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Dietary fiber and associations with adiposity and fasting insulin among college students with plausible dietary reports

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Abstract

Objective—We examined the dietary fiber intake, food sources of dietary fiber, and relationship of dietary fiber with body composition and metabolic parameters in college students with plausible dietary reports.

Research Methods & Procedures—Students (18–24 yrs) provided data on anthropometry, fasting blood chemistries, and body composition (bioelectric impedance). Diet and physical activity were assessed with the Diet History Questionnaire and the International Physical Activity Questionnaire. Plausible dietary reporters were identified (± 1 SD cutoffs for reported energy intake as a percentage of predicted energy requirement). Multiple regression analyses were conducted with the total ($n=298$) and plausible ($n=123$) samples, adjusting for age, race, sex, smoking status, physical activity, energy intake, and fat free mass (where applicable).

Results—Food sources of dietary fiber were similar in males and females. In the plausible sample compared to the total sample, dietary fiber was more strongly associated with fat mass ($\beta=-0.24$, $p<0.001$), percent body fat ($\beta=-0.23$, $p<0.001$), BMI ($\beta=-0.11$, $p<0.01$), waist circumference ($\beta=-0.67$, $p<0.05$), and fasting insulin ($\beta=-0.15$, $p<0.001$). When the effect of sex was investigated, dietary fiber was inversely related to fasting insulin and fat mass in men and women and inversely related to percent body fat, BMI, and waist circumference in men only ($p<0.05$).

Conclusions—Inclusion of implausible dietary reports may result in spurious or weakened diet-health associations. Dietary fiber is negatively associated fasting insulin levels in males and females and consistently associated with adiposity measures in males.

Keywords

Diet; glucose; body composition; adults; health; food habits

INTRODUCTION

There has been a dramatic increase in the prevalence rates of overweight and obesity in adolescents and young adults in the last 20 years (1–3). Obesity-promoting eating behaviors are pervasive in the college environment; ‘all-you-can-eat’ dining halls, the consumption of high-fat ‘junk food’, and increased snacking contribute to the weight gain that is common in college (4–6). A recent review highlights the need to assess weight-related behaviors during

this critical developmental period (7). Recent studies, including one from our group, report that up to 35% of college students may be overweight (8,9). We have also previously reported that the rate of metabolic dysfunction is surprisingly high in a sample of otherwise healthy college students, with rates ranging from 26% to 40% (10). However, we did not investigate dietary factors that may be associated with adiposity and metabolic risk factors.

In older adults, low fiber diets have been shown to contribute to the development of obesity, type 2 diabetes, and cardiovascular disease risk factors (11–14), but it is not clear whether similar effects of low fiber diets are already apparent earlier in life. The large number of college-aged students who are not meeting minimum recommended dietary guidelines for intake of dietary fiber and whole grains may have long-term health implications (6,14–17). The effect of dietary fiber on obesity, metabolic parameters, and cardiovascular disease risk factors needs to be assessed in college-aged students to determine if the deleterious impact of low-fiber diets on health outcomes affects this population.

Examinations of the associations between diet and health are frequently confounded by the inaccuracy of self-reported dietary measures (18–20). This is especially problematic given that under-reporting may occur systematically, specifically occurring more frequently in overweight reporters than in normal weight reporters (21,22). The inclusion of implausible dietary reports has been shown to lead to spurious, weakened, or contradictory relationships between diet and health (23,24). To properly examine the relationships between diet and health outcomes, implausible intake assessments should be excluded.

The goals of the current study were to 1) characterize the intakes of dietary fiber in college students in the total sample of reporters and in a subsample of plausible dietary intake reporters, 2) identify food sources of dietary fiber in the plausible dietary reporters, and 3) examine associations of dietary fiber intake with adiposity and metabolic variables in both the total sample and the plausible reporter samples.

MATERIALS AND METHODS

Subjects

As part of the Monitoring University Students Tackling Diabetes and Obesity (MUST-DO) study at the University of Kansas, 298 students (18–24 years) provided data on anthropometry, body composition, fasting blood chemistries, and oral glucose tolerance (OGTT) measures. Study methodology has been detailed elsewhere (9,10). Exclusion criteria for the study included pregnancy, currently taking any medication known to affect body composition or physical activity (e.g., prednisone etc.), taking weight control medications/supplements, being diagnosed with a major illness (e.g., asthma, cardiovascular disease, etc.), being diagnosed with any illness known to affect body composition or fat distribution (e.g., Cushing's Syndrome, etc.), having seen a psychiatrist or psychologist in the last six months or taking medications prescribed by a psychiatrist. All students provided informed consent before testing began. This study was approved by the Institutional Review Board at the University of Kansas, Lawrence.

Anthropometric and metabolic assessments

Anthropometric measures consisted of weight, height, and waist circumferences (average of three measurements), and were conducted by physical therapy interns under the supervision of a licensed physical therapist who was familiar with anthropometry. Body mass index (BMI) was calculated from height and weight, and overweight was defined as $\geq 25 \text{ kg/m}^2$ (25). After participants were seated at rest for 10 mins, systolic and diastolic blood pressure and pulse measurements were taken (average of two measurements). Bioelectric impedance analysis

(Tanita 300A; Tanita Arlington Heights, IL) was used to measure total fat mass (kilograms) and percent body fat. The students fasted at least 12 hrs prior to the visit. Glucose, insulin, triacylglycerol and HDL cholesterol comprised the fasting blood measures. All serum blood measurements were analyzed by the Laboratory Corporation of America (Kansas City, MO, and Burlington, NC) except for glucose, which was analyzed on site. LDL was calculated using the equation of Friedewald et al. (26). A 2-hour OGTT was administered using a 75-g glucose load, and 2-hour plasma glucose was measured. Plasma glucose was assayed using an automated glucose analyzer (Vitros DT60, Johnson and Johnson, Rochester, NY).

Dietary intake assessment

Participants completed the standard Diet History Questionnaire (DHQ), a validated food frequency questionnaire developed by staff at the National Cancer Institute (NCI; Diet History Questionnaire, Version 1.0. National Institutes of Health, Applied Research Program, National Cancer Institute. 2002; (27,28). The DHQ consists of questions on 124 food items consumed in the past 12 months, including questions regarding portion sizes. It can be completed in about one hour and was designed, based on cognitive research, to be easy to use (27).

Nutritional information was reduced and calculated in Diet*Calc software (Diet*Calc Analysis Program, Version 1.4.3. National Cancer Institute, Applied Research Program. November 2005) using a nutrient database developed for the DHQ by NCI (DHQ Nutrient Database, National Cancer Institute, Applied Research Program; (29). The DHQ nutrient database is created from data collected from the 1994–96 Continuing Survey of Food Intakes by Individuals (CSFII), which grouped foods reported on 24-hr recalls. Dietary fiber was the primary dietary variable of interest. The 2005 dietary guidelines put forth by the U.S. Department of Health and Human Services and U.S. Department of Agriculture define dietary fiber as composed of nondigestible carbohydrates and lignin that are intrinsic and intact in plants (30).

The amount of dietary fiber contributed to the total dietary fiber intake by each DHQ food group was obtained by summing the amount of the dietary fiber that was provided by the food for all people and dividing by the total intake of dietary fiber from all foods for all persons. The percentage contributed by each food to the sample's total dietary fiber consumption was calculated with the formula previously employed by Subar and colleagues (31). A complete list of DHQ food groups and the individual foods comprising the food group are available at http://riskfactor.cancer.gov/DHQ/database/gi_values.csfii_94-96_foodcodes.dhq_only.csv.

Physical activity assessment

To assess habitual physical activity, participants completed the long form of the International Physical Activity Questionnaire (IPAQ), a questionnaire developed to measure the daily physical activity habits of adults aged 15–69 years (32). The IPAQ has acceptable reliability and validity when assessing physical activity levels and patterns (33,34). The long form IPAQ is a 27-question instrument that assesses physical activity during the last seven days in four domains (e.g., leisure-time, work, active transportation, and domestic physical activity) and assigns metabolic equivalent values (METs) according to three intensities within each domain: walking (3.3 METs), moderate (4.0 METs), and vigorous (8.0 METs).

Screening for Reports of Implausible Dietary Intake

To identify students who reported implausible energy intake, the method developed by Huang and colleagues was used. Briefly, this method creates sex and age group- specific ± 1 standard deviation (SD) cut-offs for reported energy intake (rEI) as a percentage of predicted energy requirements (pERs; $rEI/pER \times 100$). More detailed explanations of the methodology are available (23,35).

To determine the cut-offs used to identify the implausible reporters, the predicted energy requirement, which is equal to total energy expenditure (TEE) during weight stability, was calculated for each participant using the 2002 Dietary Reference Intakes (DRI) equations (36) (EQ. 1).

$$\begin{aligned} \text{Men: TEE} &= 864 - 9.72 \times \text{age (yrs)} + \text{PA} \times [(14.2 \times \text{weight (kg)} + 503.0 \times \text{height (m)})] \\ \text{Women: TEE} &= 387 - 7.31 \times \text{age (yrs)} + \text{PA} \times [(10.9 \times \text{weight (kg)} + 660.7 \times \text{height (m)})] \end{aligned} \quad \text{EQ. 1}$$

To calculate TEE, age, weight, height, and physical activity (PA) were needed. PA was categorized into four levels according to physical activity levels (PAL; (23,35) Appendix 1), which was calculated as follows (EQ. 2).

$$\text{PAL} = \frac{(\text{METs} - 1) \times [(1.15/0.9) \times \text{Duration (minutes)}]/1440}{\text{BEE}/[0.0175 \times 1440 \times \text{weight (kg)}]} \quad \text{EQ. 2}$$

METs and duration values from the IPAQ (37) were used to calculate a PAL for each intensity within each domain, e.g., walking, moderate, and vigorous intensity levels within the work domain. To generate the daily PAL, the intensity and domain-specific PALs were summed and added to a base sedentary PAL of 1.1. Basal energy expenditure (BEE) was calculated based on the DRI (EQ. 3; (36)).

$$\begin{aligned} \text{For men: BEE} &= 293 - 3.80 \times \text{age (yrs)} + 456.4 \times \text{height (m)} + 10.12 \times \text{weight (kg)} \\ \text{For women: BEE} &= 247 - 2.67 \times \text{age (yrs)} + 401.5 \times \text{height (m)} + 8.60 \times \text{weight (kg)} \end{aligned} \quad \text{EQ. 3}$$

After pER were created for each student, rEI as a percentage of pER ($\text{rEI/pER} \times 100$) was calculated. To compute the ± 1 SD cut-off for % rEI/pER, the equation adapted from the Goldberg cut-off calculations (23,38) was used (EQ. 4).

$$1 \text{ SD} = \sqrt{\text{CV}_{\text{rEI}}^2/d + \text{CV}_{\text{pER}}^2 + \text{CV}_{\text{mTEE}}^2} \quad \text{EQ. 4}$$

Using the ± 1 SD cut-offs, a report was excluded if %rEI/pER was outside the ± 1 SD range. The method includes propagating error variances from intra-individual variation in EI reporting over the number of days of intake ($\text{CV}_{\text{rEI}/d}^2$), the error in the equations for pER (CV_{pER}^2), and measurement error and day-to-day biological variation in total energy expenditure ($\text{CV}_{\text{mTEE}}^2$) (23). CV_{pER} was estimated to be 11%, and $\text{CV}_{\text{rEI}/d}$ was estimated to be 23% using food frequency questionnaires (39). CV_{mTEE} was estimated to be 8.2% (23,39). One SD, which was computed by taking the square root of the sum of all squared components, was 27%. A record was considered plausible if the rEI as a percentage of pER was within 73% and 127%.

Data Analysis

Descriptive characteristics (means $\pm$ SD) were calculated for demographic, anthropometric, and dietary variables in both the total and plausible dietary reporter samples. Statistical tests to detect mean differences between the total and plausible reporter samples were not conducted, because the plausible reporter sample is nested within the total sample violating the assumption of independence. Statistical tests were conducted to determine whether plausible and implausible dietary reporters were significantly different in age, sex, ethnicity, height, weight,

or BMI (chi-square for categorical variables and Student's t-test for continuous variables). To examine the association between dietary factors and disease risk factors in the total and plausible samples, multiple linear regression models were employed; indicators of adiposity and metabolic parameters were regressed on dietary fiber, and the type I error was set at 0.05. To examine whether sex moderates the relationships between diet and health outcomes, a dietary fiber*sex interaction term was added to the regression models. If the interaction term was significant ($p < 0.15$), then subsequent analyses were stratified and the relationships were examined specific to sex. All regression models included relevant covariates: sex, age (years), ethnicity (white vs. non-white), current smoking status (yes/no), physical activity category (see Appendix 1), and total energy intake (kcal). Additionally, models with total fat mass (kg) as the dependent variable were adjusted for fat free mass. Analyses were conducted using SAS software (version 9.1.3, 2004, SAS Institute, Cary, NC).

RESULTS

The prevalence of and sex differences in metabolic abnormalities in this sample have previously been reported (10). Demographic, anthropometric, metabolic, and dietary characteristics of the total sample ($n=298$) and sub-sample of plausible reporters of dietary intake ($n=123$) are shown in Table 1. In both the total and plausible samples, participants reported a mean age of 20 years, height of 1.7 m, weight of 68 kg, and BMI of 23 kg/m². Both the total and plausible samples had approximately 70% female and 20% non-white participants. Under-reporting of food intake was evident in the total as compared to the plausible sample for total caloric intake (mean daily energy intake = 2198 and 2349 kcal in the total vs. plausible samples) and dietary fiber intake (mean daily fiber intake = 19.87 vs. 21.22 g in the total vs. plausible samples), though fiber density was similar (mean daily intake 9.48 vs. 9.14 g/kcal in the total vs. plausible samples). Additionally, there were not any statistically significant differences between those in the plausible and implausible samples in age, sex, ethnicity, height, weight, or BMI (all $p > 0.50$).

Table 2 and Table 3 show the food sources of dietary fiber among the sub-sample of participants with plausible reports of dietary intake for males and females, respectively. For males, the top five food sources comprised 20% of dietary fiber consumed and included Mexican mixtures, whole grain bread/rolls, fried potatoes, good fiber ready to eat (RTE) cereal, and apples. For females, the top five food sources also comprised 20% of dietary fiber consumed and included good fiber RTE cereal, high fiber RTE cereal, apples, whole grain bread/rolls, and Mexican mixtures.

Table 4 shows the results of adiposity and metabolic parameters regressed on dietary fiber in both the total sample and plausible sub-sample. Dietary fiber was significantly associated with fat mass, percent body fat, BMI, and fasting insulin in both the total sample (all $p < 0.05$) and the plausible sample (all $p < 0.01$). However, fiber associations were stronger in the plausible sample than in the total sample. Dietary fiber and waist circumference were only marginally associated in the total sample but were significantly associated in the plausible sample ($p < 0.05$).

In the plausible sample, sex was a significant effect modifier in the relationship between dietary fiber and the indicators of adiposity (all $p < 0.15$), but it was not an effect modifier in the relationship between dietary fiber and fasting insulin. Sex-stratified analyses were conducted to examine the sex-specific relationship between dietary fiber and body composition indicators in the plausible sample. Compared to women, men consumed significantly more total calories (men = 2928.3 ± 100.8 and women = 2063.2 ± 42.13 kcal, $p = 0.0001$) and dietary fiber (men = 24.4 ± 1.32 and women = 19.6 ± 0.86 g, $p = 0.002$).

Results of the sex-specific regression analyses are shown in Table 5. In males and females, there was a significant relationship between dietary fiber and fat mass (all $p < 0.05$), but the relationship was stronger in males than females. Among males there was a significant relationship between dietary fiber and percent body fat, waist circumference, and BMI (all $p < 0.05$), but these relationships were non-significant among females. There were no significant sex interactions for fiber and adiposity measures in the total sample (all $p > 0.2$).

Other metabolic components (fasting glucose, 2-hr glucose, 2-hr insulin, triglycerides, HDL cholesterol, and blood pressure) were not associated with dietary fiber intake in either the total sample or the plausible sample (all $p > 0.10$). Because some studies report fiber density instead of grams of fiber independent of total caloric intake as reported in the current study (15), analyses were also conducted with fiber density (g/kcal) as the independent variable and similar results were obtained. To ensure the effects of dietary fiber with the outcomes were not a result of total carbohydrate intake, the relationship of total carbohydrates with adiposity and metabolic parameters were investigated in a separate model, and total carbohydrates intake was not significantly associated with any of the adiposity or metabolic measures, after adjusting for covariates (all $p > 0.05$).

DISCUSSION

This study examined the sources of dietary fiber intake and its associations with adiposity and metabolic parameters in college students, a unique age group for whom few data are available. This study confirmed that the inclusion of implausible dietary reports could result in weakened diet-health associations. The inverse association between dietary fiber and health outcomes was much stronger in the plausible sample than the total sample. The strength of the relationship between dietary fiber and adiposity and fasting insulin increased by at least 40% when the implausible dietary reporters were excluded.

In college-aged men, higher dietary fiber consumption was significantly and consistently associated with lower adiposity independent of energy intake. Energy loss, through increased fecal energy excretion, is one explanation for the effect of dietary fiber on adiposity independent of energy intake (40,41). Soluble, fermentable fiber reduces overall absorption of fat and protein, such that high fiber diets result in an increase in fecal energy (42). The association found in men between dietary fiber and adiposity is similar to previous studies in which normal weight men were shown to consume more dietary fiber than their overweight and obese counterparts (17,41,43,44). These studies either only studied men or did not report whether sex was examined as a potential moderator.

In women, there was no consistent relationship between dietary fiber and measures of adiposity. Women who consumed more dietary fiber had significantly less fat mass and marginally lower percent body fat, but there was no relationship between dietary fiber and BMI or waist circumference. The stronger relationship between fiber and BMI in men compared to women is corroborated by a similar finding in the Netherlands (45). The inconsistent relationship between dietary fiber and adiposity measures in women in these studies indicates a need for future studies to examine this relationship with more precise measures of dietary fiber intake and body composition that can help to elucidate specific fat depots that may be affected by dietary fiber intake.

Howarth et al., however, used a similar method to exclude implausible reports of dietary intake and reported a significant inverse relationship between dietary fiber intake and adiposity in older women but not in men (15). The seemingly contrasting results may be attributable to study sample and methodological differences between the studies. In addition to the differences in the age of the samples, only 60% of the participants in Howarth et al. had more than a high

school diploma, while 100% of participants in the current study had at least some college. These differences in socio-economic status may help to explain the disparate findings. People with a higher socioeconomic status consume more fiber (46), as seen in the comparison of these studies; men and women in Howarth et al. reported consuming 19.4 and 15.8 g/day, respectively, which is less than the reported dietary fiber intake in the current study. Additionally, people who have higher education are more likely to have recommended dietary intake patterns, suggesting those with higher education levels have different dietary patterns than those with less education (47). Different dietary intake patterns across socio-economic levels suggest different dietary sources of fiber which may lead to differences in the relationship between dietary fiber and adiposity. Assessment of dietary fiber food sources in future studies may help to clarify this relation.

Methodological differences that may also contribute to the different findings between the Howarth et al. study and the current study include the way in which adiposity and dietary intake were assessed. Howarth used self-reported height and weight to calculate BMI (15), while we used clinician-assessed height, weight, and waist circumference and bioelectrical impedance analysis to assess body composition. This may be significant, because men and women differentially self-report weight (48). The way in which dietary intake was assessed may be another methodological difference that contributed to the differing results. Howarth et al. used a 24-hour recall to assess dietary intake, while in the current study a FFQ was used. Men, unlike women, are likely to report fiber intake differently on 24-hour recalls versus FFQ; men with high dietary fiber intake levels are more likely to report higher fiber intake, and men with lower intake levels are more likely to report less fiber intake on the FFQ than on the 24-hour recall (49). More prospective research is needed to elucidate the relationships between dietary intake and adiposity while considering sex and socioeconomic status.

The present study has several potential limitations that need to be addressed. First, this is a cross-sectional study, which precludes making any conclusions about a causal link between diet and health outcomes. Second, these findings may not generalize to college campuses with different student populations, including colleges with different distributions of student ethnicity and socio-economic status. However, generalizability may not be as limited by regional or geographic location, because food attitudes and behavior do not vary significantly among college campuses located in different geographical regions (50). Third, the assessments were collected from Fall semester 2003 to Spring semester 2005, which may have contributed to a seasonality effect.

Last, this study used ± 1 SD %rEI/pER for plausible dietary data instead of wider cutoffs that would have allowed for the inclusion of more participants and thus a larger sample size with more statistical power (38,51). By making the decision to include only dietary records that fell within ± 1 SD %rEI/pER, we attempted to exclude any reported energy intake that was not representative of habitual energy intake (39). This method resulted in the exclusion of 57.5% of the participants, introducing the possibility of systematically excluding participants with certain characteristics. However, our results showed no statistically significant differences in age, sex, ethnicity, height, weight, or BMI between the plausible and implausible reporters, thereby minimizing the likelihood of systematic bias introduced by our plausibility criterion.

To our knowledge, this study is the first to demonstrate that lower intake of dietary fiber is significantly associated with higher circulating insulin levels in college students, which is cause for concern, because higher levels of fasting insulin have been associated with an increased risk of developing type 2 diabetes and cardiovascular disease (14,52,53). Ludwig et al. assert that the relationship between dietary fiber and cardiovascular disease risk factors, including weight gain, central adiposity, elevated blood pressure, hypertriglyceridemia, low HDL-C, high LDL-C, and high fibrinogen, are mediated in part by insulin levels (43). The current study

examined, but found no evidence for associations between dietary fiber and blood pressure, triglycerides, or HDL-C. It may be that the harmful effects of high circulating insulin levels have not yet developed in these young adults. The longer-term cardiovascular disease risk factors may develop later in these students as a result of their high insulin levels. Longitudinal studies that follow college-age students through emerging adulthood would help to identify whether dietary risk factors that begin in college lead to negative health consequences in later in life.

The current study is significant, because it is one of the first to examine diet-health relationships in individuals with plausible dietary reports. Our findings suggest that the exclusion of implausible dietary reporters is critical to accurately detecting associations between diet and health outcomes. We enhanced previously published methodology for predicting energy requirements by using measured physical activity to estimate physical activity levels (23,35, 54,55). Another strength of the study includes the use of clinician-measured weight and height, because heavier female college students may strongly underestimate their self-reported weight (56).

A notable finding from the current study is that according to the USDA recommended guidelines, neither men nor women in the current study reported consuming enough dietary fiber; the average reported dietary fiber intake was approximately 7g lower than the USDA recommended daily intake of 14g per 1000 kcal (30). Dietary interventions in overweight adults that increase the consumption of whole-grains, which are high in dietary fiber, have been shown to improve fasting insulin levels (57). Coupled with the findings from the current study, these intervention results suggest that the promotion of whole grain intake, and making it more accessible and available on campuses, may be an important intervention modality for the prevention of obesity, type 2 diabetes, and cardiovascular disease on college campuses. In addition, the current study identified the food sources of fiber in this college sample, and the identification of existing food sources of fiber may help in the development of interventions to promote *healthy* high fiber foods by identifying foods already consumed in college-aged populations.

CONCLUSIONS

This study further supports the exclusion of implausible dietary reporters from studies examining the effects of diet on health outcomes. Among plausibly reporting college students, higher dietary fiber intake was associated with lower fasting insulin levels. Among men, fiber intake was negatively associated with indicators of adiposity, but not as consistently in women.

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CBW was responsible for data reduction, statistical analysis, reduction and interpretation of the data, and manuscript preparation; LAK assisted with statistical analysis and manuscript preparation; MS oversaw all medical procedures and tests in the study (study physician of the project); TKH was the Principal Investigator for this project and oversaw and managed all aspects of the study, analysis, and manuscript preparation. None of the authors had any financial or personal conflict of interest.

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Appendix 1

Definitions of categories of physical activity (PA) for use in total energy expenditure equation determined by physical activity levels (PAL)

For men:

- Sedentary: PA = 1.0, when $1.0 \leq \text{PAL} < 1.4$

- Low active: $PA = 1.12$, when $1.4 \leq PAL < 1.6$
- Active: $PA = 1.27$, when $1.6 \leq PAL < 1.9$
- Very active: $PA = 1.54$, when $1.9 \leq PAL < 2.5$

For women:

- Sedentary: $PA = 1.0$, when $1.0 \leq PAL < 1.4$
- Low active: $PA = 1.14$, when $1.4 \leq PAL < 1.6$
- Active: $PA = 1.27$, when $1.6 \leq PAL < 1.9$
- Very active: $PA = 1.45$, when $1.9 \leq PAL < 2.5$

Table 1

Characteristics of total sample and sub-sample of plausible reporters of dietary intake

	Total Sample (n=298)	Plausible Sample (n=123)
Sex (% female)	66%	67%
Ethnicity (% non-white)	18%	19%
Smoking (% smoked in past 30 days)	18%	19%
Age (years)	20.1 ± 1.7	20.1 ± 1.6
Height (m)	1.7 ± 0.1	1.7 ± 0.1
Weight (kg)	68.4 ± 13.3	68.1 ± 13.0
BMI (kg/m ²)	23.6 ± 3.4	23.6 ± 3.5
Waist circumference (cm)	76.4 ± 9.4	76.1 ± 9.4
Triglycerides (mg/dL)	86.7 ± 41.1	83.3 ± 40.7
HDL-cholesterol (mg/dL)	55.6 ± 13.6	56.1 ± 14.3
Systolic blood pressure (mmHg)	110.7 ± 8.2	109.6 ± 7.9
Diastolic blood pressure (mmHg)	71.8 ± 6.9	71.2 ± 6.4
Fasting glucose (mg/dL)	90.5 ± 7.1	90.2 ± 6.8
Two-hour glucose (mg/dL)	93.6 ± 22.3	95.3 ± 25.0
Fasting insulin (IU/ml)	7.0 ± 4.5	6.9 ± 4.4
Two-hour insulin (IU/ml)	33.6 ± 19.6	35.3 ± 20.5
Daily energy intake (kcal)	2198.2 ± 1193.5	2349.2 ± 632.9
Dietary fiber (g/day)	19.9 ± 11.2	21.2 ± 8.3
Dietary fiber density (g/kcal)	9.5 ± 3.4	9.1 ± 3.0
Carbohydrates (g/day)	281.4 ± 147.4	298.6 ± 85.2
% energy from carbohydrates	51.9 ± 7.2	51.1 ± 7.4
Protein (g/day)	84.1 ± 49.9	89.3 ± 32.2
% energy from protein	15.3 ± 3.2	15.1 ± 3.0
Fat (g/day)	76.2 ± 45.0	83.4 ± 27.0
% energy from fat	31.0 ± 5.6	32.0 ± 5.4

NOTE: Values reported are means ± SD, unless otherwise noted. Statistical tests to detect differences between total sample and plausible sample were not conducted, because samples are not independent; therefore, no p-values are reported.

Table 2

Top 20 food sources of dietary fiber among a sample of US college males with plausible reports of dietary intake (n=40)

Ranking	Food	% of fiber	Cumulative % of fiber
1	Mexican mixtures, all	4.9	4.9
2	Bread/rolls, whole grain	4.7	9.6
3	Potatoes, fried	4.2	13.8
4	RTE cereal, good fiber	3.6	17.4
5	Apples	3.3	20.7
6	Bananas	3.1	23.8
7	Beans, NFA	2.9	26.6
8	Nuts/seeds, whole	2.6	29.2
9	Vegetable medly, NFA	2.5	31.7
10	Potatoes, white, NFA	2.4	34.1
11	Breads/rolls, white	2.3	36.4
12	Pizza, with meat	2.1	38.5
13	Orange/grapefruit jce, all	2.1	40.6
14	Oranges, tangelo, etc.	1.9	42.6
15	Pasta, meatless red sauce	1.9	44.5
16	Pasta, meat/fish sauce	1.9	46.4
17	Corn, NFA	1.8	48.2
18	Chili	1.8	50.0
19	Peas, NFA	1.8	51.8
20	Beer	1.7	53.6

NOTE: RTE=Ready to eat; NFA=No fat added

Table 3

Top 20 food sources of dietary fiber among a sample of US college females with plausible reports of dietary intake (n= 83)

Ranking	Food	% of fiber	Cumulative % of fiber
1	RTE cereal, good fiber	5.2	5.2
2	Apples	5.1	10.3
3	Bread/rolls, whole grain	4.9	15.3
4	Mexican mixtures, all	2.9	18.2
5	RTE cereal, hi-fiber	2.7	20.9
6	Ckd spinach/greens, NFA	2.3	23.2
7	Bananas	2.3	25.5
8	Nuts/seeds, butters	2.3	27.8
9	Carrots, NFA	2.2	30.0
10	Vegetable medleys, NFA	2.1	32.2
11	Potatoes, fried	2.1	34.3
12	Beans, NFA	2.0	36.3
13	Broccoli, NFA	2.0	38.2
14	Oranges, tangelo, etc.	1.9	40.1
15	Tofu, soy meats	1.9	42.0
16	Nuts/seeds, whole	1.8	43.8
17	String beans, NFA	1.8	45.6
18	Potatoes, white, NFA	1.7	47.3
19	Breads/rolls, white	1.6	49.0
20	Lettuce, NFA	1.6	50.5

NOTE: RTE=Ready to eat; NFA=No fat added

Table 4

Association between dietary fiber and indicators of body composition and fasting insulin in total and plausible samples, B(SE)

Predictors	Fat mass (kg)	% Body Fat	BMI (kg/m ²)	Waist Circum. (cm)	Fasting Insulin (IU/ml)
<u>Total Sample (n=298)</u>					
Dietary Fiber (g)	-0.17(0.04) ***	-0.14(0.05) **	-0.06(0.03) *	-0.36(0.19) ⁺	-0.10(0.03) **
Age (yrs)	0.40(0.18)*	0.36(0.21) ⁺	0.09(0.11)	0.90(0.82)	-0.34(0.15)*
Race (white=0, non-white=1)	-0.03(-0.77)	-0.23(0.91)	0.54(0.49)	2.4(3.7)	0.46(.67)
Sex (male=0, female=1)	20.61(1.46)***	9.57(0.82)***	-2.13(0.44)***	-30.96(3.21)***	0.72(0.60)
Current Smoker (yes=1, no=0)	1.10(0.79)	1.28(0.93)	0.42(0.50)	4.40(3.64)	1.24(0.68) ⁺
Physical Activity	-0.31(0.55)	-0.19(0.65)	0.16(0.35)	1.47(2.55)	0.06(0.48)
Energy Intake (kcal)	0.001(0.0005)***	0.001(0.0005)*	0.0003(0.0003)	0.002(0.002)	0.0005(0.0003)
<u>Plausible Sample (n=123)</u>					
Dietary Fiber (g)	-0.24(0.07) ***	-0.23(0.08) **	-0.11(0.04) **	-0.67(0.30) *	-0.15(0.05) **
Age (yrs)	0.52(0.30) ⁺	0.56(0.34)	0.18(0.19)	1.53(1.31)	-0.31(0.24)
Race (white=0, non-white=1)	0.36(1.26)	0.36(1.40)	0.77(0.77)	4.53(5.45)	1.61(0.99)
Sex (male=0, female=1)	20.10(2.44)***	11.58(1.63)***	-1.06(0.89)	-19.37(6.28)**	2.13(1.15) ⁺
Current Smoker (yes=1, no=0)	1.41(1.33)	1.74(1.48)	0.86(0.82)	5.99(5.75)	0.65(1.05)
Physical Activity	-1.55(1.34)	-1.27(1.48)	0.37(0.81)	-3.49(5.74)	0.62(1.05)
Energy Intake (kcal)	0.002(0.001) ⁺	0.004(0.001)*	0.001(0.0008) ⁺	0.02(0.01)**	0.002(0.001) ⁺

NOTE: Model with fat mass (g) as dependent variable adjusted for fat free mass (g);

[†] BMI = body mass index;

⁺ p<0.10,

* p<0.05,

** p<0.01,

*** p<0.001;

Table 5
Sex Differences in the association between dietary fiber and indicators of body composition in plausible sample, B(SE)

Predictors	Fat mass (kg)	% Body Fat	BMI ¹ (kg/m2)	Waist Circum. (cm)
<u>Males (n=40)</u>				
Dietary Fiber (g)	-0.49(0.12) ***	-0.44(0.12) ***	-0.18(0.07) *	-0.42(0.18) *
Age (yrs)	0.95(0.59)	1.05(0.59) ⁺	0.52(0.35)	1.31(0.92)
Race (white=0, non-white=1)	-0.75(2.31)	-0.15(2.30)	1.16(1.39)	1.09(3.59)
Current Smoker (yes=1, no=0)	5.56(2.07)*	5.55(2.09)*	1.90(1.26)	6.58(3.27) ⁺
Physical Activity	-6.54(3.42) ⁺	-7.03(3.45) ⁺	-2.59(2.07)	-6.74(5.35)
Energy Intake (kcal)	0.01(0.002)***	0.01(0.002)*	0.002(0.002) ⁺	0.01(0.003)*
<u>Females (n=83)</u>				
Dietary Fiber (g)	-0.14(0.07) *	-0.17(0.09) ⁺	-0.09(0.05)	-0.16(0.12)
Age (yrs)	0.62(0.30)*	0.69(0.41) ⁺	0.17(0.23)	0.46(0.50)
Race (white=0, non-white=1)	0.45(1.21)	-0.77(1.65)	0.03(0.93)	0.08(2.02)
Current Smoker (yes=1, no=0)	-2.44(1.44) ⁺	-2.43(1.97)	-0.65(1.11)	-2.97(2.42)
Physical Activity	-1.67(1.17)	-0.57(1.59)	0.71(0.89)	-0.58(1.95)
Energy Intake (kcal)	0.01(0.002)***	0.01(0.002)*	0.002(0.001)	0.01(0.003)*

NOTE: Model with fat mass (g) as dependent variable adjusted for fat free mass (g);

¹ BMI = body mass index;

⁺ p<0.10,

* p<0.05,

** p<0.01,

*** p<0.001;

Waist Circum = average of 3 measures of waist circumference.