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Consumption of whole grains is associated with improved diet quality and nutrient intake in children and adolescents: the National Health and Nutrition Examination Survey 1999–2004

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Abstract

Objective: To examine the association of consumption of whole grains (WG) with diet quality and nutrient intake in children and adolescents.
Design: Secondary analysis of cross-sectional data.
Setting: The 1999–2004 National Health and Nutrition Examination Survey.
Subjects: Children aged 2–5 years (*n* 2278) and 6–12 years (*n* 3868) and adolescents aged 13–18 years (*n* 4931). The participants were divided into four WG consumption groups: ≥0 to <0·6, ≥0·6 to <1·5, ≥1·5 to <3·0 and ≥3·0 servings/d. Nutrient intake and diet quality, using the Healthy Eating Index (HEI)-2005, were determined for each group from a single 24 h dietary recall.
Results: The mean number of servings of WG consumed was 0·45, 0·59 and 0·63 for children/adolescents at the age of 2–5, 6–12 and 13–18 years, respectively. In all groups, HEI and intakes of energy, fibre, vitamin B_6, folate, magnesium, phosphorus and iron were significantly higher in those consuming ≥3·0 servings of WG/d; intakes of protein, total fat, SFA and MUFA and cholesterol levels were lower. Intakes of PUFA (6–12 years), vitamins B_1 (2–5 and 13–18 years), B_2 (13–18 years), A (2–5 and 13–18 years) and E (13–18 years) were higher in those groups consuming ≥3·0 servings of WG/d; intakes of added sugars (2–5 years), vitamin C (2–5 and 6–12 years), potassium and sodium (6–12 years) were lower.
Conclusions: Overall consumption of WG was low. Children and adolescents who consumed the most servings of WG had better diet quality and nutrient intake.

Keywords
Whole grains
Nutrients
Nutrient adequacy
Children
Adolescents
Diet quality
Healthy Eating Index
NHANES

In the USA, the most commonly consumed grains are wheat, oats, rice, maize and barley, with wheat comprising 66–75 % of the total[1,2]. Whole grains (WG) are defined as cereal grains that are intact, or ground or cracked fruit with the endosperm, germ and bran present in the same relative proportions as the intact grain[3,4]. Endosperm (65–75 %) is composed of starch, NSP and small amounts of protein and lipids. Germ (4–17 %) is a rich source of proteins, lipids, B vitamins and vitamin E. Bran contains dietary fibre; protein; B vitamins, including thiamin, niacin, riboflavin and pantothenic acid; and minerals, including calcium, magnesium and potassium[1,2,5,6]. WG also have other health-protective compounds, including flavonoids, lignans, resistant starches and phenols. During processing, the majority of the nutritive value of WG is preserved[2].

Consumption of WG, unlike that of refined grains, is associated with a lower risk of CVD and stroke[7,8], hypertension[8,9], type 2 diabetes[10] metabolic syndrome[11], obesity[12] and some cancers[13,14]. The mechanisms of these beneficial effects are not clear and the components of WG may act synergistically[1,15]. Most of these studies have been conducted in adults and little information is available for children or adolescents.

The 2005 Dietary Guidelines Advisory Committee recommended that at least half of the number of recommended grain servings be WG[16]. Thus, the WG recommendation for children varies; children as young as 2 years need only 1·5 servings (ounce equivalents), whereas children at the age of 9 years and above need 3 servings/d[16,17]. These recommendations are supported by the American Academy of Pediatrics[18].

Intake of WG in children and adolescents is not well documented, but studies conducted before the release of the 2005 Dietary Guidelines for Americans (DGA) suggested that consumption was low. Using data from the 1989–1991 and 1994–1996 Continuing Survey of Food Intakes by Individuals (CSFII), it was shown that children and adolescents at the age of 2–19 years consumed a daily

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average of 0·9 servings of WG in 1989–1991 and 1·0 serving in 1994–1996[19]. In all, 7 % and 9 % of children, respectively, consumed three servings of WG during the time frame of the study[19]. Low intake of WG was confirmed in another study using the CSFII data[20] and with data from the 1999–2002 National Health and Nutrition Examination Survey (NHANES). Data from the NHANES showed that children and adolescents at the age of 6–19 years consumed only 0·8–1·0 mean servings of WG/d[21]. A smaller regional study of adolescents showed a slightly higher intake with female adolescents consuming 1·3 servings and male adolescents consuming 1·4 servings of WG/d[11].

Determining WG consumption has been difficult since the definition of WG has been unclear. The vast majority of studies[22] that have assessed WG intake were not based on the current definition of WG, but on the classification scheme proposed by Jacobs *et al.*[23] in 1998, with WG defined as foods containing ≥25 % WG or bran by weight. The current definition of WG was adopted by the Food and Drug Administration (FDA) in 2006[4]. Currently, the FDA allows health claims for WG foods that contain ≥51 % WG ingredient(s) by weight per reference amount customarily consumed[24]. The new FDA definition excludes bran and pearled barley as WG[24]. The US Department of Agriculture (USDA) MyPyramid Equivalents Database (MPED) versions 1[25] and 2[26] provides quantified measures of WG foods, and it provides information with and without bran (old and new definitions) respectively.

There are no recent studies using nationally representative data looking at the consumption of WG or the relationship of WG consumption with diet quality and nutrient intake of children and adolescents. The purpose of the present study was to examine the association of WG consumption, using the FDA definition of WG, with diet quality and nutrient intake in a recent, nationally representative sample of children and adolescents.

Methods

NHANES is a continuous programme that collects information about the nutrition and health status of the US population using a complex, multi-stage, stratified probability sample of the non-institutionalized civilian US population, aged 2 years and above[27]. As recommended, the NHANES data sets from 1999–2000, 2001–2002 and 2003–2004 were concatenated[28].

Dietary assessment method

For data collection years, 1999–2002, a single multiple-pass 24 h dietary recall was conducted during an interview using computer-assisted software to record dietary intake data[29]. In 2003–2004, 2 d intakes were collected; however, for the present study, only the first day interview-administered recalls were used to assure consistency with the 1999–2002 dietary data. Parents of children 2–5 years of age provided the recalls; children (6–11 years) were assisted by an adult; and older children and adolescents (12–18 years) provided their own recall. Descriptions of these methods are provided in the NHANES Dietary Interviewer's Procedures Manual[30].

Participants and whole grains consumption categories

NHANES data collected from 1999 to 2004 were used to compare diet quality and nutrient intake of children at the age of 2–5 years (*n* 2278), 6–12 years (*n* 3868) and adolescents at the age of 13–18 years (*n* 4931). Pregnant and lactating female adolescents were excluded. In addition, there were six foods, principally breakfast cereals or bars, introduced in 2003 that could contain WG; however, there was no information available to calculate their WG content and the individuals (*n* 11) who consumed at least one of these products were also excluded. As this was a secondary data analysis with no personal identifiers, the present study was exempted by the Institutional Review Board of the LSU AgCenter.

The participants were categorized into one of four WG consumption categories: ≥0 to <0·6, ≥0·6 to <1·5, ≥1·5 to <3·0 and ≥3·0 servings/d. This categorization was chosen since the recommendation for most children and adolescents is 3 servings/d; 1·5 servings represents one-half of the recommendation; and the average number of servings was approximately 0·6 servings. WG intake was calculated using the new definition for WG (excluding bran) as outlined by the MPED[25,26]. The MPED food data files contain the number of MyPyramid equivalents/100 g of food by thirty-two MyPyramid food groups.

Nutrient analysis

The USDA 1994–98 Survey Nutrient Database[31] was used to process the dietary interview data in NHANES 1999–2000, whereas the USDA Food and Nutrient Database for Dietary Studies (FNDDS), versions 1[32] and 2[33], were used in NHANES 2001–2002 and 2003–2004, respectively. In the original release of NHANES 1999–2000, data on vitamin A intake were only available in μg retinol equivalents (μg RE), vitamin E intake data were only available in mg α-tocopherol equivalents (mg ATE), only total folate (μg) intake data, and no vitamin K (μg) or sugar (g) intake data were available as well. Currently, Dietary Reference Intakes (DRI) for vitamins A and E and folate are expressed as μg RAE, mg AT and dietary folate equivalents (DFE), respectively[34,35]. The special database released by the USDA to determine vitamin A as μg RAE and vitamin E as mg AT was used[36]. The FNDDS was used to append the intake of folate (DFE), vitamin K (μg) and total sugars (g) to the NHANES 1999–2000 database. The food composition data of added sugars were obtained from the MPED for USDA Survey Food Codes version 1·0[25].

The Healthy Eating Index (HEI)-2005 score was used to determine the diet quality[37]. The HEI contains twelve food

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components that reflect the recommendations of the DGA 2005. Dietary intake is expressed per 4184 kJ (1000 kcal) for all components except SFA and sodium, which are fixed recommendations. The maximum possible score on the index is 100. The first six components (i.e. total fruit, whole fruit, total vegetable, dark green/orange vegetables and legumes, total grain and WG) are scored from 0 to 5 points. The next five components (i.e. milk, meat and beans, oil, SFA and sodium) are scored from 0 to 10 points; and the last component of solid fat, alcohol and added sugar is scored from 0 to 20 points. Scores were calculated proportionally, except for SFA and sodium; for these components, the scores were pro-rated linearly between 0–8 and 8–10 points (8 and 10 points represented acceptable and optimal levels, respectively)[37]. To calculate HEI, 'discretionary solid fat' and 'discretionary oil' were needed. The MPED (version 2) only provides 'Total Discretionary Fats' as a single group. To overcome this problem, a ratio of 'Discretionary Oil to Discretionary Solid Fat' was created for each food using the MPED (version 1), which had these fats separated. The SAS code used to calculate HEI scores was downloaded from the Center for Nutrition Policy and Promotion website[38].

Statistical analysis

Sample-weighted data were used in all statistical analyses, and all analyses were performed using SUDAAN Release 9·0·1 (Research Triangle Institute, Research Triangle Park, NC, USA) using a modified 6-year weight sample. A 6-year weight variable was created by assigning two-thirds of the 4-year weight for 1999–2002 if the person was sampled in 1999–2002 or assigning one-third of the 2-year weight for 2003–2004 if the person was sampled in 2003–2004. The unadjusted mean WG intake and counts and percentages of children and adolescents in WG consumption groups were calculated using SUDAAN. Nutrient intake was based on all foods consumed. Least-squares mean diet quality (HEI), total energy intake and macro- and micronutrient intakes were obtained by regressing intake variables on WG consumption groups. The models were adjusted for age, gender, ethnicity and total energy (kJ (kcal)). *P* for trend was calculated using SUDAAN with WG intake as a linear independent variable in place of the WG categories. A probability of ≤0·05 was considered significant.

Results

Servings of the whole grains consumed by children and adolescents

Table 1 shows the mean number of WG consumed by each of the three age groups. Children aged 2–5 years consumed an average of 0·45 servings of WG/d, whereas children aged 6–12 years and adolescents of 13–18 years of age consumed 0·59 and 0·63 servings, respectively. Only 1·49 %, 4·00 % and 4·34 % of children aged 2–5, 6–12 years and adolescents aged 13–18 years, respectively, consumed ≥3 servings of WG/d.

Table 1 Mean number of servings of WG consumed and number (%) of consumers for the three age groups by WG consumption group

	2–5 years (*n* 2278)		6–12 years (*n* 3868)		13–18 years (*n* 4931)	
WG servings	*n*	%	*n*	%	*n*	%
Mean	0·45		0·59		0·63	
≥3	34	1·5	153	4·0	214	4·3
≥1·5 to <3·0	156	6·9	328	8·5	477	9·7
≥0·6 to <1·5	542	23·8	712	18·4	814	16·5
≥0 to <0·6	1546	67·9	2675	69·2	3426	69·5

WG, whole grains.

Healthy Eating Index, energy and nutrient intakes for children aged 2–5 years

HEI scores were significantly higher when more servings of WG were consumed ($P<0·001$; Table 2). Intakes of energy ($P<0·001$), carbohydrates ($P<0·001$), fibre ($P<0·001$), vitamins A ($P=0·05$), B_1 ($P=0·04$) and B_6 ($P<0·001$), folate ($P<0·001$), magnesium ($P<0·001$), phosphorus ($P=0·0015$) and iron ($P<0·001$) were significantly higher when an increased number of servings of WG was consumed. Intakes of protein ($P=0·05$), added sugars ($P=0·04$), total fat ($P=0·01$), SFA ($P<0·001$), MUFA ($P<0·001$), cholesterol ($P<0·001$) and vitamin C ($P=0·01$) were significantly lower when an increased number of servings of WG was consumed.

Healthy Eating Index, energy and nutrient intakes for children aged 6–12 years

HEI scores were significantly higher when an increased number of servings of WG was consumed ($P<0·001$; Table 3). Energy ($P<0·001$), carbohydrates ($P<0·001$), fibre ($P<0·001$), PUFA ($P=0·01$), vitamin B_6 ($P=0·0037$), folate ($P=0·04$), magnesium ($P<0·001$), phosphorus ($P<0·001$) and iron ($P<0·001$) intakes were higher when more servings of WG were consumed. Intakes of protein ($P=0·01$), total fat ($P=0·05$), SFA ($P<0·001$), MUFA ($P=0·01$), cholesterol ($P<0·001$), vitamin C ($P<0·001$), potassium ($P=0·05$) and sodium ($P=0·05$) were lower when more servings of WG were consumed.

Healthy Eating Index, energy and nutrient intakes for adolescents aged 13–18 years

HEI scores were significantly higher when more servings of WG were consumed ($P<0·001$; Table 4). Energy ($P<0·001$), carbohydrates ($P<0·001$), fibre ($P<0·001$), vitamins A ($P=0·04$), E ($P=0·03$), B_1 ($P=0·03$), B_2 ($P<0·001$) and B_6 ($P<0·001$), folate ($P<0·001$), magnesium ($P<0·001$), phosphorus ($P=0·03$) and iron ($P<0·001$) intakes were significantly higher when more servings of WG were consumed. Intakes of protein ($P<0·001$), total fat ($P<0·001$), SFA ($P<0·001$), MUFA

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Table 2 Diet quality, daily total energy and nutrient intakes by WG consumption groups, US children aged 2–5 years, NHANES 1999–2004*

	Total population (*n* 2278)		WG consumption group (servings/d) ≥0 to <0·6 (*n* 1546)		≥0·6 to <1·5 (*n* 542)		≥1·5 to <3·0 (*n* 156)		≥3 (*n* 34)		
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	*P* for trend
WG servings†	0·48	0·02	0·14	0·01	0·96	0·02	1·97	0·04	3·82	0·20	<0·001
HEI	52·98	0·33	51·69	0·38	56·02	0·77	57·41	1·30	57·50	2·46	<0·001
Energy (kcal)	1659·56	15·24	1621·10	17·87	1730·09	37·18	1806·80	53·30	1945·19	85·22	<0·001
Energy (kJ)	6948·25	63·81	6787·22	74·82	7243·54	155·67	7564·71	223·16	8144·12	356·8	<0·001
Protein (g)	56·37	0·38	56·57	0·45	56·10	0·86	55·97	1·90	52·51	2·11	0·05
Carbohydrate (g)	230·49	1·05	228·18	1·23	235·53	2·39	237·18	5·21	247·67	9·19	<0·001
Fibre (g)	10·65	0·11	9·91	0·12	11·94	0·27	13·79	0·51	15·79	0·79	<0·001
Total sugars (g)	124·65	0·99	125·29	1·19	124·38	2·30	121·38	4·21	113·98	9·49	0·24
Added sugars (g)	16·06	0·25	16·33	0·30	15·94	0·59	13·77	1·20	14·96	2·36	0·04
Total fat (g)	59·42	0·38	60·18	0·44	57·61	0·88	57·41	1·90	54·58	3·93	0·01
SFA (g)	22·04	0·19	22·41	0·22	21·43	0·44	20·57	0·82	18·62	1·83	<0·001
MUFA (g)	22·10	0·17	22·52	0·20	21·13	0·38	20·88	0·72	19·66	1·65	<0·001
PUFA (g)	10·53	0·11	10·46	0·13	10·35	0·25	11·43	0·53	12·08	1·24	0·14
Cholesterol (mg)	185·70	3·25	191·68	3·70	173·63	8·10	160·34	15·57	162·01	27·51	<0·001
Vitamin A (μg RAE)	605·14	13·62	592·77	16·29	626·24	32·76	679·05	58·59	612·70	103·04	0·05
Vitamin C (mg)	96·04	2·08	98·22	2·52	92·80	5·04	84·38	6·43	84·52	16·15	0·01
Vitamin E (mg AT)	4·79	0·08	4·72	0·09	5·18	0·27	4·66	0·19	4·34	0·41	0·78
Vitamin B_1 (mg)	1·33	0·01	1·31	0·01	1·41	0·03	1·33	0·04	1·45	0·13	0·04
Vitamin B_2 (mg)	1·98	0·02	1·96	0·02	2·04	0·04	2·02	0·08	1·96	0·16	0·18
Vitamin B_6 (mg)	1·44	0·02	1·40	0·02	1·53	0·04	1·59	0·07	1·67	0·21	<0·001
Vitamin B_{12} (μg)	4·28	0·08	4·29	0·10	4·41	0·24	4·08	0·28	3·20	0·41	0·07
Niacin (mg)	15·84	0·16	15·60	0·17	16·50	0·37	16·08	0·72	18·26	2·51	0·09
Folate (μg)	317·38	4·19	305·64	4·42	350·97	10·78	342·94	25·55	354·76	38·58	<0·001
Calcium (mg)	929·73	11·08	923·21	13·41	941·03	23·88	991·23	47·54	846·78	66·24	0·23
Magnesium (mg)	200·92	1·41	192·32	1·55	214·14	3·06	240·41	6·80	266·01	13·96	<0·001
Potassium (mg)	2128·61	16·17	2130·98	19·21	2119·29	36·31	2212·44	72·69	1811·32	110·47	0·35
Phosphorus (mg)	1091·00	8·31	1075·74	9·85	1119·00	18·27	1173·63	40·12	1112·58	44·07	0·0015
Iron (mg)	12·38	0·14	11·69	0·13	13·72	0·37	14·62	0·83	18·04	2·62	<0·001
Sodium (mg)	2457·35	19·15	2471·26	23·05	2452·54	45·03	2400·94	76·13	2155·36	123·03	0·06

WG, whole grains; NHANES, National Health and Nutrition Examination Survey; HEI, Healthy Eating Index; RAE, retinol activity equivalents; AT, α-tocopherol.
*Estimates were adjusted for age, gender, ethnicity and total energy intake. Models for total energy did not include total energy intake.
†WG was defined according to the new definition that excludes bran.

($P = 0·05$) and cholesterol ($P < 0·001$) were significantly lower when more servings of WG were consumed.

Discussion

The present study showed that although the overall consumption of WG was low, increasing consumption of WG was associated with improved diet quality and nutrient intake in children and adolescents. The number of servings increased slightly in each of the age groups, suggesting that older children and adolescents were more likely to consume WG than younger ones. In children aged 2–5 years, only 1·5% consumed three or more servings of WG/d; in this age group the consumption of 1·5–2·99 servings, which more closely matches the recommendations[17], was approximately 7%. The number of WG servings consumed by children and adolescents in the present study was lower than previously reported[19–21], but this is likely the result of the definition of WG used. When the current definition of WG was used[26,27], there were fewer servings consumed than when the older definition was used (data not shown).

The low consumption of WG by adults is a reason for children not consuming WG[8,12,39–41]. Interestingly, adults living with children in the household consumed fewer servings of WG than those who did not[40]. Thus, WG foods are not available to children. Parents influence what children eat by determining home food availability and accessibility[42–44]; parenting style or practices[45,46], role modelling[44,47,48] and the level to which they are influenced by their children's food preferences[49] affect what foods are consumed. Adolescents show increasing control over their food choices[50]. For adolescents, some[50], but not all studies[44,51] suggest home availability and parenting style are less important than in younger children. Taste and personal health beliefs are important influences on an adolescent's choice of foods[51]. Influences on consumption of WG in children and adolescents are understudied[47,49].

Little is known about barriers to WG consumption in children, but taste, texture and appearance were important in one study, with children preferring refined, sweetened grain products[49]. Younger children did not cite health as a reason for consuming WG and they were unable to identify WG foods, whereas older children could identify them and relate some of their health benefits[49].

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Table 3 Diet quality, daily total energy and nutrient intakes by WG consumption groups, US children aged 6–12 years, NHANES 1999–2004*

	Total population (*n* 3868)		WG consumption group (servings/d) ≥0 to <0·6 (*n* 2675)		≥0·6 to <1·5 (*n* 712)		≥1·5 to <3·0 (*n* 328)		≥3 (*n* 153)		
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	*P* for trend
WG servings†	0·65	0·02	0·12	0·01	0·99	0·01	2·02	0·03	4·31	0·12	
HEI	49·33	0·29	47·64	0·35	51·61	0·66	53·89	0·99	56·23	1·31	<0·001
Energy (kcal)	2041·36	17·52	1955·30	22·07	2124·35	38·58	2259·31	50·47	2546·66	77·53	<0·001
Energy (kJ)	8546·77	73·35	8186·45	92·40	8894·23	161·53	9459·28	211·31	10 662·36	324·60	<0·001
Protein (g)	68·02	0·44	68·88	0·55	67·54	1·18	64·05	1·46	65·04	2·32	0·01
Carbohydrate (g)	280·42	1·04	277·00	1·26	284·66	2·57	291·97	3·34	291·44	6·24	<0·001
Fibre	12·60	0·12	11·77	0·14	13·03	0·25	15·18	0·47	17·98	0·63	<0·001
Total sugars	144·62	1·09	144·98	1·37	144·85	2·46	148·67	3·68	130·88	6·29	0·16
Added sugars	23·97	0·28	24·15	0·34	23·82	0·65	24·48	1·06	21·00	1·61	0·17
Total fat (g)	74·77	0·38	75·58	0·48	73·33	0·88	72·55	1·23	72·87	2·41	0·05
SFA (g)	26·55	0·18	27·18	0·21	25·53	0·44	25·27	0·55	23·72	1·08	<0·001
MUFA (g)	28·28	0·17	28·65	0·22	28·00	0·38	27·06	0·51	26·41	1·05	0·01
PUFA (g)	14·15	0·14	13·91	0·18	14·02	0·30	14·66	0·56	17·22	0·91	0·01
Cholesterol (mg)	220·97	3·51	235·00	4·88	202·08	5·36	177·58	11·08	173·72	14·97	<0·001
Vitamin A (μg RAE)	660·90	11·56	662·69	14·19	641·53	23·47	666·19	36·40	698·42	76·82	0·56
Vitamin C (mg)	82·60	1·65	84·23	2·05	83·56	3·90	81·70	6·83	57·40	5·42	<0·001
Vitamin E (mg AT)	6·15	0·08	6·06	0·09	6·09	0·19	6·73	0·41	6·64	0·43	0·14
Vitamin B_1 (mg)	1·60	0·01	1·57	0·01	1·64	0·03	1·66	0·06	1·64	0·08	0·10
Vitamin B_2 (mg)	2·13	0·02	2·10	0·02	2·21	0·05	2·23	0·06	2·21	0·11	0·07
Vitamin B_6 (mg)	1·62	0·02	1·57	0·02	1·71	0·04	1·72	0·07	1·78	0·10	0·004
Vitamin B_{12} (μg)	4·70	0·08	4·75	0·11	4·67	0·14	4·64	0·32	4·20	0·34	0·18
Niacin (mg)	20·03	0·17	19·86	0·20	20·71	0·42	19·83	0·68	20·26	1·01	0·42
Folate (μg)	376·09	4·96	361·02	4·21	402·26	15·12	423·12	23·80	403·72	45·77	0·04
Calcium (mg)	957·29	9·86	950·69	11·72	967·00	28·19	1004·49	34·05	925·92	55·01	0·91
Magnesium (mg)	223·23	1·49	212·24	1·70	230·28	3·52	257·15	5·79	289·64	8·52	<0·001
Potassium (mg)	2211·77	16·79	2233·41	21·45	2175·33	40·60	2183·95	56·97	2092·61	86·34	0·05
Phosphorus (mg)	1222·74	8·22	1200·19	10·26	1239·17	21·85	1302·35	27·30	1332·69	48·59	<0·001
Iron (mg)	14·80	0·14	14·03	0·13	15·68	0·34	16·78	0·66	18·73	1·26	<0·001
Sodium (mg)	3148·04	21·49	3188·07	28·50	3121·01	51·59	2925·36	72·80	3098·33	105·98	0·05

WG, whole grains; NHANES, National Health and Nutrition Examination Survey; HEI, Healthy Eating Index; RAE, retinol activity equivalents; AT, α-tocopherol.
*Estimates were adjusted for age, gender, ethnicity and total energy intake. Models for total energy did not include total energy intake.
†WG were defined according to the new definition that excludes bran.

The eating habits developed in childhood can track into adulthood[52–54]; thus, it is important to encourage healthy eating habits early in life. Recently, it was shown that a school-based intervention could increase WG consumption by one serving and decrease refined grain consumption by one serving in fourth and fifth grade students[55]. School is an appropriate venue for improving WG consumption in children. This is important, since few WG were served at school[19]. Although the USDA has issued a policy encouraging adherence to the DGA in the National School Lunch Program[56], the law requires only that sponsors must offer grains, which can be either enriched or WG[57]. An Institute of Medicine Report[58] has called for industry and schools to work together to increase availability of WG in child nutrition programmes.

Consumption of WG improved diet quality as indicated by the increasing HEI scores[37,59] across the WG consumption groups. The HEI-2005 is designed to reflect the 2005 DGA[37]. That version of the HEI includes a WG component, and includes energy from solid fat, alcohol and added sugars. Inclusion of the last three components should assuage concerns about the use of the HEI with children[59]. The HEI scores are presented as the total score, which is appropriate for studying populations[37]. Although HEI scores improved with increasing levels of WG consumption, the mean score of those consuming ≥3 servings of WG/d ranged from 54 to 58 out of a maximum of 100 in the different age groups suggesting that overall diet quality of both children and adolescents could be improved[60]. The impact of WG may be small because of the low consumption levels.

Intakes of many macro- and micronutrients also improved with increased consumption of WG. The focus of this discussion will be on the shortfall nutrients in the diets of children (fibre, magnesium, vitamin E, calcium and potassium)[16]. These shortfall nutrients are found naturally in WG[1].

The majority of children do not meet the daily fibre requirement, with mean intake approximately half of the recommendation[61] for Adequate Intake[62]. The present study showed that increased WG consumption was associated with increased fibre intake; however, mean intake fell below recommendations for all age groups. In children and adolescents, fibre intake is inversely associated with serum cholesterol levels[63] and constipation[64], which is a major cause of morbidity in children[65]. Fruit, vegetable and WG

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Table 4 Diet quality, daily total energy and nutrient intakes by WG consumption groups, US adolescents aged 13–18 years, NHANES 1999–2004*

	Total population (*n* 4931)		WG consumption group (servings/d) ≥0 to <0·6 (*n* 3426)		≥0·6 to <1·5 (*n* 814)		≥1·5 to <3·0 (*n* 477)		≥3 (*n* 214)		
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	*P* for trend
WG servings†	0·68	0·02	0·09	0·01	0·99	0·01	2·04	0·03	4·73	0·17	
HEI	47·68	0·25	45·54	0·29	50·22	0·59	54·02	0·77	54·36	0·96	<0·001
Energy (kcal)	2340·68	20·74	2214·49	24·41	2380·09	43·59	2719·68	74·53	3118·41	116·37	<0·001
Energy (kJ)	9799·96	86·83	9271·63	102·20	9964·96	182·50	11 386·76	312·04	13 056·16	487·22	<0·001
Protein (g)	80·57	0·51	81·20	0·63	81·86	1·34	78·58	1·66	71·57	2·89	<0·001
Carbohydrate (g)	314·79	1·21	311·51	1·60	312·40	2·66	328·56	3·68	338·90	6·14	<0·001
Fibre (g)	13·61	0·13	12·38	0·14	14·12	0·27	16·86	0·46	21·81	0·76	<0·001
Total sugars (g)	164·87	1·33	165·90	1·83	162·92	2·80	166·86	3·72	153·51	6·29	0·16
Added sugars (g)	29·71	0·34	30·15	0·47	29·18	0·73	28·97	1·02	27·15	1·67	0·11
Total fat (g)	85·58	0·43	86·16	0·54	86·82	0·94	82·32	1·43	80·12	2·60	<0·001
SFA (g)	29·74	0·18	30·26	0·23	29·96	0·39	27·99	0·58	25·58	1·15	<0·001
MUFA (g)	32·52	0·18	32·70	0·23	33·31	0·43	30·95	0·58	30·60	1·08	0·05
PUFA (g)	16·62	0·18	16·44	0·22	16·81	0·40	16·94	0·70	17·64	0·87	0·21
Cholesterol (mg)	258·60	3·75	266·84	4·91	266·50	8·95	223·62	10·29	192·07	19·29	<0·001
Vitamin A (μg RAE)	646·90	13·96	618·69	18·39	668·33	29·69	742·10	45·47	753·26	59·42	0·04
Vitamin C (mg)	91·85	1·91	90·92	2·48	90·25	3·97	102·40	6·85	87·76	9·81	0·73
Vitamin E (mg AT)	7·14	0·12	6·89	0·12	7·13	0·22	8·58	0·70	7·49	0·49	0·03
Vitamin B_1 (mg)	1·73	0·02	1·66	0·02	1·79	0·04	1·96	0·07	1·89	0·11	0·03
Vitamin B_2 (mg)	2·22	0·02	2·13	0·02	2·32	0·05	2·55	0·08	2·48	0·14	<0·001
Vitamin B_6 (mg)	1·84	0·03	1·73	0·04	1·92	0·04	2·18	0·09	2·25	0·14	<0·001
Vitamin B_{12} (μg)	5·19	0·08	5·02	0·09	5·46	0·17	5·66	0·32	5·59	0·59	0·29
Niacin (mg)	23·19	0·21	22·61	0·24	23·87	0·44	25·18	0·88	24·53	1·45	0·18
Folate (μg)	403·46	4·55	378·20	4·12	420·21	11·32	502·16	24·16	478·94	32·28	<0·001
Calcium (mg)	994·09	10·61	970·49	13·35	1038·57	26·09	1063·64	34·19	1009·73	61·94	0·34
Magnesium (mg)	248·46	1·61	232·43	1·74	258·45	3·63	290·81	6·23	341·88	10·54	<0·001
Potassium (mg)	2446·93	17·90	2446·36	22·38	2443·72	42·93	2495·54	63·40	2362·49	105·33	0·33
Phosphorus (mg)	1353·88	8·34	1320·21	10·12	1405·52	21·70	1443·85	27·68	1438·30	53·03	0·03
Iron (mg)	16·29	0·17	15·07	0·15	16·62	0·30	20·70	0·81	22·51	1·52	<0·001
Sodium (mg)	3537·86	22·91	3555·03	30·19	3588·63	52·34	3372·54	61·91	3474·01	129·50	0·08

WG, whole grains; NHANES, National Health and Nutrition Examination Survey; HEI, Healthy Eating Index; RAE, retinol activity equivalents; AT, α-tocopherol.
*Estimates were adjusted for age, gender, ethnicity and total energy intake. Models for total energy did not include total energy intake.
†WG was defined according to the new definition that excludes bran.

intake should be encouraged in children and adolescents to help them meet the fibre requirement.

All age groups showed a significant increase in magnesium with the consumption of WG. Magnesium is an essential cofactor for over 300 metabolic reactions. In adults, higher intake is associated with an inverse risk of type 2 diabetes[66] and metabolic syndrome[67]. One of the few studies conducted in children suggested that magnesium deficiency is associated with insulin resistance in obese children[68]. Adolescents appear at greatest risk for low magnesium intake[64] . In the present study, mean intake by adolescents failed to reach the DRI (separate data by gender not shown).

Vitamin E, calcium and potassium are the remaining shortfall nutrients in the diets of children. Vitamin E is found in WG; however, only 5 %[69] to 21 %[70] of vitamin E is retained when wheat is processed. Adolescents were the only group that showed improved vitamin E intake with increased WG consumption and their mean intake did not approach the DRI of 15 mg/d for male and female adolescents aged 14–18 years[35]. Increased consumption of WG by adults was associated with increased intake of vitamin E[71]; however, that study included dietary supplements in the nutrient analysis. Of the other shortfall nutrients, only potassium showed a marginal increase with increased consumption of WG in children aged 6–12 years. It may have been that WG consumption was not high enough to influence intake of vitamin E, calcium and potassium, since WG are not good sources of these nutrients. Foods such as low-fat dairy, fruit, vegetables, nuts and oils should be encouraged along with WG in the diet to improve the intake of these micronutrients.

The present study had several limitations. NHANES collects cross-sectional data and, therefore, causal inferences cannot be drawn. Twenty-four-hour dietary recalls are subject to under- or over-reporting of energy and examiner effects[72]; single 24 h dietary recalls may not accurately reflect the usual dietary intake patterns of participants. Although 2 d recalls are now available from NHANES, only one day was used from the 2003–2004 data set; therefore, data from that reporting period would be comparable with data from the other survey years (1999–2002). Parents reported or assisted with the 24 h recalls of children aged 2–11 years; parents can often report accurately what children eat in the home[73], but may not

know what their children eat outside the home[74], which could result in reporting errors[75]. With a large sample size, 24 h recalls produce reasonably accurate group estimates of nutrient intake[76]. The strengths of the study included a nationally representative sample with a large sample size and use of the new definition of WG.

Overall consumption of WG in children and adolescents was low; however, diet quality and nutrient intake were significantly improved with increasing consumption of WG. WG consumption for children, adolescents and their parents should be encouraged by health professionals, especially registered dietitians.

There is a paucity of published research looking at WG consumption in children. Recommendations for WG intake are based on findings in adults, which have been extrapolated to children and adolescents. Few studies have looked at ethnic and socio-economic influences on WG consumption in these age groups[35]. Barriers to WG intake in children and adolescents have not been widely studied[45], and only recently have results from interventions to increase consumption of WG in children been published[55]. Nutrition education programmes that increase awareness, health benefits and consumption of WG should be made more widely available. Finally, it is important to quantify the effect that WG consumption has on health parameters, such as weight, in children.

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