0.5 g fiber/(kg body weight · d) up to 35 g/d. The IOM's DRI for dietary fiber is 14 g fiber/1000 kcal consumed or between 19 and 38 g/d in children, depending on age. The FDA Labels guide is 12 g/1000 kcal consumed.

Table 2. Fiber intake recommendations (AI) in children ages 2–18 y old[1]

Age and gender groups	AI for children
	g total fiber/d
1–3 y	19
4–8 y	25
AI for boys	
9–13 y	31
14–18 y	38
AI for girls	
9–13 y	26
14–18 y	26

[1] Adapted from the DRI (2). AI, adequate intake.

Most of these intake recommendations are based on scientific evidence on the relationship between dietary fiber intake and health outcomes in adults. As shown above, the currently existing fiber intake recommendations do not align, which may lead to confusion in the caretakers of children. For instance, using the AAP method, a 5-y-old child should consume age + 5 g or 10 g fiber/d. However, if the IOM intake recommendations are applied to the same child, the adequate intake is 25 g/d, a difference of 15 g fiber/d. Despite the intake recommendations for fiber, the question first addressed in 1995 (65) remains: "How much fiber is right for kids?" Then, the review concluded that age + 5 g was a reasonable minimum intake recommendation for fiber in children ≥ 3 y old. It is also important to point out that age + 5 g is much easier to comprehend and to remember than fiber recommendations based on a child's body weight (per the AAP) or energy intake (per the FDA). The age + 5 g does not exceed the AAP and FDA recommendations. In contrast, high fiber intake recommendations, defined as age + 15 g, was declared to result in fiber intakes that are too high; thus, at the time, the age + 10 g rule was supported (27).

Conclusions

Although the effects of dietary fiber on chronic diseases of public health importance have been explored in adults, whether fiber affects children's health in a similar fashion remains unknown. Existing clinical studies support the importance of fiber intake for bowel function, although an identification of the fiber type and amount most beneficial to that effect cannot be determined with the existing scientific data. There is a pivotal need to close this gap by providing data from rigorous clinical studies in children of various ages, because fiber likely differentially affects individuals by age. Until such data are forthcoming, all population intake data studies suggest a dire need to increase the efforts to encourage fiber consumption in children. Current data indicate that considerable improvements could be achieved on the 3 health concerns described in this paper. Furthermore, the fact that American children are subject to concurrent, conflicting fiber intake recommendations speaks to an additional need for more and more in-depth studies on the relationship between fiber intake and various health outcomes. Caretakers of children, such as parents and healthcare professionals, are presently not prepared to guide their children's fiber intake. Appropriate studies must be conducted to provide conclusive evidence to either support or refute some, if not all, of the current pediatric fiber intake recommendations.

Childhood obesity and its relationship to adult obesity is a threat to public health and the nation's well-being. Current recommendations for fiber intake, regardless of which authoritative body's recommendation, have not been pursued with the same vigor as the campaigns to reduce sodium and saturated fats. This gap is surprising given the specific health benefits associated with increased dietary fiber as summarized in this paper. The opportunity to improve children's health and positively influence their adult health should be a top priority. The DRI for fiber, based on energy, has an important advantage in that it allows comparisons between foods that are fiber dense (g fiber/100 kcal) and those with low fiber content, thus simplifying food choices by dietitians and families. Selection of the DRI for fiber as a single, consistent recommendation will also facilitate the implementation of higher fiber into mandated nutrition programs (e.g., school meal programs). Increasing the awareness of benefits to children's health through increased dietary fiber will also help to promote higher fiber content in the food supply.

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