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A Prospective Analysis of Dietary Fiber Intake and Mental Health Quality of Life in the Iowa Women's Health Study.

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Abstract

Objective.—Recent studies have reported associations between dietary intake and mental health. Dietary fiber is one nutrient that may modulate mental health, specifically depression risk, through the gut microbiome. We prospectively examined the association between dietary fiber intake and

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Contributors

Seth Ramin contributed to conception and design, development of methodology, analysis and interpretation of data, and drafting and revision of the manuscript.

Margaret A. Mysz contributed to conception and design, development of methodology, analysis and interpretation of data, and drafting and revision of the manuscript.

Katie Meyer contributed to drafting and revision of the manuscript.

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DeAnn Lazovich contributed to acquisition of data, analysis and interpretation of data, drafting and revision of the manuscript, and study supervision.

Anna Prizment contributed to conception and design, development of methodology, analysis and interpretation of data, drafting and revision of the manuscript, and study supervision. Anna Prizment had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the analysis.

Ethical approval

The use of the Iowa Women's Health Study (IWHS) dataset was approved by the University of Minnesota Institutional Review Board. All work was conducted in accordance with the Code of Ethics of the World Medical Association Helsinki Declaration. The privacy and rights of all subjects were preserved.

Provenance and peer review

This article has undergone peer review.

Research data (data sharing and collaboration)

There are no linked research data sets for this paper. The data are confidential and the authors do not have permission to share data.

Conflict of interest

The authors declare that they have no conflict of interest.

mental health-related quality of life (QOL) scores, a proxy for depressive symptoms, in a cohort of 14,129 post-menopausal women in the Iowa Women's Health Study.

Methods.—Dietary intake was assessed at baseline [1986] using a 127-item food frequency questionnaire. Mental health-related QOL scores were assessed at the follow-up questionnaire [2004] using the Mental Health (MH) component and Mental Health Composite (MCS) scales derived from the SF-36 Health Survey. The association between dietary fiber intake and mean QOL scores was examined using linear regression, with adjustment for age, alcohol intake, energy intake, waist-to-hip ratio, physical activity, smoking status, and education.

Results.—The median dietary fiber intake was 19.0 g/day, ranging from 1.1 to 89.4 g/day. Multivariable-adjusted mean MH scores were higher among those with higher fiber intake ($P_{for\ trend} = 0.02$). For MCS score, the association with fiber intake observed in a model adjusted for age and energy intake became insignificant after multivariable adjustment.

Conclusions.—Our study is one of the first prospective analyses of the association between higher dietary fiber intake and increased MH QOL scores later in life. Given a plausible biological mechanism underlying the association between fiber intake and mental health, additional studies are warranted.

Keywords

dietary fiber; mental health; depression; quality of life; prospective cohort

Introduction

Depression is one of the most prevalent mental health disorders: it affects 1 in 12 adults every year in the United States.[31] Depression is associated with decreased productivity, reduced quality of life, and increased mortality, demonstrating a need for prevention and treatment as a public health priority.[8] Identified risk factors for depression include family history of depression, childhood trauma, stress, alcohol consumption, tobacco use, physical illness, age, and medication use.[11]

Dietary patterns have been previously implicated in the presence or development of depressive symptoms.[14,15,36] A case-control study conducted in Chinese adults found that a diet rich in fruits and vegetables was inversely associated with the prevalence of depressive symptoms.[43] Conversely, this study found that a diet that contains sweets (cakes, ice-cream, candied fruits, etc.) or animal products was positively associated with the prevalence of depressive symptoms.[43] Another study found that a diet with poor nutritional quality was associated with elevated depressive symptoms in young adult females.[34] Therefore, diet quality could modify an individual's risk for depression.

Research in animal models suggests that a diet low in fiber plays an important role in the development and sustainability of depressive symptoms.[26,39,41] The mechanism has not been determined, but studies, conducted in both animal and human models, suggest that dietary fiber intake may modulate mental health issues through the gut microbiome.[6,9,17] Gut microbial organisms, living symbiotically with the human host, serve a major function in the fermentation of dietary fiber. Low-fiber diets may result in a loss of biodiversity within the

microbiome, causing increased gut permeability, systemic inflammation, and consequently, depressive symptoms.[3,9,16,17] Furthermore, when provided with a plethora of dietary fiber, these gut microbial organisms produce short chain fatty acids that promote human health.[39] A recent review concluded that the gut microbiome may dramatically affect the functioning of the central nervous system and brain development.[9] Therefore, it is plausible that a diet deficient in fiber may pose an increased risk for depressive symptoms.

Epidemiological evidence linking dietary fiber intake and depressive outcomes is scarce but consistent.[10,26,41,44] Cross-sectional studies of Japanese[26] and Chinese[41] populations demonstrated an inverse association between dietary fiber intake and the manifestation of depressive symptoms. A cross-sectional study of the NHANES cohort found that the intake of total dietary fiber, vegetable fiber, and fruit fiber were inversely associated with the prevalence of depressive symptoms.[44] A cross-sectional study of an Australian population demonstrated similar associations between dietary glycemic intake, fiber intake, and depressive symptoms.[10] To our knowledge, no studies have prospectively assessed the association between dietary fiber intake and depression.

To address this gap, we examined the relationship between dietary fiber intake at baseline and mental health outcomes after 17 years of follow-up in 14,129 post-menopausal women in the Iowa Women's Health Study (IWHS) cohort. Mental Health and Mental Health Composite Quality of Life (QOL) Scores derived from the SF-36 (36-item Short Form) survey used in this study are appropriate surrogates for assessing the presence of depressive disorders, as demonstrated in a cohort of elderly Swedish females.[38] We hypothesized that women consuming more dietary fiber would experience higher mental health QOL scores.

Methods

Iowa Women's Health Study

The details of the IWHS study have been previously reported.[4] In summary, the IWHS cohort commenced in 1986 from a random list of women aged 55-69 years with Iowa driver's licenses. At the baseline, 41,836 participants completed the self-administered questionnaire on diet and lifestyle behaviors, and demographic characteristics.[22] Additional questionnaires were administered in 1987, 1989, 1992, 1997, and 2004. The use of the IWHS dataset was approved by the University of Minnesota Institutional Review Board.

Inclusion Criteria

Of the original IWHS cohort, 20,844 (68.9%) of the 30,232 participants thought to be alive in 2004 responded to the final questionnaire. Women were excluded if, at baseline, they left more than 30 dietary questions unanswered, or if they reported extremely low (<600 Kcal) or high (>3500 Kcal) total daily energy intake. These exclusions were applied because previous studies examining the Food Frequency Questionnaire (FFQ) have demonstrated that the dietary data collected were both valid and reproducible when these criteria were utilized.[29] Further, women were excluded if they did not complete the 2004 questionnaire, did not answer questions about QOL, or if they did not reside in Iowa at the study's termination. A total of 14,129 women were available for this analysis.

Fiber Intake

Total dietary fiber intake at baseline (1986) was assessed using the 127 food-item Harvard Food Frequency Questionnaire (FFQ). This questionnaire was previously validated for this cohort study by comparing nutrient values based on a 24-hour dietary recall survey in 44 study participants;[22] therefore, it is considered an accurate measure of dietary intake over the previous year. For this study, participants were divided into quartiles based on total dietary fiber intake reported. Additional analyses were completed by separating fiber intake into nutrient sources: fiber from refined grains and from whole grains (also analyzed as quartiles).

Mental Health

Quality of life (QOL) was assessed during the 2004 questionnaire that included the Medical Outcomes Study (MOS), a 36-item Short-Form Health Survey (SF-36). The SF-36 is a validated self-assessment of QOL across various domains, both physical and psychological. This assessment includes 8 scales and measures the quality of life experienced in the last 4 weeks.[40] Of these 8 scales, five are related to mental health: overall mental health, role emotional, social functioning, vitality, and general health.[22] For the current study, two mental health metrics: Mental Health (MH) component and Mental Health Composite Scores (MCS) were utilized. Both of these scales have been validated for detection of anxiety and depressive symptoms in an elderly population.[24] The MCS is a combination of the raw scores from all eight scales on the SF-36 assessment (physical functioning, role limitations due to physical problems, social functioning, bodily pain, general mental health, role limitations due to emotional problems, vitality, and general health perceptions) .[24]

Other Measures

The IWHS questionnaire at baseline and 2004 included questions on smoking and alcohol intake, reproductive and medical history, medications, and current body and weight measurements (weight, height, and waist and hip circumference – baseline only). Waist-to-hip ratio (WHR) was calculated by dividing the waist circumference (1 inch above umbilicus) by the hip circumference (maximal protrusion) as measured by a partner with a provided study measure tape. Body mass index (BMI) was calculated as self-reported weight in kilograms divided by their height in meters squared (1986). The use of antidepressants (yes/no) was queried in 2004.

Statistical Analysis

All statistical analyses were completed using PC-SAS, version 9.4 (SAS Institute Inc, Cary, NC, US). All P- values were 2-sided, with a p-value < 0.05 being considered statistically significant. Analysis of variance (ANOVA), chi-square tests, or Fisher's Exact tests were used to test the distribution of participant characteristics across dietary fiber intake categorized into quartiles. Linear regression was used to evaluate the association between fiber intake and Mental Health (MH) and Mental Composite (MCS) QOL scores on a continuous scale. Tests for trends were calculated by fitting categorical variables as ordinal variables in the regression models.

The following characteristics were examined as potential confounders: age, total daily energy intake, alcohol consumption, BMI, education level, physical activity, smoking status, WHR, history of diabetes, hypertension, antidepressant use, and hormone replacement therapy (HRT) use. Potential confounders were included in multivariable models if previously reported as a risk factor for low-mental health scores, were associated with dietary fiber intake, and altered the QOL-total fiber intake association by at least 10%. Using these criteria, the confounders included in the final model were daily energy intake, age, WHR, education, alcohol consumption, physical activity, and smoking status. Three models were considered for the association between fiber intake and mental health. The first included adjustment for total energy intake and age. In the second model, education, alcohol consumption, WHR, physical activity, and smoking status were added to Model 1. The final model included all of these confounders and was further adjusted for the use of antidepressants.

The use of antidepressants and education were examined as possible modifiers of the effect of the role of fiber in mental health status. A stratified analysis on these factors was conducted and statistically tested for an interaction by including a cross-product between fiber and antidepressant use or education in the regression model.

In addition, we examined the association between fiber intake from refined and whole grains and QOL scores using multivariable linear regression.

Results

Study Population

The median dietary fiber intake was 19.0 g/day ranging from 1.1 to 89.4 g/day (compared to the Recommended Daily Intake of 25 g/day for women per the Dietary Guidelines for Americans, 2010).[44] Women in the lowest quartile for fiber intake (<14.6 g/day) were more likely to be younger, consume less calories and more alcohol, have higher WHR, and be former or current smokers (Table 1). These women were also less likely to have an education beyond high school or participate in higher activity levels compared to other groups. BMI, antidepressant use, history of diabetes and hypertension, and estrogen use did not differ across fiber intake. The overall mean MH and MCS scores were 52.5 (SD = 8.39) and 53.5(SD = 9.09), respectively.

Fiber Intake and Mean Mental Health-Related QOL Scores

Linear regression models adjusted for daily energy intake and age (model 1), demonstrated a statistically significant, positive association between dietary fiber intake and mean mental health-related scores (P-value = <0.0001 and 0.0005 for MH and MCS scores, respectively; Table 2). Further adjustment for education status, alcohol intake, WHR, physical activity, and smoking status (model 2) did not greatly alter observed means or trends for the association with mean MH scores ($P_{\text{for trend}} = 0.02$). However, the association with MCS scores was no longer statistically significant after adjustment ($P_{\text{for trend}} = 0.41$). These results were not found to vary by anti-depressant use ($P_{\text{for interaction}} = 0.68$ for MH and 0.84

for MCS) or education status ($P_{\text{for interaction}} = 0.12$ for MH and $P_{\text{for interaction}} = 0.31$ for MCS).

Refined and Whole Grain Fiber Intake and Mean Mental Health – Related QOL Scores

The associations between whole grain fiber intake and both the MH and MCS scores were similar to the corresponding associations reported for total dietary fiber intake with a positive, statistically significant trend observed for MH ($P_{\text{for trend}} = 0.02$), but not for MCS score ($P_{\text{for trend}} = 0.17$ for MCS) (Table 3). Conversely, refined fiber intake showed an indication of an inverse association with MH score, but did not reach statistical significance (Table 4).

Discussion

In this prospective cohort study of 14,129 postmenopausal women, three upper quartiles versus the lowest quartile of total dietary fiber intake were similarly associated with higher MH QOL scores ($P_{\text{for trend}} = 0.02$) after adjustment for demographic, socioeconomic, and lifestyle factors. A positive trend between MH and whole grain fiber intake and a suggestive inverse trend for refined fiber intake in relation to MH were observed. There were no statistically significant associations for the MCS score.

Differences in the multivariable associations for MH and MCS may reflect underlying differences in how each score is determined. For instance, the Mental Health scale encompasses anxiety, depression, loss of behavioral/emotional control, and psychological well-being, whereas the Mental Health Composite scale also accounts for other mental and physical aspects. Of the two scales used, conclusions about the association between fiber intake and the development of depressive symptoms is more appropriately captured by the MH scale as it is the most valid component for distinguishing groups that differ in severity of psychiatric conditions.[25]

The biological mechanisms that link dietary fiber to depression, as measured by mental health related quality of life, are not completely understood. There is, however, some research that suggests that the gut microbiome may play a role. Recent experimental and epidemiological studies reported that modifications in diet and resulting changes in gut microbiota are responsible for increasing rate of depression and inflammatory-related diseases.[3,9,12,21,33,37] One such dietary change is the deficiency of dietary fiber in the modern diet. Dietary fiber is an important food source for bacteria living in the gut, with experimental animal studies demonstrating that dietary fiber promotes a well-functioning microbiome.[39] Specifically, when provided with sufficient fiber, anti-inflammatory bacteria will produce byproducts that are beneficial for proper brain functioning.[27,37,39] If these gut bacteria are not provided with dietary fiber, the balance of beneficial and inflammatory-promoting bacteria in the gut may be disrupted, leading to inflammation in both humans and animals.[5,7,17,23] This has been supported, specifically, by a recent study that found that diets higher in fat and lower in fiber were associated with higher populations of *Bacteroidetes* and *Actinobacteria* than in subjects with higher fiber diets.[42] These bacterial species are pro-inflammatory, thus indicating that through changes in gut microbiota, low dietary fiber intake may modulate systemic inflammation.[2] This inflammation has been linked to the

development of depression and anxiety in both animals and humans.[3,12,21,33] Still, it is uncertain how fiber influences the composition of the gastrointestinal flora, and how shifts in this composition affect depression risk. A meta-analysis of probiotic intake, which influence microbiome composition, and depression risk did not find a significant association after adjustment, but did support the inverse fiber intake – depression risk relationship found by other studies.[6]

The current epidemiological literature is consistent but scarce regarding the association between dietary fiber and depressive symptoms. Three cross-sectional studies provide evidence of an inverse association between dietary fiber intake and depressive symptoms.[26,41,44] The study of Japanese employees aged 16-69 years reported a statistically significant inverse relationship between dietary fiber intake from fruits and vegetables, and depressive symptoms: OR (95% CI) = 0.65 (0.45,0.95) for the highest compared to lowest tertiles of fiber intake after adjusting for education attainment, smoking, physical activity, and demographics.[26] Similarly, an inverse relationship between dietary fiber and depressive symptoms was observed in a population of elderly Chinese individuals: multivariable OR (95% CI) = 0.66 (0.46,0.96), for >13g/day compared to <6 g/day.[41] While these studies provide some evidence, their generalizability is questionable due to the specific populations evaluated, as these populations tend to differ in diet, physical activity, customs and traditions, societal pressures, healthcare, and education in comparison to westernized cultures. Some of these concerns have been addressed by the cross-sectional study in the diverse U.S. cohort (NHANES) that also found an inverse association between dietary fiber intake and the prevalence of depressive symptoms after adjustment for several covariates including sex, race, household income, and marital status: multivariable OR (95% CI) = 0.59 (0.44-0.79).[44] Still, the cross-sectional design of this study is limited by reverse causality: individuals that have lower mental health QOL scores may consume poorer quality diets.[18,35] Thus, a major strength and novelty of our study is its prospective study design.

Additional strengths of our study include a large, population-based sample of post-menopausal women, assessment of dietary fiber intake using validated FFQ, and two established, validated scales for assessing mental health status. Furthermore, our study included assessment and adjustment for important factors that relate to fiber intake and mental health, such as age, educational attainment, smoking status, body composition, antidepressant use, and physical activity level.

Some limitations of this study include a lack of generalizability, as this study was restricted to post-menopausal white women residing in Iowa. Other populations, such as the non-white or males, may have different influences or risks for their QOL.[13,19] Selection bias may also be of concern because our analysis only included cohort members that were alive in 2004. Additionally, individuals with poor MH scores might be less likely to respond to the survey in 2004. Also, assessment of mental health status or antidepressant use at baseline was not done, though we would expect this to bias the association towards the null because it is unlikely that those with depression eat more fiber. Although the baseline questionnaire did not query mental health at baseline, a baseline question asked the participants to self-report their general health (excellent, good, fair, poor), and 98.4% of responders reported a general health of fair or better, demonstrating a generally healthy cohort at baseline. Since we expect

that individuals with depression are more likely to have a poorer perception of their overall health, it is unlikely that those reporting good health had poor mental health. Furthermore, there was no correlation between general health status and dietary fiber intake at baseline (correlation coefficient was 0.00021), implying that the association observed in our study was not driven by the fact that women with poor mental health consumed less fiber. Another limitation of this study is that we only considered fiber intake at baseline, and dietary intakes could change over time. However, dietary habits among post-menopausal women are difficult to break as demonstrated in the IWHS study: protein, fat, carbohydrate, alcohol, fruit, vegetable, and whole grain consumption assessed at baseline [1986] and follow-up [2004] remained stable.[30] Importantly, the main goal of this study was to determine if diet in middle age impacted mental health in later years, and this association would not be affected by dietary changes. Lastly, differences over fiber quartiles were small and may not be clinically or biologically meaningful in our study. In our fully adjusted models, the difference between scores across fiber intake categories did not exceed 1.0 point. The clinically meaningful difference in QOL scores is considered to be 0.5 SD[32], and therefore the meaningful difference in our study would be 4.2 points (SD = 8.39). The weak association observed in our study could be partially attributed to a long follow-up, which could cause regression towards the mean.

To address some of these limitations, future prospective cohort studies examining the association among other populations are warranted. Also, other studies should consider assessing diet and mental health status at several points over time, to provide a better test of causality. Lastly, supplemental analyses examining fiber from refined versus whole grain sources suggests that the quality of the source of food influences the association, with whole grain fiber demonstrating a significant, positive association. This may suggest that fiber intake is simply a proxy for quality of diet, and that it is quality of diet that influences depressive symptom risk. A study in adolescents found that the quality of diet at baseline was positively associated with higher quality of life, and improvements in diet over time improved mental health over time.[13] A meta-analysis of four cohort and nine cross-sectional studies reported that a healthy dietary pattern (high fruit, vegetable, whole grains, poultry, fish, and reduced fat dairy products) was associated with reduced odds of depression.[20] A prospective study of dietary patterns and the onset of depressive symptom risk five years from baseline found diets rich in processed meat, chocolate, sweet desserts, fried food, and high-fat dairy products demonstrated a positive association.[1] Therefore, a future study should develop a method of assessing diet quality and evaluate its association with mental health-related QOL scores.

In this prospective study, we found a statistically significant association between fiber intake quartiles and validated Mental Health scores in post-menopausal women. This study suggests a role for diet in mental health, which would lend itself to intervention studies testing nutritional strategies in preventing and treating mental illnesses.

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Highlights

- In this study, dietary fiber intake was positively associated with mental health quality of life scores later in life
- This association suggests a role for dietary fiber in mental health, as quality of life score can reflect depression risk
- The fiber intake - mental health quality of life score association differs across fiber source (whole grain vs. refined)

Table 1:

Participant's characteristics by fiber intake category. Iowa Women's Health Study (N=14,129).

Population Characteristics[a] Mean ± SD or N (%)	Total fiber intake (g/day)				P-value[b]
	<14.6 N=3,492	*14.7-18.9 N=3,571*	*19.0-24.0 N=3,564*	*24.1-89.4 N=3,502*	
Mean fiber intake (grams)	11.6 ± 2.3	16.8 ± 1.2	21.4 ± 1.5	30.3 ± 6.6	<0.0001
Total energy intake (kcal/day)	1336 ± 358	1658 ± 381	1901 ± 428	2358 ± 589	<0.0001
Age	60.2 ± 3.8	60.3 ± 3.8	60.6 ± 4.0	60.8 ± 4.0	<0.0001
BMI	26.8 ± 4.8	26.7 ± 4.7	26.6 ± 4.6	26.6 ± 4.6	0.14
WHR	0.83 ± 0.08	0.82 ± 0.08	0.82 ± 0.08	0.82 ± 0.08	<0.0001
Education					<0.0001
<12 years	519 (14.9%)	428 (12.0%)	390 (11.0%)	446 (12.7%)	
12 years	1577 (45.1%)	1526 (42.7%)	1487 (41.7%)	1296 (37.0%)	
>12 years	1396 (40.0%)	1617 (45.3%)	1687 (47.3%)	1760 (50.3%)	
Physical Activity Level					
Low	1932 (55.3%)	1620 (45.3%)	1472 (41.3%)	1202 (34.3%)	<0.0001
Medium	872 (25.0%)	1027 (28.8%)	1088 (30.5%)	1075 (30.7%)	
High	688 (19.7%)	924 (25.9%)	1004 (28.2%)	1225 (35.0%)	
Smoking Status					
Never	2161 (61.9%)	2466 (69.0%)	2626 (73.7%)	2670 (76.2%)	
Former	737 (21.1%)	723 (20.3%)	638 (17.9%)	622 (17.8%)	<0.0001
Current	594 (17.0%)	382 (10.7%)	300 (8.4%)	210 (6.0%)	
Alcohol (g/day)	4.80 ± 10.5	3.70 ± 7.9	3.48 ± 7.8	3.09 ± 6.5	<0.0001
Antidepressant use (Yes)[c]	395 (11.3%)	373 (10.5%)	347 (9.7%)	339 (9.7%)	0.08
History of diabetes (Yes)	89 (2.55%)	103 (2.88%)	107 (3.00%)	124 (3.54%)	0.11
History of high blood pressure (Yes)	1080 (30.9%)	1110 (31.1%)	1122 (31.5%)	1073 (30.6%)	0.80
History of estrogen use (Yes)	510 (14.6%)	584 (16.4%)	594 (16.7%)	553 (15.8%)	0.09

[a] Assessed at baseline (1986) unless noted otherwise.

[b] p-values (two-sided) were calculated using one-way ANOVA F-test for continuous variables and Chi-square test for categorical variables.

[c] Assessed at the 2004 questionnaire.

Table 2:

Mental health-related quality of life scores (means and standard errors) by daily fiber intake in women. Iowa Women's Health Study (N=14,129)[a,b].

Score	Total fiber intake (g/day)				P-value
	<14.6	14.7-18.9	19-24.1	24.2-89.4	
MH score					
Model 1[c]	51.6 (0.16)	52.5 (0.14)	52.6 (0.14)	53.1 (0.17)	<0.0001[g]
Model 2[d]	52.0 (0.16)	52.6 (0.14)	52.5 (0.14)	52.7 (0.17)	0.03[g]
Model 3[e]	52.0 (0.16)	52.6 (0.13)	52.5 (0.13)	52.7 (0.16)	0.02[g]
Adjusted β[f]	0 (reference)	0.55 (0.17,0.93)	0.46 (0.05, 0.88)	0.62 (0.12, 1.12)	0.02[h]
MCS score					
Model 1[c]	52.9 (0.17)	53.7 (0.15)	53.7 (0.15)	53.9 (0.18)	0.0005[g]
Model 2[d]	53.3 (0.18)	53.7 (0.15)	53.6 (0.15)	53.6 (0.18)	0.29[g]
Model 3[e]	53.3 (0.17)	53.7 (0.15)	53.6 (0.15)	53.6 (0.17)	0.26[g]
Adjusted β[f]	0 (reference)	0.43 (0.01,0.85)	0.26 (−0.19,0.72)	0.31 (−0.24,0.85)	0.41[h]

Abbreviations: MH – mental health, MCS – mental health composite score.

[a] Comparisons are pairwise within a row.

[b] Results presented as Least-Squares Means (SE)

[c] Model was adjusted for total caloric intake (Kcal/day) and age (years).

[d] Model was adjusted for total caloric intake (Kcal/day), age (years), education status (categorical <12, 12, and >12 years), alcohol intake (g), WHR, physical activity (low, medium, high), and smoking status (never, current, former). Reference group: <14.6 g/day of fiber, <12 years of education, never smoker, and low physical activity level.

[e] Model was adjusted for total caloric intake (Kcal/day), age (years), education status (categorical; <12, 12, and >12 years), alcohol intake (g), antidepressant use (yes, no), smoking status (never, current, former), WHR, physical activity (low, medium, high). Reference group: <14.6 g/day of fiber, <12 years of education, never smoker, antidepressant nonuser, and low physical activity level.

[f] β Estimate (95% CI) based on fully adjusted Model 3.

[g] P-values were calculated using multiple partial F-Test.

[h] Tests for trend were calculated by fitting categorical variables as ordinal variables.

Table 3.

Mental health-related quality of life scores (means and standard errors) by daily whole grain fiber intake. Iowa Women's Health Study(N=14,129)[a].

Score	Total whole grain fiber intake (grams/day)				P-value
	0-1.19	1.2-2.83	2.83-5.04	5.05-34.3	
MH score					
Least-Square Means[b]	52.3 (0.14)	52.3 (0.13)	52.7 (0.13)	52.6 (0.14)	0.03[d]
Adjusted β[b,c]	0 (reference)	0.01 (−0.36,0.38)	0.47 (0.09,0.85)	0.33 (−0.06,0.71)	0.02[e]
MCS score					
Least Square Means[b]	53.5 (0.15)	53.3 (0.15)	53.8 (0.15)	53.6 (0.15)	0.06[d]
Adjusted β[b, c]	0 (reference)	−0.23(−0.63,0.18)	0.32(−0.09,0.74)	0.12(−0.30,0.54)	0.17[e]

Abbreviations: MH – mental health, MCS – mental health composite score.

[a]Comparisons are pairwise within a row.

[b]Adjusted for total caloric intake (Kcal/day), age (years), education status (categorical; <12, 12, and >12 years), alcohol intake (g), antidepressant use (yes, no), smoking status (never, current, former), WHR, and physical activity (low, medium, high). Reference group: <14.6 g/day of fiber, <12 years of education, never smoker, antidepressant nonuser, and low physical activity level.

[c]β Estimate (95% CI) from linear regression models.

[d]P-values were calculated using multiple partial F-test.

[e]P-values for tests for trend were calculated by fitting categorical variables as ordinal variables.

Table 4.

Mental health-related quality of life scores (means and standard errors) by daily refined fiber intake. Iowa Women's Health Study (N=14,129)[a].

Score	Total refined fiber intake (grams/day)				P-value
	0-0.79	0.80-1.27	1.28-1.95	1.96-15.9	
MH score					
Least-Square Means[b]	52.6 (0.14)	52.4 (0.13)	52.6 (0.13)	52.2 (0.14)	0.14[d]
Adjusted β[b,c]	0 (reference)	−0.21 (−0.59,0.16)	−0.08 (−0.47,0.30)	−0.45 (−0.86,−0.04)	0.08[e]
MCS score					
Least-Square Means[b]	53.5 (0.15)	53.6 (0.15)	53.7 (0.14)	53.3 (0.16)	0.20[d]
Adjusted β[b,c]	0 (reference)	0.10 (−0.31,0.51)	0.21 (−0.20,0.63)	−0.23 (−0.68,0.22)	0.48[e]

Abbreviations: MH – mental health, MCS – mental health composite score.

[a]Comparisons are pairwise within a row.

[b]Adjusted for total caloric intake (Kcal/day), age (years), education status (categorical; <12, 12, and >12 years), alcohol intake (g), antidepressant use (yes, no), smoking status (never, current, former), WHR, and physical activity (low, medium, high). Reference group: <14.6 g/day of fiber, <12 years of education, never smoker, antidepressant nonuser, and low physical activity level.

[c]β Estimate (95% CI) from linear regression models.

[d]P-values were calculated using multiple partial F-test.

[e]P-values for tests for trend were calculated by fitting categorical variables as ordinal variables.