

Effects of cereal fiber on bowel function: A systematic review of intervention trials

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Abstract

AIM: To comprehensively review and quantitatively summarize results from intervention studies that examined the effects of intact cereal dietary fiber on parameters of bowel function.

METHODS: A systematic literature search was conducted using PubMed and EMBASE. Supplementary literature searches included screening reference lists from relevant studies and reviews. Eligible outcomes were stool wet and dry weight, percentage water in stools, stool frequency and consistency, and total transit time. Weighted regression analyses generated mean change (\pm SD) in these measures per g/d of dietary fiber.

RESULTS: Sixty-five intervention studies among generally healthy populations were identified. A quantitative examination of the effects of non-wheat sources of intact cereal dietary fibers was not possible due to an insufficient number of studies. Weighted regression analyses demonstrated that each extra g/d of wheat fiber increased total stool weight by 3.7 ± 0.09 g/d ($P < 0.0001$; 95%CI: 3.50-3.84), dry stool weight by 0.75 ± 0.03 g/d ($P < 0.0001$; 95%CI: 0.69-0.82), and stool frequency by 0.004 ± 0.002 times/d ($P = 0.0346$; 95%CI: 0.0003-0.0078). Transit

time decreased by 0.78 ± 0.13 h per additional g/d ($P < 0.0001$; 95%CI: 0.53-1.04) of wheat fiber among those with an initial transit time greater than 48 h.

CONCLUSION: Wheat dietary fiber, and predominately wheat bran dietary fiber, improves measures of bowel function.

Key words: Comprehensive review; Dietary fiber; Wheat bran; Cereal; Bowel function

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Core tip: This comprehensive review evaluates available data on the effects of intact cereal dietary fiber on bowel function and provides a quantitative summary of the effect of intact wheat fiber on bowel function using weighted regression analysis. Insufficient observations were available from non-wheat cereals for quantitative analysis. Results found an increase in total stool weight of 3.7 ± 0.09 g per gram intact wheat fiber. Transit time decreased by approximately 45 min per gram intact wheat fiber when initial transit time was greater than 48 h. Therefore, intact wheat dietary fiber, predominantly from wheat bran, improves bowel function.

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INTRODUCTION

Composition, consistency, frequency, and weight of bowel movements are key indicators of intestinal and digestive health^[1]. Abnormalities in these factors serve as diagnostic criteria for prevalent gastrointestinal disorders such as functional constipation^[2,3]. According to the most widely accepted criteria (Rome III)^[2], characteristics of functional constipation include defecation associated with straining, hard stools, a sensation of incomplete evacuation or anorectal obstruction, manual maneuvering to facilitate defecation, and less than three stools per week. Normal, healthy bowel function, on the other hand, is characterized by soft, regularly shaped stool that is easy to pass, and bowel movements occurring twice per day to three times per week, depending on the individual^[4]. Functional constipation is a heterogeneous and common disorder that affects apparently healthy populations^[5]. Reports of prevalence vary widely, depending on definition, demographic factors, and sampling^[6-9], but could be as high as 27%^[3].

Constipation and digestive discomfort have multiple

etiologies^[3], including certain medications, abuse of laxatives, hormonal disorders and inadequate dietary fiber intakes. Suboptimal dietary fiber consumption is increasingly a global concern, as average intakes are well below recommendations across many countries^[10,11]. This creates considerable clinical and public health opportunities to identify strategies that will increase dietary fiber intakes to improve bowel function and help prevent digestive disorders. In addition, increasing dietary fiber consumption offers a safer and cost-effective alternative to laxatives for preventing or alleviating symptoms of constipation^[5].

Dietary fiber is naturally present in different food groups, including cereals, vegetables, fruits, beans, and peas. This review provides an overview of intervention studies examining intact cereal dietary fibers (ICDF), which are derived from any part of the cereal plant, including the kernel, hull, or stalk and are minimally processed, although some degree of processing may be required to obtain the fiber-rich portion of the kernel (*e.g.*, milling of bran) or to improve food functionality or safety (*e.g.*, pearling, grinding, or bleaching). In contrast, fibers that are extracted, isolated, or made by chemical or enzymatic means, such as the synthesis of fibers from endosperm starch or the enzymatic hydrolysis of long chain fibers into oligosaccharides are not ICDF and are not included in this analysis. Cereal bran, the hard outer layer of a grain kernel, is a highly concentrated source of dietary fiber: per 100 g, wheat bran contains 43 g fiber, rice bran contains 21 g fiber, and oat bran contains 15 g fiber^[12].

Although a large body of literature supports a role of ICDF, predominately wheat bran fiber^[5,13], in promoting normal, healthy bowel function through increasing stool weight, past reviews were conducted more than two decades ago^[14,15]. Since that time, a number of intervention studies have been published. In addition, less is known about the effects of wheat fiber on other measures of bowel function or the effectiveness of other ICDF such as those from oat, barley, rice, corn, and sorghum. Therefore, the purpose of the present study was to review, evaluate, and quantitatively summarize results from published intervention studies that examined the effects of ICDF on parameters for healthy bowel function, including stool wet weight, stool dry weight, percentage water in stool, stool frequency, intestinal transit time, and stool consistency. Although the heterogeneity of included studies does not allow for a meta-analytical approach, a quantitative estimate using weighted regression analysis on indicated parameters is provided on the pooled results of available studies.

MATERIALS AND METHODS

Literature search and study selection

A comprehensive literature search using PubMed

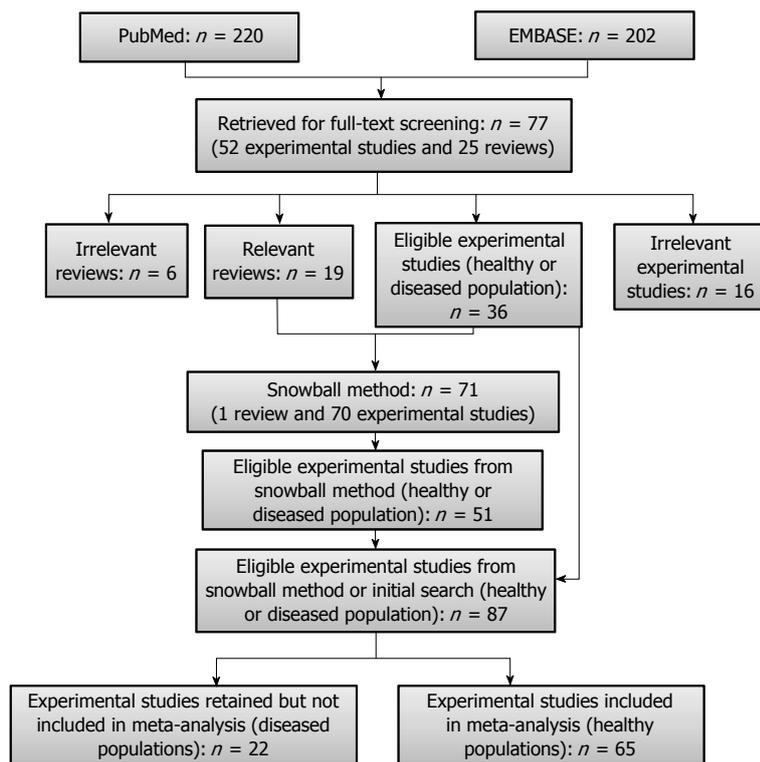


Figure 1 Literature search flow diagram.

and EMBASE was performed to identify intervention studies in human populations through 6 October 2012 (PubMed) and 18 October 2012 (EMBASE) with no lower date limit. The full search string used in each database is available in the Online Data Supplement (Appendix 1). A combination of free text terms, with different spellings and designed to capture relevant cereals and grains, fiber or bran, and relevant bowel function outcomes (e.g., stool, transit, volume, and bulk), was used. Supplementary literature searches involved examining the reference lists of all relevant studies and pertinent reviews to identify articles not captured in the initial search. The search flow is illustrated in Figure 1. The review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines^[16]. The PRISMA checklist is available in the Online Data Supplement (Appendix 2).

Interventions were considered eligible if the following criteria were met: (1) the study was performed with an ICDF; (2) the study was conducted in a human population aged > 1 year; (3) a relevant outcome measurement of bowel function, including total stool weight, stool dry weight, percentage stool water, number of bowel movements per day, consistency of stools, or transit time, was examined; and (4) the publication was written in the English language. Study populations with underlying gastrointestinal disorders, such as constipation, diarrhea, irritable bowel syndrome, diverticular disease, or ulcerative colitis, were eligible for inclusion in the search strategy and

data extraction, but were not included in the present quantitative analyses. Both controlled and uncontrolled trials were included in this systematic review. Two independent reviewers (de Vries J and Verbeke K) screened the titles and abstracts for relevance to the systematic review to ensure quality-control. Potentially eligible articles were reviewed jointly to resolve any discrepancies.

Data extraction and quality assessment

The following general study information was extracted using FileMaker Pro software: first author; hypothesis; sex; sample size; study design; duration; physiological characteristics of participants; details of the intervention; details of the control group; background diet (including fiber content); fiber intervention; total fiber intake (background diet fiber plus fiber intervention); dose of food or ingredient in intervention; measured outcome parameter; method used to measure outcome parameter; and description of any adverse events. Outcome data for total stool weight (g/d), stool dry weight (g/d), percentage water in stools, number of bowel movements per day, consistency of stools, and transit time (h) were extracted, and included baseline and trial end values, change-from-baseline values, statistical significance of change values, and differences in the trial end value between the intervention and control arm. Lowest effective dose was identified by visual inspection of the data as reported in the individual studies.

Study quality was assessed through assignment of

scores according to two appraisal systems: (1) criteria developed by the FSANZ for the review of publications that are considered to support submitted health claims (0-15 points)^[17]; and (2) criteria for human intervention studies as described by Welch *et al.*^[18] (0-20 points).

Statistical analysis

The included publications report on intervention studies with a diversity of study designs. Therefore, a meta-analytical approach according to PRISMA criteria was not feasible. Instead, the potential effect of ICDF on bowel function parameters was quantitatively estimated by a weighted regression on the results of those ICDF that had more than 5 observations per parameter. A weighted regression by sample size was chosen because not all publications reported SD on their results.

Means, standard deviations, and 95%CI for ICDF dose (g/d) and bowel function parameters were generated. Weighted regression analyses, in which data from each published study were weighted by the number of subjects used in the study, was performed using SAS version 9.2 (Cary, North Carolina, United States). The regression analysis was not forced through zero because the intercept was different from zero (3.06 ± 1.52 g; $P < 0.0439$; 95%CI: 0.08-6.03). Stool consistency was an eligible outcome, but due to the diversity of both the methods used to estimate stool consistency and the qualitative reporting of results, weighted regression analysis was not possible. For the analysis of total transit time, a multivariable weighted regression analysis was performed to account for differences in the relationship with the intervention fiber amount that depended upon the initial transit time. Comparisons of the effects of wheat fiber vs other ICDFs on bowel function parameters were not feasible due to a limited number of studies examining other ICDFs.

Data used for the control group differed according to the type of study. For placebo-controlled trials, data from the control arm was used. The control in these studies was most often white wheat, a usual diet, or a gelatin capsule. In some cases, a positive control, such as a laxative, cellulose, wheat bran (if another type of ICDF was examined), or another cereal was used. For uncontrolled trials, the baseline values of the intervention group were used as the control. Some studies conducted a dose-response intervention, in which case the lowest dose was considered the control.

RESULTS

Study characteristics

A flow diagram of the literature search is shown in Figure 1. The literature search included both healthy and diseased populations until the final stage, at which time the studies conducted in healthy populations,

were separated from studies conducted in diseased populations. The search yielded 220 references in PubMed and 202 references in EMBASE, of which 77 articles were retained for full-text screening and reference list review. The 77 articles included both original experimental research publications ($n = 52$) and reviews ($n = 25$). Thirty-six of the experimental studies were deemed eligible and 19 of the review articles were deemed relevant for screening of reference lists (snowball method). Overall, screening of reference lists from all relevant review articles and eligible experimental studies resulted in 71 additional articles (1 review and 70 experimental studies) that subsequently underwent full-text screening. Fifty-one of the 71 articles were eligible for inclusion. Therefore, the 51 eligible experimental studies identified by the snowball method and the 36 eligible experimental studies identified in the initial search resulted in a combined total of 87 experimental studies, 65 of which were conducted in generally healthy populations and therefore included in the quantitative analyses. From the 65 studies, 87 study arms examined the effect of ICDF on total fecal weight, 47 on dry fecal weight, 36 on percentage fecal water, 43 on stool frequency/bowel movements, and 57 on transit time.

Primary characteristics, including the first author, publication year, sex distribution of study population, type of study design, and the specific ICDF evaluated, of the 65 interventions are provided in the Online Data Supplement (Appendix 3)^[11,19-82]. Fifty-seven percent of the studies were placebo-controlled, 32% were randomized, and 6% were single- or double-blinded. Wheat fiber, and primarily wheat bran fiber (90% of wheat fiber studies), was the most common dietary fiber provided in the intervention with 75 observations in 65 intervention studies. Only 13 of the observations were ICDF from other sources, including corn ($n = 4$), barley ($n = 3$), rye ($n = 2$), oat ($n = 1$), rice ($n = 1$), and sorghum ($n = 1$). Most publications, also the more recent ones, provide insufficient details for an adequate description of the dietary fiber sources used.

Stool bulking, stool frequency, and transit time

Table 1 shows the number of comparisons for different ICDFs and different bowel function outcomes. It also presents the level of fiber provided across the interventions. Table 2 presents the mean \pm SD and 95%CI effects, plus ranges from the individual studies, of the fiber intervention on total stool weight (g/d), dry stool weight (g/d), percentage water in stool (%), and stool frequency (times/d), as well as the average fiber intakes provided in the interventions for each of these outcomes for wheat, barley, and corn. Table 2 also shows results from the weighted regression analysis of wheat fiber (per g/d), compared to control, on change in total and dry stool weight, stool frequency (number of defecations/day), and transit time (h). The mean effects and weighted change on bowel

Table 1 Summary of comparisons for different intact cereal dietary fibers and bowel function outcomes

	Source of intact fiber						
	Wheat	Barley	Corn	Oat	Rice	Rye	Sorghum
Total stool weight							
Observations ¹ , <i>n</i>	75	3	4	1	2	2	1
Fiber intervention (g/d), mean ± SD or range ²	15.2 ± 8.3	10.2, 23	6.0, 42	14.3	17.1, 20.7	13, 20.6	2.5
Dry stool weight							
Observations, <i>n</i>	40	1	3	1	1	1	-
Fiber intervention (g/d), mean ± SD or range ²	14.7 ± 8.5	21	6, 42	14.3	20.7	20.6	-
Fecal water							
Observations, <i>n</i>	30	3	2	-	1	-	-
Level of fiber interv. (g/d), mean ± SD or range ²	16.0 ± 7.4	10.2, 23	15, 42	-	20.7	-	-
Stool frequency							
Observations, <i>n</i>	34	2	2	-	2	2	1
Fiber intervention (g/d), mean ± SD or range ²	13.6 ± 6.4	21, 23	15, 42	-	17.1, 20.7	20.6, 36.4	2.5
Transit time							
Observations, <i>n</i>	52	-	-	1	2	1	1
Fiber intervention (g/d), mean ± SD or range ²	14.8 ± 8.6	-	-	2.7	17.1, 20.7	20.6	2.5

¹May include > 1 observation from studies examining > 1 dose of intact cereal dietary fiber; ²Fiber intakes are shown as mean ± SD of all observations if > 5 observations were available, the range of values from individual studies if 2-4 observations were available, and a single estimate if only one observation was available.

Table 2 Fiber intakes and effects on total stool weight, dry stool weight, percentage water in stool, stool frequency, and transit time

	Source of intact cereal dietary fiber		
	Wheat	Barley	Corn
Total stool weight			
Observations, <i>n</i>	75	3	4
Fiber (g/d), mean ± SD or range	15.2 ± 8.3	10.2-23	6.0-42
Total effect (g/d), mean ± SD or range	65.4 ± 37.8	49.6-65	1.2-96.3
Average fecal bulking index, Δ in g/d stool weight per g/d fiber	4.7 ± 2.7	3.6 ± 2.4	2.1 ± 1.5
Fecal bulking index by regression, Δ in g/d stool weight per g/d fiber	3.67 ± 0.09 ^b (3.50-3.84)	-	-
Dry stool weight			
Observations, <i>n</i>	40	1	3
Fiber (g/d), mean ± SD or range	14.7 ± 8.5	-	6-42
Total effect (g/d), mean ± SD or range	14.4 ± 9.4	-	4.8-31
Fecal bulking index by regression, Δ in g/d stool weight per g/d fiber	0.75 ± 0.03 ^b (0.69-0.82)	-	0.7-0.9
Fecal water			
Observations, <i>n</i>	30	3	2
Fiber (g/d), mean ± SD or range	16.0 ± 7.4	10.2-23	-
Total effect by regression (Δ% water), mean ± SD or range	1.5 ± 2.1	-1.8-10	-
Stool frequency			
Observations, <i>n</i>	34	2	2
Fiber (g/d), mean ± SD or range	13.6 ± 6.4	-	-
Total effect (times/d), mean ± SD or range	0.34 ± 0.23	-	-
Frequency index by regression, Δ in times/d per g/d fiber	0.004 ± 0.002 ^a (0.003-0.078)	-	-
Transit time			
Observations, <i>n</i>	52	0	0
Fiber (g/d), mean ± SD	14.8 ± 8.4	-	-
Δ in h per g/d fiber by regression (those with initial transit time between 24-48 h)	0.78 ± 0.13 ^b (0.53-1.04)	-	-
Δ in h per g/d fiber by regression (those with initial transit time between 48-96 h)	-0.75 ± 0.04 ^b (-0.84- -0.67)	-	-

^a*P* < 0.05, ^b*P* < 0.01 *vs* control.

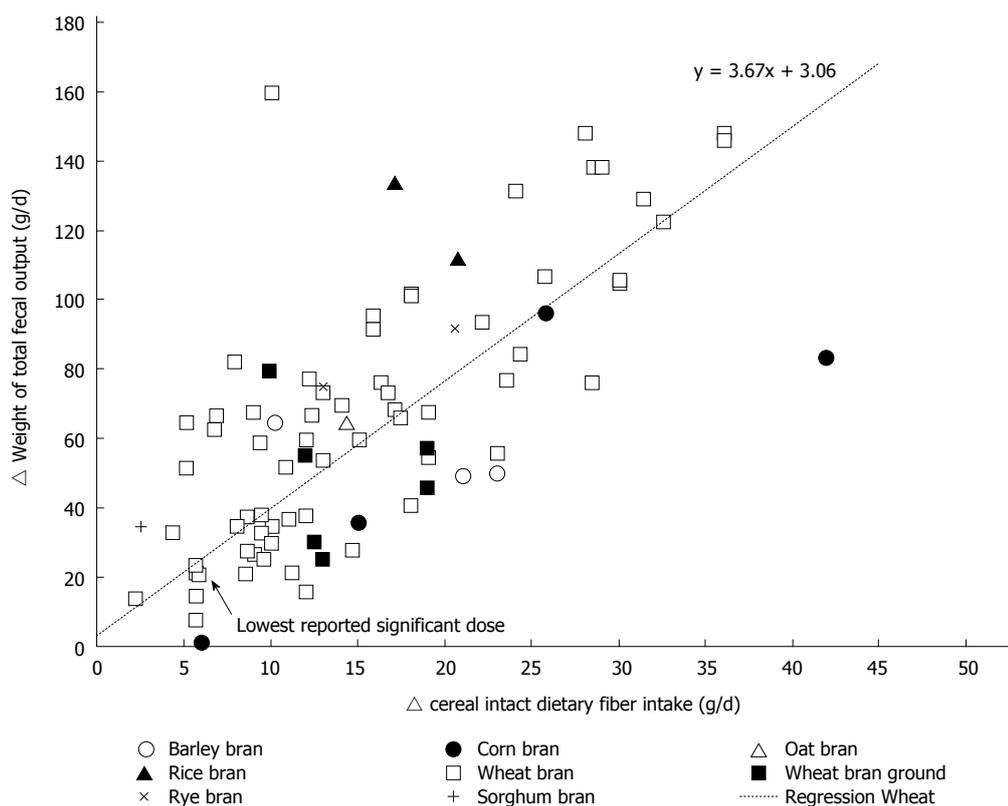


Figure 2 The delta weight of total fecal output (g/d) related to the amount of intact cereal dietary fiber intervention (g/d) in healthy individuals.

function parameters among interventions that used ICDF from barley and corn were not estimated given the limited number of observations (< 5 observations were available for each). The data of oat, rice, rye, and sorghum ICDF on these parameters from the individual studies are listed in the supplemental information (Appendix 4).

Among the studies included in the quantitative analysis (wheat fiber studies), mean fiber intakes ranged from 13.6 ± 6.4 g/d among studies that examined stool frequency to 16.0 ± 7.4 g/d among studies that investigated percentage water in stool. On average, the wheat fiber intervention increased total stool weight by 65.4 ± 37.8 g/d, dry stool weight by 14.4 ± 9.4 g/d, percentage water in stool by $1.5\% \pm 2.1\%$, and stool frequency by 0.34 ± 0.23 bowel movements per day.

The weighted changes per g/d of wheat fiber intake were as follows: an increase of 3.7 ± 0.09 g/d ($P < 0.0001$; 95%CI: 3.50-3.84) for total stool weight; an increase of 0.75 ± 0.03 g/d ($P < 0.0001$; 95%CI: 0.69-0.82) for dry stool weight. Weighted regression analysis of the results of all studies did not reveal an effect of the fiber intervention on transit time. Upon stratification by baseline transit time, an increase of 0.78 ± 0.13 h/g ($P < 0.0001$; 95%CI: 0.53-1.04) of wheat fiber was observed among those with an initial transit time of 24-48 h, and a decrease of 0.75 ± 0.04 h/g [$P < 0.0001$; 95%CI: (-0.84) - (-0.67)] of wheat fiber was observed among those with an initial

transit time of 48-96 h. Individual study data on the change in the bowel function parameters per gram of wheat fiber intake are shown in Figure 2 for total stool weight, Figure 3 for dry stool weight, Figure 4 for percentage water in stool, and Figure 5 for stool frequency. The lowest effective dose of wheat fiber that significantly increased fecal output, as reported in one of the included individual intervention studies, was 5.7 g/d ($P < 0.05$)^[53].

DISCUSSION

The present review provides the most comprehensive evaluation to date on the effects of ICDF on multiple measures of bowel function. Wheat fiber, and primarily wheat bran fiber, was found to improve measures of bowel function, including total stool weight, dry stool weight, and stool frequency, as well as intestinal transit time among those with an initial transit time greater than 48 h.

Wheat bran fiber is the most extensively studied cereal fiber for measures related to bowel function^[5,13], with the first study dating back more than 90 years^[82]. Leading nutrition and health authorities, including the US Institute of Medicine^[83], Health Canada^[84], and the European Food Standards Agency (EFSA)^[85], have concluded that wheat bran fiber increases stool bulking and shortens intestinal transit time. In 2010, EFSA provided a Scientific Opinion^[85], wherein an unequivocal cause and effect relationship between the consumption

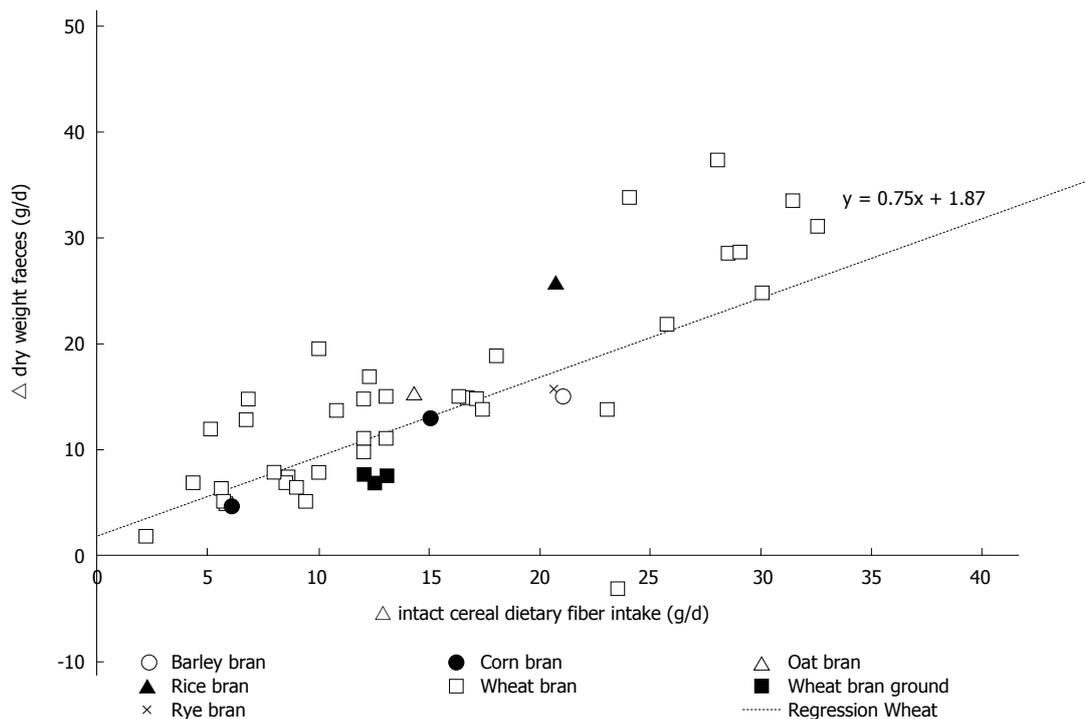


Figure 3 The delta weight of dry fecal output (g/d) related to the amount of intact cereal dietary fiber intervention (g/d) in healthy individuals.

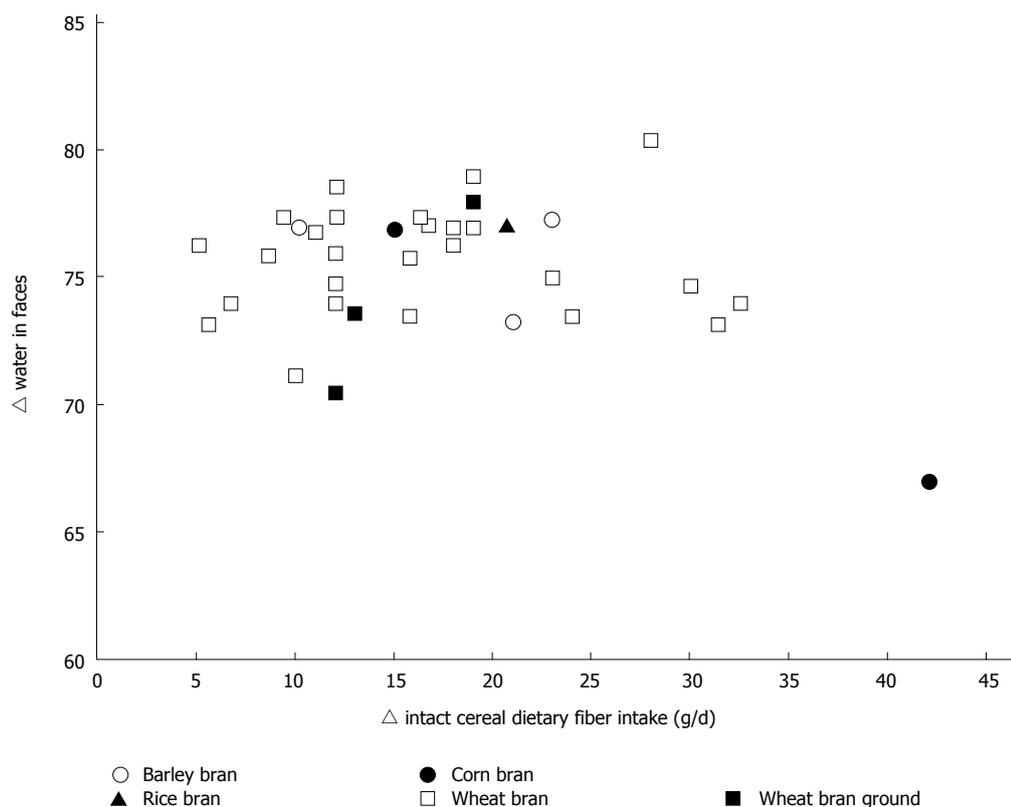


Figure 4 The % fecal water related to the amount of intact cereal dietary fiber intervention (g/d) in healthy individuals.

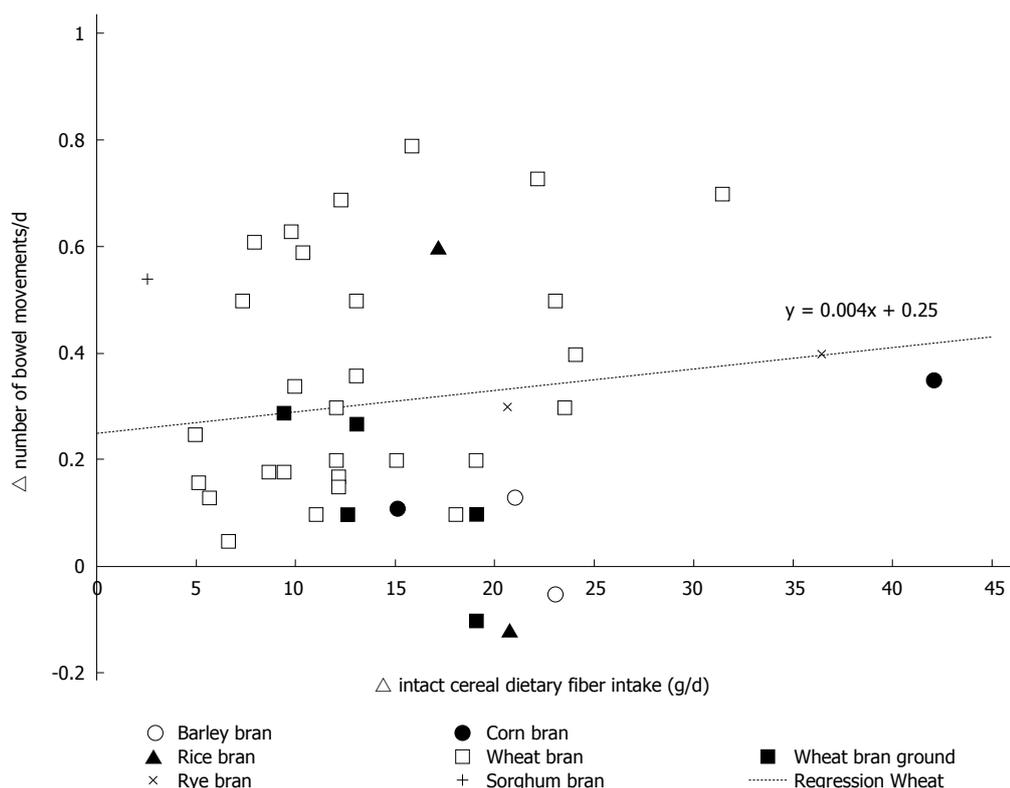


Figure 5 The delta number of bowel movements related to the amount of intact cereal dietary fiber intervention (g/d) in healthy individuals.

of wheat bran fiber and an increase in stool bulk and intestinal transit time was concluded and two health claims in relation to these intestinal functions were passed. A health claim was also approved by the Canadian Food Inspection Agency after the agency concluded that wheat bran promotes laxation and regularity^[84]. Furthermore, wheat bran is considered the benchmark against which other fibers are compared for their effects on regularity^[84]. Compared to wheat bran fiber, less is known concerning the effects of other sources of ICDF on bowel function, largely because far fewer studies have been conducted on other ICDF.

Given the heterogeneity in study designs utilized in the individual studies, a weighted regression, rather than a traditional meta-analysis, was considered to be a superior method to examine the effect of wheat fiber on stool parameters. The average fecal bulking index, reported in Table 2, provides an indicative estimate of effect of ICDF from wheat (75 observations), barley (3 observations) and corn (4 observations) on total fecal bulking. These results indicate that wheat bran might have the best properties to increase total fecal bulk.

Different sources of dietary fiber are not equal in their functionality and effects on bowel function, as evidenced by Health Canada using wheat bran as the gold standard fiber^[84]. Cummings^[14] evaluated nearly 100 interventions, published from 1932 to 1991, on dietary fiber and fecal weight, and compared the effectiveness of different sources of fiber. Among 41 interventions that examined wheat fiber—which consisted largely of wheat bran—the mean increase

in fecal weight per g/d of wheat fiber was 5.4 g. The mean increases in fecal weight per g/d of other sources of fiber were smaller in magnitude: fruit and vegetables (4.7 g), gums and mucilages (3.7 g), cellulose (3.5 g), oats (3.4 g), corn (3.3 g), legumes (2.2 g), and pectin (1.2 g). Of note, findings for the other cereal sources of ICDF were from fewer studies. Nevertheless, based on the available evidence, wheat fiber was the most effective source of fiber for increasing fecal weight.

The varying effects of different dietary fibers on fecal bulking are likely related to different underlying mechanisms of action. The effects of wheat bran fiber on stool weight are largely attributable to its high resistance to fermentation by colonic bacteria, combined with its water binding capacity (1 g of fiber binds about 3 g of water), therefore contributing to a stronger effect on increasing stool bulking compared to more easily fermented ICDF, such as those from oats and barley^[14,86,87]. The resulting increased volume of fecal mass stimulates colonic movement, thereby helping to reduce transit time and increase stool frequency^[14].

Since the review on fiber and bowel function conducted by Cummings^[14] more than 40 interventions have been published, 30 of which were in healthy populations and therefore included in the present evaluation. The heterogeneity of the included studies did not allow for a meta-analytical approach according to PRISMA requirements. Therefore, a weighted regression analysis by sample size was conducted

as an alternative approach to achieve a quantitative estimate. Similar to the findings by Cummings^[14], an increase in fecal weight was observed in the current analysis. The smaller estimated increase in fecal weight, compared to the earlier review (3.7 g/d vs 5.4 g/d)^[14], is likely due to the weighted regression method applied in the present analysis, in which the regression equation was not forced through zero, thus influencing the slope of the regression line. Based on a visual inspection of a funnel plot on the total stool weight data (Appendix 5), publication bias is unlikely the cause of the positive intercept of the regression. Furthermore a greater number of placebo-controlled trials were included in the present analysis.

In addition, changes in other bowel function parameters, such as stool frequency, transit time, dry stool weight, and percentage water in stools were also quantitatively evaluated; studies on stool composition were too heterogeneous to allow for a quantitative approach. Provision of wheat fiber showed beneficial effects on dry stool weight and stool frequency, as well as on intestinal transit time among those with an initial transit time greater than 48 h. This arbitrary level of 48 h was used because normal stool frequency was considered to be between 1 to 2 bowel movements per day. When transit time is already optimal, *i.e.*, between 24 and 48 h, additional dietary fiber would not be expected to alter transit^[88]. Adding dietary fiber that is resistant to fermentation does not increase the overall percentage of water as the amount of water bound by the fiber is similar to the average water content of fecal samples (about 75%).

Different methodologies were used in the different studies to determine transit time. First, several markers, including indigestible dye, radio-opaque markers, poly-ethylene glycol, and chromium sesquioxide, were used to estimate transit time. Secondly, transit time was calculated in different ways based on the recovery of the markers in the feces. Cummings *et al.*^[32] demonstrated that the mean transit time method with a single dose estimate was approximately 15% lower compared to an estimate with the 80% method. Wrick *et al.*^[51] examined the use of radio-opaque pellets, poly-ethylene glycol and chromium sesquioxide as markers to estimate transit time and concluded that there was no significant difference in transit time estimates between marker types. It remains possible that the different methods may yield different estimates of transit time. However, an analysis stratified by the type of methodology to estimate transit time would have lowered the power of the analysis. We concluded that a weighted regression analysis on all available data, categorized according to initial transit time with a cut off point of 48 h, provided the best estimate on the effects of ICDF on transit time.

Inadequate dietary fiber intake is increasingly a global concern, as average intakes are well below recommendations across many countries^[10,11]. The

International Life Sciences Institute Europe Dietary Carbohydrates Task Force summarized sex-specific dietary fiber consumption across nine European countries, in addition to the United States and Japan^[10]. The resulting report found that average dietary fiber intakes were below the lower end of the World Health Organization recommendation (25-40 g/d)^[89], with only a few exceptions. These findings have potentially serious health consequences beyond impaired bowel function^[60,83]. Inadequate dietary fiber intakes have been associated with increased risk for type 2 diabetes, cardiovascular disease, certain cancers, weight gain, diverticular disease, obesity, and constipation^[60,83]. Given the high content of dietary fiber in wheat bran (43 g compared to 21 g in rice bran and 15 g in oat bran, per 100 g^[12]), wheat bran can play an important role in helping individuals increase overall dietary fiber intakes. Increasing wheat bran intake is a relatively simple dietary strategy to improve bowel function.

A notable strength of this research is the large volume of studies evaluated ($n = 65$), highlighting its comprehensive and inclusive nature on ICDF and bowel function. A number of parameters of bowel function that had not been quantitatively evaluated previously were examined, which is a substantial contribution to the literature. In addition, this review includes 20 years of research since the last review by Cummings^[14]. Several limitations should also be considered. Due to the exhaustive and inclusive nature of this review, a large number of included interventions were uncontrolled trials, and most studies were not randomized. Therefore, observed changes in parameters for healthy bowel function cannot be fully attributed to the intervention, as the placebo effect remains possible^[90]. In addition, proper quantitative evaluations of the effects of other ICDF were not feasible due to the limited available data. Future studies that examine other ICDF will provide valuable contributions to this line of research.

In summary, the current comprehensive review of interventions with ICDF on bowel function is spanning more than 90 years of research in healthy individuals. The results of the 65 included publications indicate that wheat fiber promotes healthy bowel function through improvements in total stool weight, dry stool weight, intestinal transit time, and stool frequency. Based on the large volume of available evidence, incorporating wheat fiber, primarily wheat bran fiber, into the diet can positively affect bowel function. As wheat was the only cereal for which a quantitative estimate of its effect was possible, more research on the effects of other cereals is warranted.

COMMENTS

Background

Composition, consistency, frequency, and weight of bowel movements are key indicators of intestinal and digestive health. Infrequent bowel movements and

low stool weights are very common in many countries.

Research frontiers

The effects of intact cereal dietary fibers on bowel function have not been systematically reviewed previously. Constipation and irregular bowel movements are highly prevalent in the general population but can often be averted through simple, realistic, and inexpensive changes in dietary practices such as increasing dietary fiber intakes.

Innovations and breakthroughs

This systematic review provides the first quantitative estimate of the effect of wheat fiber on multiple measures of bowel function based on the results of 90 years of research.

Applications

Findings from this comprehensive review may help gastroenterologists choose relatively inexpensive solutions in the prevention of constipation.

Peer-review

This is a useful review on the impact of specific dietary cereal fibers on bowel functions.

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