Supplemental Methods

Breath gases

Breath hydrogen and methane concentrations were measured in triplicate following a ≥12 h overnight fast during study weeks 2 and 8. Sample collections were separated by >5 min. Expired air was collected into tubes which were then sealed and shipped to Commonwealth Laboratories (Billerica, MA) for breath gas quantification using stationary gas chromatography (QuinTron Breath Tracker SC, Milwaukee, WI) (1). Expired CO_2 was used to correct for contamination from non-alveolar air (2).

Eating behavior and food craving questionnaires

Subjective appetite was measured weekly throughout the study using visual analog scales. Measurements were obtained by having participants rate their average level of hunger, satiety, prospective consumption, and diet satisfaction over the past week on a straight, unmarked, 10 cm line anchored at either end by terms indicting opposite extremes of a spectrum (e.g., "not at all" vs. "extremely") (3). Measurements taken during study weeks 1 and 2 were averaged prior to analysis to provide baseline appetite scores.

Eating behavior and food cravings were assessed during study weeks 2 and 8 by questionnaire. Eating behaviors were assessed by the Three Factor Eating Questionnaire (4). The Three Factor Eating Questionnaire is a validated questionnaire that assesses three dimensions of eating behavior: cognitive restraint (conscious control of dietary intake), disinhibition (tendency to overeat in response to emotional and environmental cues), and hunger (feelings and perceptions of hunger). Food cravings were assessed by the Food Cravings Inventory and the Food Cravings Questionnaire-State. The reliability and validity of the Food Cravings Inventory have been previously reported (5). The questionnaire defines a craving as an intense desire to consume a particular food that is difficult to resist. Participants rated their frequency of craving each of 28 different food products over the previous two weeks on a 5-point Likert scale ranging from "never" to "always/almost every day". Four subscale (high fats, sweets, carbohydrates/sweets, and fast-food fats) scores were calculated by averaging the responses for food items within each subscale. A total score was calculated by averaging the responses for all 28 items. The reliability and validity of the Food Cravings Questionnaire-State have been previously reported (6). The questionnaire assesses the strength of food cravings at the moment of administration by asking respondents to rate their level of agreement with 15 separate statements on a 5-point Likert scale ranging from “strongly disagree” to “strongly agree”. Five subscale (intense desire to eat, anticipation of positive reinforcement, anticipation of relief from negative states and feelings, preoccupation with food and lack of control over eating, and feelings of hunger) scores were calculated by summing the responses for the three questions within each subscale.

Volunteers were instructed to maintain habitual physical activity levels throughout the study. To assess adherence to this instruction, physical activity was assessed during study weeks 2 and 8 using the International Physical Activity Questionnaire- short form (7). The International Physical Activity Questionnaire is a validated questionnaire that asks participants to estimate the average amount of time spent daily over the previous week engaged in several categories of physical activity. Responses were used to calculate total physical activity levels according to standard procedures (7).

Supplemental results

Comparison of sub-cohorts completing CGM and OGTT measurements with other study completers

Forty-one study completers opted to participate in the CGM measurement. Relative to the other study completers, this self-selected cohort had lower pre-intervention fasting glucose concentrations (5 mg/dL [95% CI: 1, 10 mg/dL] P = 0.03), but did not differ in pre-intervention fasting insulin (P = 0.86) or HOMA-IR (P = 0.53), age (P = 0.38), sex (P = 0.20), or weight change during the intervention (P = 0.42). Twenty-four study completers opted to participate in the OGTT measurements. Relative to the other study completers, this self-selected cohort had lower pre-intervention BMI (2.5 kg/m^2 [95% CI: 0.9, 4.2 kg/m^2] P = 0.003), fasting glucose (10 mg/dL [95% CI: 5, 15 mg/dL] P < 0.001), fasting insulin (2.7 µU/mL [95% CI: 0, 5.3 µU/mL] P = 0.05), and HOMA-IR (0.9 [95% CI: 0.2, 1.6] P = 0.01), but did not differ in age (P = 0.56), sex (P = 0.45), or weight change during the intervention (P = 0.32).

References

1. Braden B. Methods and functions: Breath tests. Best Pract Res Clin Gastroenterol 2009;23:337-52.
2. Niu HC, Schoeller DA, Klein PD. Improved gas chromatographic quantitation of breath hydrogen by normalization to respiratory carbon dioxide. J Lab Clin Med 1979;94:755-63.
3. Stubbs RJ, Hughes DA, Johnstone AM, Rowley E, Reid C, Elia M, Stratton R, Delargy H, King N, Blundell JE. The use of visual analogue scales to assess motivation to eat in human subjects: A review of their reliability and validity with an evaluation of new hand-held computerized systems for temporal tracking of appetite ratings. Br J Nutr 2000;84:405-15.
4. Stunkard AJ, Messick S. The Three-Factor Eating Questionnaire to measure dietary restraint, disinhibition and hunger. J Psychosom Res 1985;29:71-83.
5. White MA, Grilo CM. Psychometric properties of the Food Craving Inventory among obese patients with binge eating disorder. Eat Behav 2005;6:239-45.
6. Cepeda-Benito A, Gleaves DH, Fernandez MC, Vila J, Williams TL, Reynoso J. The development and validation of spanish versions of the state and trait Food Cravings Questionnaires. Behav Res Ther 2000;38:1125-38.
7. Hallal PC, Victora CG. Reliability and validity of the international physical activity questionnaire (IPAQ). Med Sci Sport Exerc 2004;36:556.
8. Ross AB. Present status and perspectives on the use of alkylresorcinols as biomarkers of wholegrain wheat and rye intake. J Nutr Metab 2012;2012:462967.
9. Elia M, Cummings JH. Physiological aspects of energy metabolism and gastrointestinal effects of carbohydrates. Eur J Clin Nutr 2007;61 Suppl 1:S40-74.

Supplemental Table 1. Study menus.

	Refined grain (n = 40)	**Whole grain (n = 41)**
Cycle 1[1]		
Breakfast		
	Cornflakes cereal	Whole wheat Chex cereal with added wheat bran and raisins
	Banana	Banana
	Skim milk	1% milk
Lunch		
	Tuna sandwich, white bread	Tuna sandwich, whole wheat bread
	Vanilla pudding	Vanilla pudding
	Cranberry juice	Cranberry juice
Snack		
	Saltine crackers with peanut butter	Brown rice cakes with peanut butter
Dinner		
	Turkey meatloaf with white bread crumbs	Turkey meatloaf with 100% whole wheat bread crumbs
	White flour spaghetti with sauce	100% whole grain spaghetti with sauce
	Mixed vegetables	Mixed vegetables
	Shortbread cookies	100% whole wheat fig newtons
Cycle 2		
Breakfast		
	Banana-orange muffin (white flour)	100% whole wheat muffin
	Butter, strawberry jam	Butter, grape jelly
	Skim milk	Skim milk
		Peach slices
Lunch		
	Chicken vegetable stir-fry	Chicken vegetable stir-fry
	White flour spaghetti	100% whole wheat spaghetti
	Vanilla wafer cookie with peaches	Nature Valley granola bar
Snack		
	Mozzarella cheese stick	Mozzarella cheese stick
	Pretzels	Apple
	Light cranberry juice and ginger ale	
Dinner		
	Orzo pasta with cucumber salad	Whole grain couscous and cucumber salad
	Hamburger, white bun	Hamburger, 100% whole wheat bun
	Ketchup, caramelized onions	Ketchup, caramelized onions
	Roasted potatoes	Roasted potatoes
	Applesauce	Peach dessert with wheat bran topping
Cycle 3		
Breakfast	Waffles with maple syrup	100% whole wheat waffles with maple syrup and butter

	Scrambled eggs	Boiled egg
	Skim milk	Skim milk
Lunch		
	Grilled vegetable Panini with cheese on white bread	Grilled vegetable Panini with cheese on 100% whole wheat bread
	Iceberg lettuce with Italian dressing	Vanilla pudding
Snack		
	Pita chips with tomato salsa	100% whole wheat pita chips with tomato salsa
Dinner		
	Turkey chili	Turkey chili
	White flour tortilla	100% whole wheat tortilla
	White rice	Brown rice
	Ginger ale	Ginger ale

[1]Study intervention diets were provided on a 3-day cycle menu for 6 wk.

Supplemental Table 2. Study outcomes measured before and following 6-wk consumption of a refined grain-based or whole grain-rich diet in participants adherent to the diets[1].

	Refined Grain			Whole Grain				P-value[2]		
	n	Week 2[3]	ΔWeek 2-8 [95% CI]	n	Week 2[3]	ΔWeek 2-8 [95% CI]	β ± SE[4]	Model 1	Model 2	Model 3
Anthropometrics and resting metabolism										
Body weight (kg)	35	75.8 ± 11.1	-0.7 [-1.3, -0.1]	30	72.2 ± 11.2	-0.1 [-0.7, 0.4]	0.5 ± 0.4	0.19	0.16	-
Body fat (%)	35	30.2 ± 8.5	-1.0 [-1.8, -0.2]	30	29.9 ± 9.0	-0.1 [-1.0, 0.7]	0.9 ± 0.6	0.13	0.13	0.36
Fat mass (kg)	35	22.8 ± 6.9	-0.9 [-1.6, -0.3]	30	21.8 ± 8.3	-0.1 [-0.8, 0.6]	0.8 ± 0.5	0.09	0.10	0.37
Fat free mass (kg)	35	53.0 ± 10.5	0.2 [-0.2, 0.7]	30	50.4 ± 9.6	0.0 [-0.6, 0.6]	-0.2 ± 0.4	0.57	0.48	0.31
WC (cm)	34	89.6 ± 10.3	-0.7 [-1.4, 0.1]	30	87.3 ± 10.4	-0.3 [-1.0, 0.5]	-0.3 ± 0.5	0.51	0.47	0.95
Waist-to-hip ratio	34	0.9 ± 0.1	0.0 [-0.01, 0.01]	30	0.9 ± 0.1	0.0 [-0.01, 0.01]	0.0 ± 0.01	0.52	0.36	0.44
RMR (kcal/d)	33	1434 ± 261	-16 [-53, 20]	29	1370 ± 248	29 [-20, 78]	35 ± 28	0.22	0.23	0.28
Adjusted RMR (kcal/d)[5]	33	1412 ± 126	-22 [-57, 12]	29	1423 ± 131	8 [-43, 58]	34 ± 26	0.18	-	-
RQ	33	0.84 ± 0.05	0.01 [-0.01, 0.03]	29	0.82 ± 0.04	0.01 [-0.01, 0.03]	-0.02 ± 0.01	0.12	0.11	0.05
Stool characteristics										
Stool weight (g wet wt/d)	34	90 (85)	-11 [-29, 7]	30	93 (102)	69 [43, 94]	86 ± 14	<0.0001	<0.0001	<0.0001
Stool energy density (kcal/g dry wt)	34	5.1 ± 0.3	-0.04 [-0.15, 0.07]	30	5.1 ± 0.3	-0.15 [-0.26, -0.05]	-0.12 ± 0.06	0.06	0.09	0.08
Total stool energy (kcal/d)	34	141 (102)	-27 [-52, -2]	30	149 (130)	70 [26, 115]	108 ± 21	<0.0001	<0.0001	<0.0001

Fiber-adjusted total stool energy (kcal/d)[6]	34	97 (104)	-27 [-51, -3]	30	108 (124)	31 [-14, 75]	70 ± 20	0.001	0.001	0.002
Fasting glucose and insulin										
Glucose (mg/dL)	35	90 ± 11	0.4 [-3, 5]	30	91 ± 9	-3 [-5, 0]	-2.9 ± 2.5	0.24	0.36	0.39
Insulin (µU/mL)	35	9.6 (6.4)	-0.3 [-1.6, 0.9]	30	7.7 (4.5)	-0.9 [-2.3, 0.5]	-1.0 ± 0.7	0.18	0.13	0.12
HOMA-IR	35	2.3 (1.5)	-0.1 [-0.5, 0.3]	30	1.7 (1.3)	-0.3 [-0.7, 0.1]	-0.3 ± 0.2	0.16	0.15	0.14
QUICKI	35	0.35 ± 0.04	0 [-0.01, 0.01]	30	0.35 ± 0.03	0.01 [-0.00, 0.01]	0.01 ± 0.01	0.21	0.24	0.22
Oral glucose tolerance test										
Glucose AUC (min*mg/dL)	12	15023 ± 3781	495 [-859, 1849]	6	13662 ± 1510	-1028 [-2831, 776]	-2046 ± 832	0.03	0.03	0.04
Insulin AUC (min*mg/dL)	12	5939 ± 2762	-686 [-1785, 414]	6	5495 ± 2668	936 [-1494, 3366]	1550 ± 1006	0.14	0.57	0.38
Matsuda index	12	6.7 ± 3.2	0.2 [-0.8, 1.3]	6	8.1 ± 4.0	-0.7 [-3.8, 2.4]	-0.4 ± 0.9	0.64	0.98	0.86
24-hr continuous glucose monitoring										
24-hr mean (mg/dL)	16	98 ± 10	1 [-3, 6]	13	98 ± 7	3 [-6, 12]	1.7 ± 4.4	0.70	0.63	0.71
24-hr CV (%)	16	12.2 (9.8)	1.0 [-2.8, 4.8]	13	13.0 (5.5)	0.2 [-5.4, 5.8]	1.1 ± 2.1	0.61	0.59	0.70
24-hr SD (mg/dL)	16	11.7 (11.2)	1.4 [-2.7, 5.4]	13	13.9 (6.2)	1.0 [-4.0, 6.0]	0.8 ± 2.6	0.77	0.70	0.82
AUC (hr*mg/dL)	16	2357 ± 241	26 [-87, 138]	13	2341 ± 169	74 [-151, 299]	41 ± 106	0.70	0.64	0.71

[1]Diet non-adherence was defined as total plasma alkylresorcinol concentrations ≥ 95 nmol/L following the run-in diet (weeks 1 and 2), or < 95 nmol/L (whole grain only) and ≥ 65 nmol/L (refined grain only) following the intervention (8).

[2]ANCOVA, Model 1 adjusted for baseline value of outcome; model 2 adjusted as in model 1 + age, sex, and baseline BMI; model 3 adjusted as in model 2 + weight change.
[3]Values are mean ± SD or median (IQR). No statistically significant differences during Week 2.
[4]β values obtained from Model 1 with Refined Grain as the reference group.
[5]Adjusted for age, sex, fat mass and fat free mass using the residual method.
[6]Calculated as total stool energy – total fiber intake * 2.2 kcal/g. 2.2 kcal/g is the average non-metabolizable energy in fiber (9).
RMR, resting metabolic rate; QUICKI, quantitative insulin sensitivity check index; RQ, respiratory quotient; WC, waist circumference.

Supplemental Table 3. Breath hydrogen and methane concentrations before and following 6-wk consumption of a refined grain-based or whole grain-rich diet[1].

	Refined Grain			Whole Grain				P-value[1]		
	n	**Week 2**[2]	**ΔWeek 2-8 [95% CI]**	**n**	**Week 2**[2]	**ΔWeek 2-8 [95% CI]**	**β ± SE**[3]	**Model 1**	**Model 2**	**Model 3**
Breath H_2 (ppm)	40	3 (8)	4 [-1, 9]	40	8 (11)	0 [-5, 5]	-2 ± 3	0.43	0.48	0.38
Breath CH_4 (ppm)	40	0 (34)	-4 [-12, 4]	40	0 (14)	-1 [-6, 4]	0 ± 4	0.93	0.93	0.79

[1]ANCOVA, Model 1 adjusted for baseline value of outcome; model 2 adjusted as in model 1 + age, sex, and baseline BMI; model 3 adjusted as in model 2 + weight change.
[2]Values are median (IQR). No statistically significant differences during Week 2.
[3]β values obtained from Model 1 with Refined Grain as the reference group.

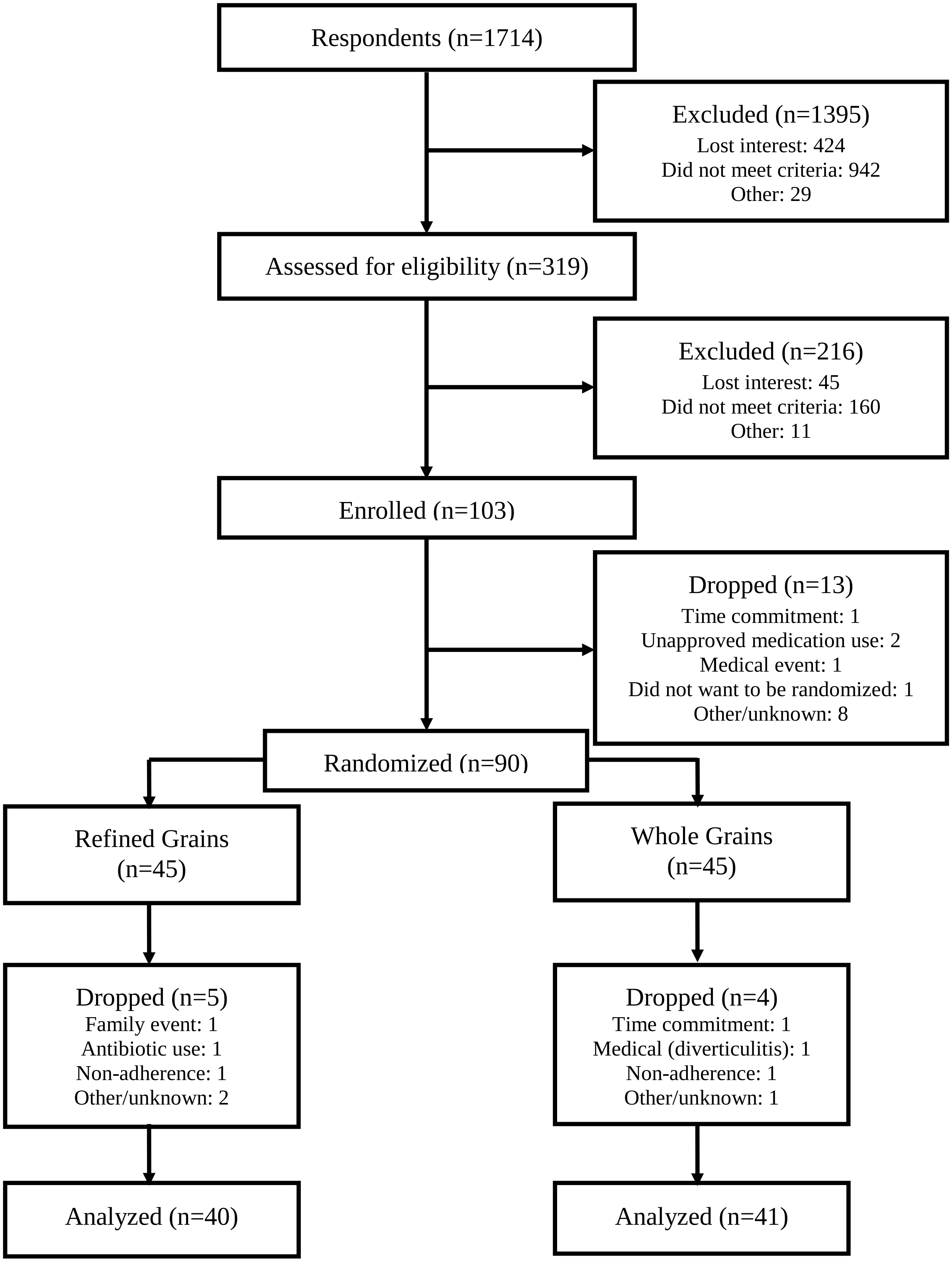
Supplemental Table 4. Food cravings and eating behavior questionnaire responses before and following 6-wk consumption of a refined grain-based or whole grain-rich diet[1].

	Refined Grain			Whole Grain				P-value[1]		
	n	Week 2[2]	ΔWeek 2-8 [95% CI]	n	Week 2[2]	ΔWeek 2-8 [95% CI]	β ± SE[3]	Model 1	Model 2	Model 3
Food Cravings-State (score range)										
Intense desire to eat (3-15)	40	7.7 ± 3.9	0.7 [-0.3, 1.7]	41	7.1 ± 3.3	0.9 [-0.2, 2.0]	-0.1 ± 0.7	0.89	0.99	0.74
Pos reinforcement (3-15)	40	6.6 ± 3.0	0.7 [-0.2, 1.7]	41	7.2 ± 2.9	0.7 [-0.4, 1.9]	0.3 ± 0.6	0.61	0.56	0.48
Relief from neg state (3-15)	40	6.2 ± 3.0	0.8 [-0.1, 1.7]	41	6.9 ± 2.7	0.4 [-0.6, 1.5]	0.04 ± 0.6	0.94	0.77	0.77
Lack of control (3-15)	40	5.3 ± 2.1	0.0 [-0.9, 0.8]	41	4.8 ± 2.1	1.0 [0.3, 1.8]	0.8 ± 0.52	0.12	0.07	0.09
Hunger (3-15)	40	7.8 ± 3.1	1.0 [-0.1, 2.0]	41	8.2 ± 3.4	1.1 [-0.1, 2.3]	0.4 ± 0.6	0.54	0.38	0.31
Total score (15-75)	40	33.7 ± 12.8	3.2 [-0.5, 6.9]	41	34.3 ± 11.4	4.2 [1.0, 8.3]	1.3 ± 2.3	0.55	0.39	0.32
Food Cravings Inventory (score range)										
High fat foods (1-5)	40	1.5 ± 0.6	0.03 [-0.1, 0.2]	41	1.6 ± 0.6	0.1 [-0.0, 0.3]	0.1 ± 0.1	0.23	0.13	0.15
Sweets (1-5)	40	1.7 ± 0.7	0.1 [-0.1, 0.3]	41	1.8 ± 0.8	0.1 [-0.0, 0.3]	0.02 ± 0.1	0.84	0.79	0.70
Starches (1-5)	40	1.7 ± 0.7	-0.1 [-0.3, 0.1]	41	1.6 ± 0.7	0.1 [-0.1, 0.2]	0.2 ± 0.1	0.12	0.13	0.19
Fast-food fats (1-5)	40	1.9 ± 0.8	-0.1 [-0.3, 0.1]	41	1.9 ± 0.8	0.1 [-0.1, 0.2]	0.2 ± 0.1	0.24	0.18	0.20
Total (1-5)	40	1.7 ± 0.6	0 [-0.2, 0.2]	41	1.7 ± 0.7	0.1 [-0.0, 0.2]	0.1 ± 0.1	0.24	0.19	0.21
Three-Factor Eating Questionnaire										

(score range)										
Hunger (0-14)	38	2.2 ± 2.2	0.7 [0.03, 1.4]	38	2.7 ± 2.4	0.1 [-0.6, 0.8]	-0.5 ± 0.5	0.33	0.49	0.55
Disinhibition (0-16)	38	9.9 ± 4.8	-0.3 [-1.2, 0.6]	38	9.7 ± 4.4	0.2 [-1.1, 1.5]	-0.4 ± 0.8	0.61	0.59	0.53
Restraint (0-21)	38	3.0 ± 2.2	0.5 [-0.04, 1.0]	38	3.3 ± 2.7	0.5 [-0.2, 1.2]	0.1 ± 0.4	0.90	0.72	0.65

[1]ANCOVA, Model 1 adjusted for baseline value of outcome; model 2 adjusted as in model 1 + age, sex, and baseline BMI; model 3 adjusted as in model 2 + weight change.
[2]Values are mean ± SD. No statistically significant differences during Week 2.
[3]β values obtained from Model 1 with Refined Grain as the reference group.

Supplemental Figure 1. CONSORT diagram.



Supplemental Figure 2. Weekly self-reported ratings of A) hunger, B) fullness C) satisfaction with the amount of food consumed, and D) satisfaction with the type of food consumed while consuming a refined grain-based diet (n=40) or a whole grain-rich diet (n=41) for 6 wk. Values are mean ± SEM. Main and interactive effects of time and diet were examined using marginal models with unstructured covariance structure. Covariates in the model were the mean of ratings measured during the run-in phase (weeks 1 and 2), age, BMI, sex and weight change during the 6-wk intervention.