

# Cereal consumption and indicators of cardiovascular risk in adolescent girls

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## Abstract

**Objective:** To examine the association between cereal consumption and cardiovascular risk factors including waist, height, total cholesterol, LDL cholesterol and HDL cholesterol in a sample of adolescent girls.

**Design:** Longitudinal study.

**Setting:** The study was conducted from 1987 to 1997 and data were collected at three study sites (University of California at Berkeley, University of Cincinnati and Westat Inc., Rockville, MD, USA). Mixed models were used to estimate the association between the number of days of eating cereal and these four outcome variables.

**Subjects:** Girls (*n* 2371) who participated in the 10-year National Heart, Lung, and Blood Growth and Health Study (NGHS) and completed a 3 d food diary in years 1–5 and 7, 8 and 10.

**Results:** Adolescent girls who ate cereal more often had lower waist-to-height ratio ( $P < 0.005$ ), lower total cholesterol ( $P < 0.05$ ) and lower LDL cholesterol ( $P < 0.05$ ), taking into account sociodemographic variables, physical activity levels and total energy intake.

**Conclusions:** Findings suggest that cereal consumption is associated with markers of cardiovascular risk and that childhood patterns of consumption may influence the development of risk factors later in adolescence.

## Keywords

Cereal  
Cholesterol  
Waist-to-height ratio  
Cardiovascular risk

Cereal is a popular breakfast choice for children. Children who consume cereal, relative to other breakfast foods, are less likely to be overweight or obese and evidence lower BMI<sup>(1–6)</sup>. One study of Greek children aged 12–17 years indicated that youth who ate cereal had 33% lower probability of being overweight or obese, regardless of age, gender or degree of physical activity<sup>(3)</sup>. Williams<sup>(6)</sup> reported that the lowest mean BMI and mean waist circumference were found in children (aged 1–12 years) who consumed cereal at breakfast when compared with those who ate other types of breakfasts or skipped breakfast.

Although weight is a useful indicator of health, it is not necessarily optimal. In fact, recent research has shown that waist-to-height ratio (WHtR) is a better predictor of health and disease outcomes than BMI, although most of these studies have been conducted with adults<sup>(7–10)</sup>. Notably, a recently published meta-analysis concluded that ‘statistical evidence supports the superiority of ... WHtR over BMI, for detecting cardiovascular risk factors in both men and women’<sup>(11)</sup>.

The advantage of WHtR as a discriminator for CVD risk has also been found in children, although the studies are fewer in number. Kahn *et al.*<sup>(12)</sup> analysed data from 4- to 17-year-olds who participated in the Third National

Health and Nutrition Examination Survey (NHANES III) in a population-based comparison of BMI and WHtR to predict CVD risk. This large-scale study found that WHtR was a significantly better predictor of adverse cardiovascular risk factors than BMI. McCarthy and Ashwell<sup>(13)</sup> reported that WHtR is more closely linked to childhood morbidity than BMI, and suggested it to be used as an ‘additional or alternative measure to BMI’ (p. 988) in studies of health.

A second useful indicator of CVD risk is cholesterol level<sup>(14)</sup>. Elevated LDL cholesterol levels are a major risk factor for CVD and the need for management of high cholesterol levels in children was recently highlighted<sup>(15)</sup>. Because cholesterol levels can be altered by changes in eating habits, increasing our understanding of the relationship between dietary factors and cholesterol levels may have important implications for prevention. Although several studies have examined the relationship between cereal consumption and cholesterol levels in adults<sup>(16)</sup>, very few have focused on children<sup>(17)</sup>. In one large study of 4–18-year-olds, Gibson<sup>(18)</sup> reported that relative to low or average consumers, high consumers of breakfast cereals had lower total and LDL cholesterol. Nicklas *et al.*<sup>(19)</sup> provided evidence that serum lipid and

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lipoprotein levels continue to track from childhood into young adulthood, suggesting the need for preventive measures aimed at developing healthy lifestyles early in life. Thus, furthering our understanding of the relationship between health risk markers, such as WHtR and cholesterol, and dietary behaviour, such as cereal consumption, is important for both predicting and potentially managing early risk factors for CVD.

The goal of the current study was to examine associations between cereal consumption and WHtR as well as total LDL and HDL, cholesterol. Based on previous research, we hypothesized that greater cereal consumption would be associated with lower WHtR as well as lower total and LDL cholesterol.

## Experimental methods

As previously reported, the National Heart, Lung, and Blood Growth and Health Study (NGHS) is a 10-year longitudinal study of 2379 girls who were 9 or 10 years old at study entry<sup>(20)</sup>. Participants (all female) were recruited from three study sites in the USA: University of California at Berkeley, University of Cincinnati/Cincinnati Children's Hospital Medical Center and Westat Inc./Group Health in Rockville, MD. The study protocol was approved by the Institutional Review Boards of all participating sites. All girls who entered the NGHS had assented and a parent or guardian consented to their participation.

## Procedures and measures

Three-day food records that had been previously validated<sup>(21)</sup> were collected at visits (study years) 1–5 and then again at years 7, 8 and 10. Dietitians used age-appropriate materials to instruct girls to record all food and drink, type of meal (breakfast, snack, lunch, etc.) and time of intake for three consecutive days that included two weekdays and one weekend day. Dietitians rated each eating event reported in the food diaries as either a 'meal' or a 'snack'. Food records were coded and analysed for nutrient content<sup>(22)</sup>. Nutrient values were updated annually to reflect changes in the nutrient composition of individual foods. The predictor of interest was the number of days (out of 3 d reported annually) that each girl consumed cereal, either ready-to-eat or cooked. Cereal food codes were identified using labels in the data. The outcome variables were WHtR (waist and height (cm) were measured in all study years except year 1) and total LDL and HDL, cholesterol (mg/dl) derived from 12 h fasting blood specimens obtained in the morning in study years 1, 3, 5, 7 and 10<sup>(23,24)</sup>. Cut-off values indicating risk for children include (i)  $>0.49$  for WHtR<sup>(25)</sup>; (ii) total cholesterol  $>200$  mg/dl; (iii) HDL cholesterol  $<35$  mg/dl; and (iv) LDL cholesterol  $>130$  mg/dl<sup>(26)</sup>.

Girls' age was recorded as age at last birthday. Race (black or white) was self-reported. Girls were categorized

as being from one- or two-parent households. The highest level of parental education for either parent (an indicator of socio-economic status) was categorized as  $\geq 4$  years of college *v.*  $< 4$  years. The number of parents in the household was one or two. Age of menarche was calculated as the difference in years between a girl's date of birth and the date when she started having her periods. Physical activity was assessed using the habitual activity questionnaire<sup>(27)</sup>. A physical activity score was computed by multiplying an estimate of 'metabolic equivalents' for the recorded activities by the weekly frequency, duration and fraction of the year during which activities were performed.

## Statistical analysis

The number of days when cereal was eaten in each visit (out of 3 d possible) was the primary measure of the quantity of cereal consumed. There were two reasons for using the number of days when cereal was eaten as the measure of the quantity consumed. First, gram amounts of the cereal consumed were available only in visit three and after; in earlier visits, participants recorded cereal amounts in a variety of units. Second, the amount of cereal consumed varied within a relatively narrow range – for visits when gram amounts of cereal consumed were available, the widest interquartile range was 28–66 g/d<sup>(28)</sup>.

Analyses estimated the association of days eating cereal with each outcome variable: WHtR, total cholesterol, HDL cholesterol and LDL cholesterol. Mixed models were used to take full advantage of the longitudinal data<sup>(29)</sup>. Briefly, for each girl, an intercept and slope of days eating cereal with each outcome was estimated (the intercept and slope are random effects, potentially varying across girls), using data for all visits; then the mean slope of days eating cereal with each outcome was computed, averaging across girls and visits. To ensure that the association between cereal consumption and the outcomes did not vary across visits, cereal-by-visit interactions were tested in preliminary models, but the interactions were left out of the final models because they did not approach significance. Mixed models accounted for the correlation among repeated measures within girls and enabled unbiased estimation in the presence of missing data arising from girls' occasional failure to participate in study visits<sup>(29,30)</sup>.

A separate model was estimated for each outcome. Cereal consumption was the predictor of primary interest. All models adjusted for potential confounds of the cereal/outcome associations, namely age, study site, race, age of menarche, parental education, number of parents in the household, physical activity, average daily energy intake, average daily intake of fibre, fruit, vegetables and milk, respectively, and the number of days eating breakfast (because meal labels were not obtained in the study, breakfast was defined as eating between 5 am and 10 am on weekdays or 5 am and 11 am on weekends, based on previous study<sup>(31)</sup>). Parameter estimates, 95% CI and hypothesis tests are reported for cereals; the other covariates were

viewed as adjustment variables (potential confounds of the cereal effects), and therefore estimates for these are not reported but are available from the authors upon request.

Statistical tests compared the lowest level of cereal consumption (0 d eating cereal in a visit, or infrequent cereal consumption) with each higher level of cereal consumption. All tests were two-sided;  $P < 0.05$  was the criterion of statistical significance. Analyses were performed with the SAS statistical software package version 9.1 (SAS Institute, Cary, NC, USA).

**Results**

The analysis included the 2371 girls who completed a full 3 d food diary in at least one study year; of these girls, 98.2% had food diaries available in two or more study years. Of the 2371 girls included in the analysis, 51.0% were black, 35.1% had a parent with  $\geq 4$  years of college education, 68.5% were from two-parent households, 37.3% were from the Berkeley site, 36.5% from the Cincinnati site and 26.2% from the Westat/Group Health site. Table 1 shows descriptive statistics for cereal consumption and the outcome variables, by age. Table 2 shows the basic sociodemographic characteristics, physical activity score and nutrition indicators (energy, fruit, vegetable and milk intake) by the average number of days eating cereal (out of 3 d possible) across all visits.

On average, girls who consumed cereal on 3 d had significantly lower WHtR than girls who consumed cereal on 0 d (Table 3). Girls who consumed cereal on 2 or 3 d had significantly lower total cholesterol than did those who consumed cereal on 0 d, on average. On average, girls who consumed cereal on 1, 2 or 3 d had significantly lower LDL cholesterol than did those who consumed cereal on 0 d. However, there was no significant association between cereal consumption and HDL cholesterol. These analyses adjusted for the measures of sociodemographic characteristics, physical activity and nutrition shown in Table 2 (as well as the study site, age and number of days eating breakfast). Therefore, the results are interpreted as the estimated association of days eating cereal with each outcome, holding these other factors constant.

The results indicate that adolescent girls who ate cereal more often had lower WHtR, as well as lower total cholesterol and lower LDL cholesterol, even after adjusting for differences in sociodemographic factors, physical activity, nutrition variables and total energy intake. However, it should be noted that none of the mean values fell into the at-risk range for the variables studied in this sample. Earlier study<sup>(32)</sup> found that cereal consumption was related to BMI; the present study extends that finding to potentially include more powerful predictors of CVD risk and offers suggestive evidence that cereal eating is associated with markers of cardiovascular risk in adolescent girls.

**Table 1** Percentage of mean and sd for cereal consumption and WHtR and cholesterol, by age

Measure	Age (years)																																
	9	10	11	12	13	14	15	16	17	18	19	9	10	11	12	13	14	15	16	17	18	19											
	%	%	%	%	%	%	%	%	%	%	%	Mean	SD																				
Consumed cereal, 0 of 3 d	20.0	24.3	31.2	33.2	38.9	41.5	41.6	44.2	45.3	43.6	43.7	0.527	0.010	0.439	0.053	0.440	0.057	0.438	0.059	0.438	0.061	0.445	0.067	0.444	0.069	0.449	0.071	0.457	0.071	0.459	0.077	0.478	0.083
Consumed cereal, 1 of 3 d	27.2	29.4	27.7	28.8	28.1	30.1	27.6	28.3	28.4	26.6	26.9	173.0	28.0	169.2	30.1	166.5	26.3	162.6	28.3	160.5	26.4	158.1	26.8	159.2	28.7	160.5	31.2	155.5	36.7	165.4	34.0	164.4	33.7
Consumed cereal, 2 of 3 d	32.5	29.0	25.4	24.9	21.1	19.5	20.7	18.5	15.7	20.2	20.1	107.0	26.7	103.3	28.0	99.1	24.2	96.0	25.4	92.5	24.0	91.4	25.0	93.6	26.4	94.4	29.4	93.4	28.7	98.5	31.3	98.4	30.1
Consumed cereal, 3 of 3 d	20.3	17.3	15.7	13.1	11.8	8.9	10.0	9.0	10.6	9.6	9.2	54.6	12.7	53.6	12.6	54.9	12.7	54.0	11.7	55.7	11.7	55.5	10.7	53.2	10.5	54.5	11.5	49.7	10.8	54.0	11.9	53.3	12.7
WHtR																																	
Total cholesterol (mg/dl)																																	
LDL cholesterol (mg/dl)																																	
HDL cholesterol (mg/dl)																																	

WHtR, waist-to-height ratio. Gram amounts of cereal consumed were not collected during the first and second visits of the National Heart, Lung, and Blood Growth and Health Study, and therefore no data on this measure are available for 9-year-olds.

**Table 2** Mean and SD of measure or percentage of girls by average number of days eating cereal (out of 3 d possible) across visits, for selected measures of sociodemographic characteristics, physical activity and nutrition

Measure	Average number of days eating cereal (out of 3 d possible) across visits							
	0 d		>0–1 d		>1–2 d		>2 d	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number of girls	75		1123		991		182	
Black (%)	60.0		59.5		44.1		33.0	
College-educated parent (%)	30.7		32.0		35.9		52.5	
Number of parents in household	1.73	0.45	1.67	0.47	1.69	0.46	1.76	0.43
Physical activity score (MET)	21.1	12.6	18.3	11.4	19.6	11.5	22.5	11.8
Average daily energy intake								
kJ	7643	1856	7753	1791	8043	1797	8086	1804
kcal	1827	444	1853	428	1922	430	1933	431
Average daily fibre intake (g)	9.7	3.0	10.9	3.0	12.1	3.3	13.1	3.7
Average daily fruit intake								
kJ	293.7	287.0	339.3	236.4	371.1	241.8	453.1	272.0
kcal	70.2	68.6	81.1	56.5	88.7	57.8	108.3	65.0
Average daily vegetable intake								
kJ	475.3	282.4	484.5	229.3	448.5	220.9	422.2	192.5
kcal	113.6	67.5	115.8	54.8	107.2	52.8	100.9	46.0
Average daily milk intake								
kJ	288.3	281.2	452.7	277.0	651.9	321.3	861.5	353.5
kcal	68.9	67.2	108.2	66.2	155.8	76.8	205.9	84.5

MET, metabolic equivalent units.

**Table 3** Estimated WHtR, total, HDL and LDL cholesterol (mg/dl; 95% CI) by number of days consuming cereal

Outcome variable	Days consumed cereal (out of 3 d possible during the 3 d food diary)							
	0 d		1 d		2 d		3 d	
	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
Waist/height ratio	0.450	0.447, 0.454	0.449	0.444, 0.454	0.448	0.444, 0.453	0.440*	0.439, 0.449
Total cholesterol	162.2	159.9, 164.4	161.2	158.9, 163.5	160.4*	158.0, 162.7	160.2*	158.6, 162.8
HDL cholesterol	56.0	55.0, 56.9	56.4	55.4, 57.4	55.4	54.4, 56.4	55.6	54.5, 56.7
LDL cholesterol	94.5	92.5, 96.6	93.1*	91.0, 95.2	93.0*	90.8, 95.2	92.5*	90.1, 94.9

\*Significantly different from 0 d consuming cereal,  $P < 0.05$ .

†Estimates are from mixed models adjusting for age, study site, race, parental education, age of menarche, number of parents in the household, physical activity level, average daily energy intake, average daily intake of fibre, fruit, vegetables and milk and number of days of eating breakfast. The estimates are interpreted as the expected value of a given outcome variable, averaged over the other covariates, which were centre-coded to enable such interpretation.

## Discussion

The variables that might influence the relationship between cereal consumption and indicators of health have only begun to be studied. Potential mediators of these links include dietary fat levels<sup>(18)</sup>, glycaemic index<sup>(33)</sup>, nutrient fortification<sup>(34)</sup>, consumption of whole grains<sup>(35)</sup> and breakfast frequency<sup>(36)</sup>. One recent study of adults<sup>(37)</sup> found significant associations between cereal fibre and several health variables, including lower BMI, smaller waist circumference, and lower cholesterol and glucose levels, suggesting that fibre intake may be one important factor mediating the health effects of cereal consumption. Mozzaffarian *et al.*<sup>(38)</sup> found support for this hypothesis with an elderly sample for which cereal fibre consumption was inversely associated with cardiovascular incidents (i.e. stroke, myocardial infarction); individuals in the highest quintile of cereal fibre intake had a 21% lower

risk of cardiovascular events. Other studies have linked whole grains, including oat fibre, to lower cholesterol in adult samples<sup>(16,39)</sup>. Research is needed to better understand the mechanisms by which cereal consumption may lower cholesterol in children and longer-term data will be necessary to determine whether this association continues into adulthood<sup>(40)</sup>.

In the present study, cereal consumption was related to both lower total cholesterol and lower LDL cholesterol in adolescent girls. A previous study with a different sample of children found that higher ready-to-eat cereal consumption was associated with both lower total and LDL cholesterol in boys<sup>(41)</sup>. The mechanisms that might explain this relationship in children are most likely complex and have not been well studied to date. It is possible that the nutrient content of cereal, particularly as related to whole grains, directly impacts the cholesterol levels<sup>(42)</sup>. Another explanation is that the link with cholesterol is

related to the connection between cereal consumption and physical activity. An earlier study found that children who were high cereal consumers also tended to engage in more physical activity<sup>(28)</sup>, and recent data indicate that higher physical activity is associated with lower cholesterol levels in children and adolescents<sup>(43)</sup>. In a recent review, e.g., five of eight intervention-based studies found significant improvements in at least one lipid/lipoprotein variable in the children who received a physical activity programme, relative to controls<sup>(44)</sup>. Alternatively, previous studies of this cohort have indicated that girls who ate cereal also consumed less fat in their diets, which most likely relates to cholesterol levels<sup>(45,46)</sup>. For example, in a study of 7-year-old children in Finland, serum cholesterol concentrations were found to be lower in those who had diets lower in saturated fat<sup>(47)</sup>, suggesting the possibility of intervention targets. Further study is needed to determine exactly how cereal consumption might influence risk for CVD in children and to develop programmes for reducing cholesterol levels in children at risk.

The relationship between dietary intake, body composition, sexual maturation during adolescence and lipid levels is complex<sup>(48)</sup>. Studies of the effects of diet on HDL cholesterol in children have been less consistent than those on LDL cholesterol<sup>(18,49–51)</sup>, suggesting that dietary changes may have a stronger effect on LDL than HDL cholesterol, as was seen in the present study. Future research exploring interventions to decrease LDL cholesterol and raise HDL cholesterol is needed<sup>(52)</sup>.

There are several limitations to the present study. Due to the large sample size, NGHS had excellent statistical power to detect associations between cereal consumption and health outcomes, and therefore statistically significant differences do not necessarily represent practically large effects. As is typical of epidemiological studies, dietary information was based on self-report and may therefore be subject to recall errors or under-reporting. Because meal labels were not collected in the study, breakfast was defined based on the time of consumption, but these times could include snacks as well as breakfast meals. Finally, although demographically diverse in terms of geography and socio-economic status, the NGHS is not a nationally representative sample of girls. These limitations are offset by several strengths, such as the low attrition rate and the availability of 3 d of food intake data.

The present study adds to the growing body of evidence indicating that cereal consumption is associated with a number of positive health benefits that should be studied further.

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