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Intake of wholegrain products is associated with dietary, lifestyle, anthropometric and socio-economic factors in Denmark

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Abstract

Objective: To evaluate the association between wholegrain products intake and other dietary, lifestyle, anthropometric and socio-economic factors.

Design: Cross-sectional study, with data on diet, lifestyle and socio-economic factors obtained from questionnaires. Anthropometric measurements were collected by trained professionals. Multiple linear and principal components regression analyses were used in statistical analyses.

Setting: Part of the Diet, Cancer and Health study, a prospective cohort study to evaluate the aetiological role of diet on cancer risk, conducted in the greater Copenhagen and Aarhus area, Denmark.

Subjects: Men and women (*n* 54 720) aged 50–64 years.

Results: In multiple linear regression analyses focusing on individual dietary factors, intake of wholegrain products was associated with intake of all dietary factors studied (fish, red meat, poultry, processed meat, dairy products, fruits, vegetables, cakes and refined-grain products). The strongest positive associations were seen for intake of vegetables and processed meat, whereas the strongest negative associations were seen for intake of red meat and refined-grain products. Regression analyses on dietary patterns identified by principal components analysis yielded similar results. Also, wholegrain products intake was positively associated with cycling, taking dietary supplements and high school education, and negatively associated with intake of alcohol, BMI and smoking.

Conclusions: Intake of wholegrain products is associated with other dietary factors, healthier lifestyle habits and higher socio-economic status. Therefore future studies need to account for the possible confounding by other dietary and lifestyle-related parameters when investigating relationships between wholegrain products intake and disease risk.

Keywords
Wholegrain products
Intake
Determinants
Cross-sectional study

In recent years, there has been considerable international interest in the effect of whole grains in relation to mortality and a number of chronic diseases. Prospective studies have shown an inverse relationship between the consumption of wholegrain products or specific foods with a high content of whole grains and risk of total mortality[1–4], CVD[2,5–9], type 2 diabetes[10–14] and certain cancers[15–17]. A high intake of wholegrain products has also been linked to lower BMI[18–21], lower gain in weight or BMI[22–24] and lower risk of presence of the metabolic syndrome[25–27], which is described as a cluster of risk factors that is related to the onset of CVD, type 2 diabetes and perhaps also specific cancers. Although the evidence is not entirely consistent, there seems to exist a protective role of wholegrain products and it has been highly indicated that intake of wholegrain products is of considerable importance for public health.

Whole grains contribute a range of beneficial nutrients including dietary fibres, vitamins, minerals and phytochemicals, and the possibly protective effect of whole grains may be mediated via the effect of these compounds[28]. However, increased knowledge of the biological aspects of whole grains is needed to gain full insights into the health potential of wholegrain products. Whether the beneficial effects of wholegrain products indicated by existing research are due to a direct effect of the wholegrain products and/or simply to the effect of confounding is another important issue. Other factors

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might confound an association between consumption of wholegrain products and disease, thus the associations observed in studies supporting a protective effect of wholegrain products may simply reflect the effect of other dietary or non-dietary factors and not the causal association between wholegrain products and disease. Earlier studies have indicated that high consumption of whole grains is associated with healthier dietary and lifestyle habits[3,29–31]. It is possible that these associations may vary between populations because of differences in food and lifestyle habits.

To further clarify the effect of wholegrain products in relation to risk of diseases, it is important to understand the association between intake of wholegrain products and other risk factors of diseases for accurate interpretation of the increasing number of studies relating high intake of wholegrain products to lower risk of chronic diseases. The aim of the present study was to evaluate the association between intake of wholegrain products and other dietary, lifestyle, anthropometric and socio-economic factors.

Methods

Study population and design

The Diet, Cancer and Health study is a prospective cohort study established with the primary purpose to evaluate the aetiological role of diet on cancer risk. A more detailed description of the cohort has been published elsewhere[32]. In brief, from December 1993 to May 1997, all men and women living in the greater Copenhagen and Aarhus area and fulfilling the following inclusion criteria: age between 50 and 64 years, born in Denmark and not registered with a previous cancer diagnosis in the Danish Cancer Registry, were invited to participate in the study (80 996 men and 79 729 women). Subjects were identified by the unique 10-digit identification number, which is allocated to every Danish citizen by the Central Population Registry. Of the invited persons, 27 178 men (33·6 % of those invited) and 29 875 women (37·5 % of those invited) participated in the study. All participants attended one of two established study centres in Copenhagen or Aarhus. The Diet, Cancer and Health study and the present study were approved by the Regional Ethical Committees on human studies in Copenhagen and Aarhus, and by the Danish Data Protection Agency.

Dietary information

A validated 192-item semi-quantitative FFQ completed at baseline was used for estimating the participants' habitual diet during the preceding 12 months[33–36]. Consumption was assessed in twelve categories of predefined responses, ranging from 'never' to '8 times or more per day'. Daily intakes of foods and nutrients for each participant were calculated by the FOODCalc program (www.foodcalc.dk) using population-specific standardized recipes and portion sizes.

'Wholegrain products' comprised intake of rye bread, wholegrain bread, crisp bread, oatmeal and corn, and was measured in g/d. Other dietary factors of interest included 'red meat', 'poultry', 'processed meat', 'fish', 'lean dairy products', 'fatty dairy products', 'fruits', 'vegetables', 'cakes' and 'refined-grain products'. Intake of all dietary factors was measured in g/d. Intake of 'alcohol' was measured in g/d and was assessed by summing the products of frequency of use of specific beverages (beer, wine, fortified wine and spirits) by their ethanol content. In the questionnaire, the participants indicated which type of fat they preferred for cooking, denoted as 'use of fatty substance when cooking'. Participants were grouped into three categories as vegetable oil users, margarine/butter users or non-users of a fatty substance when cooking. A section of the FFQ asked for information on the use of dietary supplements. Participants were asked about the exact brand, type, frequency and doses of the dietary supplements they used. Three categories of 'use of dietary supplements' were created. Participants were categorized as a supplement non-user, a multivitamin/mineral supplement user (i.e. a person taking a multivitamin/mineral supplement only) or a user of any supplement (i.e. taking one or more supplements alone or in combination with a multivitamin/mineral supplement).

Lifestyle and socio-economic factors

A lifestyle questionnaire was used for collecting information on lifestyle habits, social factors, reproductive factors and health status. Information included in the present study pertained to smoking status, alcohol habits, physical activity during leisure time, use of hormone replacement therapy (HRT; women only) and school education. Alcohol habits were defined in two ways: (i) 'alcohol status', with the four categories of never drinkers, ex-drinkers, occasional drinkers and current drinkers; and (ii) 'alcohol preference', with the four categories of wine drinkers, beer drinkers, spirit drinkers and mixed drinkers. A participant's preference for a specific beverage type was based on whether the person's intake of that beverage constituted ≥50 % of their total alcohol intake. If intake of none of the specific beverage types exceeded 50 %, the person was categorized as a mixed drinker. Participants were divided into three categories of 'smoking status': never smokers, past smokers and current smokers. Physical activity during leisure time was assessed by twelve questions covering the average number of hours per week spent in the past year on six types of activities: 'walking', 'cycling', 'sports', 'gardening', 'housework' and 'hobby work', during summer and winter, respectively. The number of hours spent on physical activity during summer and winter were averaged. Women were divided into three categories of 'HRT use': never users, past users and current

users. Socio-economic status was defined based on the participant's school education. Participants were divided into three categories of 'school education': low school education (≤7 years), medium school education (8–10 years) and high school education (≥11 years).

Anthropometric measurements

All participants were measured in light underwear. At baseline, weight, height and waist circumference were measured for every participant at the study centres by trained professionals. BMI was calculated as [weight (kg)]/[height (m)]^2. Waist circumference was measured at the smallest horizontal circumference between the ribs and iliac crest (the natural waist) or, in case of an indeterminable waist narrowing, halfway between the lower rib and the iliac crest. Waist circumference was measured to the nearest half centimetre.

Definition of the study population for analysis

Of the 57 053 participants, 569 were excluded because of a cancer diagnosis reported to the Danish Cancer Registry before entry into the study. Additionally, thirty-seven were excluded because they failed to fill in the lifestyle questionnaire and 1382 were excluded because of unrealistic or missing values in the dietary, lifestyle, anthropometric or socio-economic variables. Finally, fifty-five and 290 were excluded because of missing values or a null intake of wholegrain products, respectively. Thus 54 720 participants (26 175 men and 28 545 women) were included in the analyses.

Statistics

The descriptive characteristics are presented as median values with 5th and 95th percentiles for continuous variables and categorical variables are presented as percentages. The associations between intake of wholegrain products and dietary, lifestyle, anthropometric and socio-economic variables were investigated in multiple linear regression analyses. Intake of wholegrain products measured in g/d was the dependent variable. Associations were investigated in models including age, centre (Copenhagen and Aarhus), dietary variables (fish, red meat, poultry, processed meat, lean dairy products, fatty dairy products, fruits, vegetables, refined-grain products and cakes), lifestyle variables (alcohol intake, alcohol status, alcohol preference, smoking status, physical activity, use of fatty substance when cooking, use of dietary supplements and use of HRT), anthropometric variables (BMI and waist circumference) and socio-economic variables (school education). Age, all dietary variables, BMI, waist circumference and all physical activity variables were entered as continuous variables. Smoking status, alcohol status, alcohol preference, use of fatty substance when cooking, use of dietary supplements and use of HRT were entered as categorical variables with the categories previously described.

For all continuous variables the assumption of linearity was evaluated by linear splines with three or nine boundaries placed at the quartiles (25th, 50th and 75th) or centiles (10th to 90th) of the distribution[37]. The six physical activity variables (walking, cycling, sports, housework, gardening and hobby work) were log-transformed and showed no signs of deviation from linearity when evaluated by linear splines with three boundaries. For the dietary variables (fish, red meat, poultry, processed meat, lean dairy products, fatty dairy products, fruits, vegetables, refined-grain products and cakes), BMI, waist circumference and alcohol intake, the assumption of linearity was not appropriate and in these cases the estimates and tests should be interpreted with caution. To take into account that the assumption of linearity was not met for specific variables a separate model for each of the variables entering the model as a linear variable was made, with all other linear variables entering the model as spline parameters. All linear variables were scaled to reflect realistic and practical increments in the daily intake of the food items (based on the interquartile range).

Principal components analysis was applied to extract dietary patterns from ten food groups (fish, red meat, poultry, processed meat, lean dairy products, fatty dairy products, fruits, vegetables, refined-grain products and cakes) using the correlation matrix. The main constituents of the ten dietary patterns (components) extracted are shown in Appendix 1 (women) and Appendix 2 (men). Scoring coefficients indicate the degree of correlation between the original variables (residuals of food group intakes) and the components extracted. A positive scoring coefficient indicates that the original dietary variable is positively associated with the particular component, while a negative scoring coefficient implies a negative association. Multiple linear regression analysis was applied to model the associations between intake of wholegrain products and dietary patterns calculated from the principal components analysis. The ten components were included in the model simultaneously, with additional adjustments for age, centre and all lifestyle, anthropometric and socio-economic variables studied.

The GLM and PRINCOMP procedures in the SAS statistical software package release 9·0 (SAS Institute Inc., Cary, NC, USA) on a TextPad platform were used for the statistical analyses.

Results

The baseline characteristics of the participants are shown in Table 1. The median age at entry into the study for the 54 720 participants included was 56 years (range 50–64 years). The median intake of wholegrain products was 140 g/d among men and 119 g/d among women (Table 2). Rye bread contributed to 63 % and 55 % of the total wholegrain products intake among men and women, respectively (Table 2).

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Table 1 Baseline characteristics of participants included in the Diet, Cancer and Health cohort study (1993–7)

	Men (*n* 26 175)			Women (*n* 28 545)		
	Median	P5	P95	Median	P5	P95
Demographic variables						
Age (years)	56	50	64	56	50	64
Centre						
Aarhus (%)	32			30		
Copenhagen (%)	68			70		
Dietary variables						
Fish (g/d)	42	13	99	35	11	85
Red meat (g/d)	100	46	190	63	27	121
Poultry (g/d)	20	5	62	16	4	56
Processed meat (g/d)	35	9	89	18	4	50
Lean dairy products (g/d)	163	19	922	206	20	764
Fatty dairy products (g/d)	63	18	515	65	20	316
Fruits (g/d)	143	23	468	202	38	567
Vegetables (g/d)	151	47	341	172	51	389
Cakes (g/d)	14	2	67	13	2	57
Refined grain products (g/d)	55	18	140	38	13	103
Lifestyle variables						
Use of fatty substance when cooking						
None (%)	0·3	–	–	0·3	–	–
Vegetables oils (%)	28	–	–	30	–	–
Margarine/butter (%)	72	–	–	70	–	–
Use of dietary supplements						
Non-user (%)	37	–	–	24	–	–
Multivitamin/mineral user (%)	18	–	–	15	–	–
Any user (%)	45	–	–	61	–	–
Alcohol intake* (g/d)	20	2	80	10	1	42
Alcohol status						
Never drinker (%)	0·2	–	–	1	–	–
Ex-drinker (%)	1·3	–	–	1	–	–
Occasional drinker (%)	1	–	–	2	–	–
Current drinker (%)	97	–	–	96	–	–
Alcohol preference*						
Wine drinker (%)	34	–	–	66	–	–
Beer drinker (%)	42	–	–	14	–	–
Spirits drinker (%)	3	–	–	3	–	–
Mixed drinker (%)	19	–	–	14	–	–
Smoking status						
Never smoker (%)	26	–	–	44	–	–
Past smoker (%)	35	–	–	24	–	–
Current smoker (%)	39	–	–	33	–	–
Hormone replacement therapy use						
Never user (%)	–	–	–	55	–	–
Past user (%)	–	–	–	16	–	–
Current user (%)	–	–	–	30	–	–
BMI (kg/m^2)	26	21	33	25	20	34
Waist circumference (cm)	95	81	114	80	67	103
Recreational activity						
Walking (h/week)	3	1	12	3	1	12
Cycling (h/week)	2	0·5	10	2	0·5	10
Sports (h/week)	2	0·5	7·5	1·5	0·5	6
Household activity						
Housework (h/week)	2	1	10	5	2	20
Gardening (h/week)	2	0·5	10	2	0·5	8
Hobby work (h/week)	2	1	11	1	0·5	7
Socio-economic variables						
Education						
Low (%)	34	–	–	31	–	–
Medium (%)	42	–	–	50	–	–
High (%)	24	–	–	19	–	–

P5, 5th percentile; P95, 95th percentile.
*Among current drinkers.

Table 3 (women) and Table 4 (men) show the univariate and mutual adjusted regression coefficients and corresponding 95 % confidence intervals for the regression of wholegrain products *v.* dietary, physical activity and other lifestyle, anthropometric and socio-economic factors. In the univariate analyses with adjustment for age and centre, intake of wholegrain products was significantly associated with all dietary variables studied

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Table 2 Baseline intakes of total grain products, wholegrain products and rye bread of participants included in the Diet, Cancer and Health cohort study (1993–7)

	Men (*n* 26 175)			Women (*n* 28 545)		
	Median	P5	P95	Median	P5	P95
Total grain products (g/d)	210	100	356	166	80	290
Wholegrain products (g/d)	140	48	279	119	40	237
% of the total grain intake	71	–	–	76	–	–
Rye bread (g/d)	63	20	163	63	11	113
% of the whole grain intake	63	–	–	55	–	–

P5, 5th percentile; P95, 95th percentile.

among both men and women. All physical activity and other lifestyle, anthropometric and socio-economic variables studied, except hours per week spent walking or gardening among men and hours per week spent doing housework or hobby work and HRT use among women, were in addition significantly associated with intake of wholegrain products in univariate analyses. Among both men and women, mutual adjustments weakened the associations for the most of the dietary variables, except for intake of red meat, processed meat and refined-grain products, where the estimated associations were strengthened. Among the dietary variables, intake of wholegrain products was strongest positively associated with intake of processed meat and vegetables and strongest negatively associated with intake of red meat and refined-grain products after mutual adjustments. Regarding the physical activity variables mutual adjustments weakened all the estimated associations, resulting in only hours per week spent cycling being significantly positively associated with intake of wholegrain products among both men and women. For the remaining lifestyle, anthropometric and socio-economic variables, mutual adjustments resulted in that intake of wholegrain products among women was positively associated with being a multivitamin/mineral user, being an ex-drinker and medium or high school education, but negatively associated with intake of alcohol, BMI and current smoking. Among men, intake of wholegrain products was also positively associated with being a multivitamin/mineral user or any user of dietary supplements and high school education, but negatively associated with intake of alcohol, BMI and waist circumference, use of margarine/butter when cooking, a preference for drinking beer and current smoking after mutual adjustments.

Twelve per cent (women) and 15 % (men) of the variation in the wholegrain products intake was explained by dietary variables. Taking the physical activity variables into consideration, 13 % (women) and 17 % (men) of the variation was explained by dietary and physical activity variables combined. Overall, the multiple regression model explained 16 % and 21 % of the variance in the wholegrain products intake among women and men, respectively (Tables 3 and 4).

Table 5 shows the mutually adjusted regression coefficients and their corresponding standard errors and *P* values of the ten principal components extracted from the principal components analysis. Among men, the strongest positive association with intake of wholegrain products was seen for component 10 ($\beta = 21{\cdot}6$, SE 0·6), which loaded positively on processed meat and vegetables and negatively on red meat and refined-grain products. This component accounted for 6 % of the variation in the total intake of wholegrain products. Intake of wholegrain products was also highly positively associated with component 1 ($\beta = 8{\cdot}4$, SE 0·3), which loaded positively on all dietary factors studied, and component 5 ($\beta = 10{\cdot}8$, SE 0·4), which was characterized by intake of dairy products and fruits. The strongest negative association was seen for component 2 ($\beta = -4{\cdot}9$, SE 0·4). This component loaded positively on red meat, processed meat, cakes and refined-grain products and negatively on fish, poultry, fruits and vegetables. Among women, the strongest positive association with intake of wholegrain products was seen for component 1 ($\beta = 7{\cdot}1$, SE 0·2), which loaded positively on all dietary factors and accounted for 3 % of the variation in the total intake of wholegrain products. Component 10 was also highly positively associated with wholegrain products intake ($\beta = 13{\cdot}6$, SE 0·5). This component loaded positively on processed meat and vegetables and negatively on red meat. The strongest negative association was seen for component 2 ($\beta = -5{\cdot}1$, SE 0·30), which loaded positively on red meat, processed meat, cakes and refined-grain products and negatively on fish, poultry, fruits and vegetables.

Discussion

In the present study we found that intake of wholegrain products is associated with several dietary, lifestyle, anthropometric and socio-economic factors in a cohort of Danish middle-aged men and women with a high consumption of this food group. Among both men and women the intake of wholegrain products was positively associated with other dietary factors, especially intake of processed meat and vegetables, and negatively associated with intake of red meat and refined-grain products. In addition, positive associations with more hours of cycling per week, taking dietary supplements and high

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Table 3 Regression derived coefficients (β) and 95 % confidence intervals of dietary, lifestyle, anthropometric and socio-economic variables among 28 545 women included in the Diet, Cancer and Health cohort study (1993–7)

	Analysis adjusted for age and centre		Mutual adjusted analysis		
	β*	95 % CI	β*	95 % CI	R^2
Dietary variables					0·12§
Fish (per 25 g)	8·9	8·2, 9·6	3·0	2·3, 3·8	
Red meat (per 50 g)	−2·6	−3·8, −1·4	−10·6	−11·8, −9·3	
Poultry (per 10 g)	3·7	3·3, 4·1	1·8	1·4, 2·2	
Processed meat (per 10 g)	2·6	2·1, 3·1	5·8	5·4, 6·3	
Lean dairy products (per 100 g)	2·4	2·1, 2·6	1·3	1·1, 1·6	
Fatty dairy products (per 50 g)	2·1	1·8, 2·4	1·4	1·2, 1·7	
Fruits (per 100 g)	4·6	4·2, 5·1	0·3	−0·1, 0·8	
Vegetables (per 100 g)	13·6	12·9, 14·2	8·8	8·1, 9·5	
Cakes (per 10 g)	2·5	2·1, 2·8	3·0	2·7, 3·4	
Refined grain products (per 30 g)	−6·2	−7·0, −5·5	−10·7	−11·5, −10·0	
Physical activity variables					0·13‖
Walking (per 1 h)	2·3	0·2, 4·4	−1·3	−3·4, 0·7	
Cycling (per 1 h)	11·6	9·4, 13·8	7·8	5·7, 9·8	
Sports (per 1 h)	5·2	2·3, 8·1	−2·2	−4·9, 0·5	
Housework (per 1 h)	0·3	−1·8, 2·5	−0·1	−2·1, 2·2	
Gardening (per 1 h)	3·6	1·3, 5·9	2·1	−0·1, 4·3	
Hobby work (per 1 h)	0·5	−2·9, 3·8	−0·4	−3·6, 2·7	
Lifestyle and socio-economic variables					0·16¶
Use of fatty substance when cooking					
None	Ref.		Ref.		
Vegetable oil	14·9	1·0, 28·8	9·2	−3·6, 21·9	
Margarine/butter	0·2	−13·7, 14·1	3·2	−9·6, 15·9	
Use of dietary supplement					
Non-user	Ref.		Ref.		
Multivitamin/mineral user	12·3	9·9, 14·6	6·2	4·0, 8·3	
Any user	14·8	13·1, 16·5	6·4	4·8, 8·0	
Alcohol intake† (per 10 g)	−2·7	−3·2, −2·3	−1·9	−2·4, −1·5	
Alcohol status					
Never drinker	Ref.		Ref.		
Ex-drinker	20·0	9·7, 30·3	11·6	2·3, 20·9	
Occasional drinker	4·3	−5·0, 13·6	6·2	−4·8, 17·2	
Current drinker‡	14·0	6·4, 21·5	11·3	−1·3, 23·9	
Alcohol preference†					
Wine drinker	Ref.		Ref.		
Beer drinker	−7·7	−9·8, −5·6	−0·6	−2·5, 1·4	
Spirits drinker	−6·9	−10·9, −3·0	−1·1	−4·7, 2·5	
Mixed drinker	−1·1	−3·2, 1·0	−0·2	−2·2, 1·7	
Smoking status					
Never smoker	Ref.		Ref.		
Past smoker	−1·3	−3·1, 0·5	−0·8	−2·5, 0·9	
Current smoker	−18·4	−20·0, −16·7	−10·5	−12·1, −8·9	
Hormone replacement therapy use					
Never user	Ref.		Ref.		
Past user	−2·0	−4·1, 0·1	−0·4	−2·3, 1·4	
Current user	−0·1	−1·7, 1·6	−0·8	−2·3, 0·7	
BMI (per 1 kg/m^2 increment)	−1·1	−1·2, −0·9	−1·3	−1·6, −1·0	
Waist circumference (per 1 cm increment)	−0·4	−0·5, −0·4	0·1	0·0, 0·3	
Education					
Low	Ref.		Ref.		
Medium	8·3	6·7, 10·0	4·1	2·6, 5·6	
High	23·4	21·3, 25·5	13·2	11·1, 15·2	

Ref., reference.
*Regression coefficients (β) reflect the difference in the intake of wholegrain products (g/d) for each given increment in the independent variable.
†Among current drinkers.
‡Current drinkers with median intake of 20 g alcohol/d.
§Variation in intake of wholegrain products explained by dietary variables.
‖Variation in intake of wholegrain products explained by dietary and physical activity variables.
¶Variation in intake of wholegrain products explained by dietary, physical activity, lifestyle (including anthropometry) and socio-economic variables.

school education and negative associations with alcohol intake, BMI and smoking were observed among both men and women.

Although the participants in the present study are high consumers of wholegrain products, these results still mirror findings of previous studies on populations with different consumption patterns. In the Iowa Women's Health Study a higher intake of whole grains was associated with higher education, lower BMI and waist:hip ratio, being a non-smoker, doing more regular physical

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Table 4 Regression derived coefficients (β) and 95 % confidence intervals of dietary, lifestyle, anthropometric and socio-economic variables among 26 175 men included in the Diet, Cancer and Health cohort study (1993–7)

	Analysis adjusted for age and centre		Mutual adjusted analysis		
	β*	95 % CI	β*	95 % CI	R^2
Dietary variables					0·15§
Fish (per 25 g)	9·4	8·7, 10·2	4·7	4·0, 5·5	
Red meat (per 50 g)	−2·2	−3·2, −1·2	−10·1	−11·1, −9·1	
Poultry (per 10 g)	3·4	2·9, 3·8	0·7	0·3, 1·1	
Processed meat (per 10 g)	3·7	3·4, 4·1	6·0	5·7, 6·3	
Lean dairy products (per 100 g)	2·3	2·0, 2·6	1·2	1·0, 1·5	
Fatty dairy products (per 50 g)	1·3	1·1, 1·6	0·8	0·5, 1·0	
Fruits (per 100 g)	7·4	6·8, 8·0	1·8	1·3, 2·4	
Vegetables (per 100 g)	18·0	17·1, 18·9	12·9	11·9, 13·9	
Cakes (per 10 g)	2·0	1·6, 2·3	1·9	1·6, 2·3	
Refined grain products (per 30 g)	−6·8	−7·4, −6·1	−11·7	−12·4, −11·1	
Physical activity variables					0·17‖
Walking (per 1 h)	2·2	−0·3, 4·8	−0·3	−2·6, 2·1	
Cycling (per 1 h)	17·1	14·5, 19·8	10·9	8·4, 13·4	
Sports (per 1 h)	6·3	2·6, 10·0	2·8	−0·5, 6·1	
Housework (per 1 h)	3·4	0·4, 6·3	2·4	−0·3, 5·2	
Gardening (per 1 h)	2·2	−0·4, 4·9	−1·8	−4·4, 0·7	
Hobby work (per 1 h)	4·8	2·3, 7·4	2·3	−0·2, 4·8	
Lifestyle and socio-economic variables					0·21¶
Use of fatty substance when cooking					
None	Ref.		Ref.		
Vegetable oil	−18·4	−34·1, −2·7	−8·4	−22·8, 5·8	
Margarine/butter	−33·7	−49·3, −18·1	−14·5	−28·7, −0·2	
Use of dietary supplement					
Non-user	Ref.		Ref.		
Multivitamin/mineral user	13·6	11·1, 16·2	5·4	3·2, 7·7	
Any user	16·9	15·0, 18·9	6·9	5·1, 8·7	
Alcohol intake† (per 10 g)	−4·3	−4·7, −4·0	−2·8	−3·1, −2·5	
Alcohol status					
Never drinker	Ref.		Ref.		
Ex-drinker	2·8	−17·6, 23·2	−1·1	−19·0, 16·8	
Occasional drinker	−1·1	−21·8, 19·6	−1·1	−23·9, 21·7	
Current drinker‡	−6·0	−24·9, 12·9	−2·4	−26·8, 21·9	
Alcohol preference†					
Wine drinker	Ref.		Ref.		
Beer drinker	−11·1	−13·2, −9·1	−2·8	−4·8, −0·9	
Spirits drinker	−6·8	−12·6, −1·0	−2·2	−7·4, 2·9	
Mixed drinker	0·1	−2·4, 2·7	−0·3	−2·5, 2·0	
Smoking status					
Never smoker	Ref.		Ref.		
Past smoker	−2·7	−5·0, −0·4	1·0	−1·0, 3·1	
Current smoker	−15·2	−17·4, −12·9	−6·4	−8·4, −4·3	
BMI (per 1 kg/m^2 increment)	−2·9	−3·2, −2·7	−2·2	−2·7, −1·7	
Waist circumference (per 1 cm increment)	−1·1	−1·2, −1·0	−0·2	−0·4, −0·1	
Education					
Low	Ref.		Ref.		
Medium	1·2	−0·8, 3·3	−2·1	−4·0, −0·2	
High	12·9	10·6, 15·3	3·4	1·1, 5·7	

Ref., reference.
*Regression coefficients (β) reflect the difference in the intake of wholegrain products (g/d) for each given increment in the independent variable.
†Among current drinkers.
‡Current drinkers with median intake of 10 g alcohol/d.
§Variation in intake of wholegrain products explained by dietary variables.
‖Variation in intake of wholegrain products explained by dietary and physical activity variables.
¶Variation in intake of wholegrain products explained by dietary, physical activity, lifestyle (including anthropometry) and socio-economic variables.

activity, using vitamin supplements and HRT. Higher whole grains intake was also associated with greater energy intake, consumption of less refined grains, sucrose and red meat, and consumption of more fruits and vegetables[29]. Additionally, surveys performed in the USA and UK have shown that consumers of whole grains are more often non-smokers, regular exercisers and consume more fruits and vegetables[30,31]. In a Norwegian study it was concluded that Norwegian wholegrain bread eaters were less likely to be smokers and were more physically active than white bread eaters, and in addition had lower serum cholesterol and systolic blood pressure and ate less total and saturated fat as a proportion of energy intake[3].

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Table 5 Mutual adjusted regression analysis derived coefficients (β), standard errors, R^2 and P values of dietary patterns*, † (ten principal components (PC)) for the intake of wholegrain products among 26 175 men and 28 545 women included in the Diet, Cancer and Health cohort study (1993–7)

	Women									
	PC1	PC10	PC2	PC8	PC9	PC5	PC3	PC6	PC7	PC4
Intake of wholegrain products (g/d)										
R^2	0·0323	0·0616	0·0845	0·0999	0·1089	0·1171	0·1197	0·1203	0·1209	0·1209
β‡	7·1	13·6	−5·1	9·3	5·9	5·1	0·2	1·5	5·1	−1·2
SE	0·2	0·5	0·3	0·4	0·4	0·3	0·2	0·4	0·3	0·3
P value	$<10^{-3}$	$<10^{-3}$	$<10^{-3}$	$<10^{-3}$	$<10^{-3}$	$<10^{-3}$	0·491	$<10^{-3}$	$<10^{-3}$	$<10^{-3}$
	Men									
	PC10	PC1	PC5	PC2	PC8	PC9	PC6	PC3	PC7	PC4
Intake of wholegrain products (g/d)										
R^2	0·0613	0·0964	0·1183	0·1318	0·1449	0·1514	0·1516	0·1517	0·1517	0·1517
β‡	21·6	8·4	10·8	−4·9	10·6	6·7	−1·6	−3·3	0·1	−0·9
SE	0·6	0·3	0·4	0·4	0·5	0·5	0·5	0·4	0·5	0·4
P value	$<10^{-3}$	$<10^{-3}$	$<10^{-3}$	$<10^{-3}$	$<10^{-3}$	$<10^{-3}$	$<10^{-3}$	$<10^{-3}$	0·859	0·0025

*See Appendix 1 and 2 for description.
†Principal components are presented in descending order of how much of the total variation in the intake of wholegrain products they explain (R^2).
‡Mutual adjusted and adjusted for age, centre, alcohol intake, alcohol preference, alcohol status, physical activity (hours per week spent walking, hours per week spent cycling, hours per week spent doing sports, hours per week spent gardening, hours per week spent doing housework, hours per week spent doing hobby work), intake of dietary supplements, smoking status, school education, use of a fatty substance when cooking, BMI, waist circumference and hormone replacement therapy (women only).

Dietary factors may cluster together; thus instead of looking at individual foods or nutrients, dietary pattern analysis has recently emerged as an alternative and complementary approach in the study of diet in relation to diseases[38]. In addition to the single nutrient approach, we used principal components analysis to extract dietary patterns from the ten food groups studied and evaluated these in association to intake of wholegrain products. We observed that different dietary patterns were differently related to intake of wholegrain products. In both men and women, the strongest positive associations with intake of wholegrain products were seen for a dietary pattern (PC1) that could be interpreted as a 'varied' dietary pattern because of positive loadings for all dietary factors studied and a dietary pattern (PC10) that was characterized by a contrast between processed meat and vegetables (positive scoring coefficients) and red meat and refined-grain products (negative scoring coefficients). These two dietary patterns explained more than half of the variation in the total intake of wholegrain products among men (9·6 %) and women (6·2 %). In the present study, describing the diet in combination and relating this to the intake of wholegrain products yielded results that were comparable to the results obtained in regression analyses focusing on individual dietary factors, indicating that the study of dietary patterns could be a useful alternative when evaluating the association between wholegrain products and other dietary factors.

There is growing epidemiological evidence indicating that whole grains or wholegrain foods reduce the risk of several chronic diseases including CVD[2,5–9], type 2 diabetes[10–14] and some cancers[15–17]. Whole grains contain many bioactive compounds that might be responsible for their protective effects; e.g. fermentable carbohydrates that affect the gut environment, compounds that function as antioxidants (e.g. trace minerals and phenolic compounds) and phyto-oestrogens with potential hormonal effects[28]. Alternatively, the protective effects of whole grains and wholegrain foods towards the development of chronic diseases could be mediated via their beneficial effect on weight control through the promotion of satiety and enhancement of satiation[28]. In the present study, higher wholegrain products intake was associated with lower BMI, which is comparable to findings from other cross-sectional studies[18–21]. Also, risk of obesity or abdominal obesity has cross-sectionally been reported to be lower among persons with high intakes of whole grains compared with persons with low intakes[25]. In addition, in prospective studies intake (or change in intake) of whole grains has been inversely associated with weight gain or gain in BMI[22–24]. Cross-sectionally, high intakes of whole grains have been linked to less frequent development of metabolic syndrome[25–27], a risk factor of CVD and type 2 diabetes. Epidemiological studies have also indicated that persons with the metabolic syndrome are at increased risk of colon cancer[39].

The strengths of the present study are its large size and that data on dietary intake were measured by a validated FFQ[34–36]. Measurements of alcohol habits, smoking status and physical activity in leisure time were also collected by a comprehensive lifestyle questionnaire. At baseline, anthropometric measurements (height, weight, waist circumference) were measured by trained health professionals. We used data from a large population with a high degree of variability in the intake of wholegrain products, which allowed us to consider a number of

different factors altogether. There are several limitations to our study. First, our study is cross-sectional. Second, we cannot exclude that measurement errors introduced by either the participants or the questionnaires may have affected the results. In spite of the comprehensive model tested in the present study, including several dietary, lifestyle and socio-economic factors hypothesized to be associated with intake of wholegrain products, only 16 % and 21 % of the variation in the intake of wholegrain products among women and men, respectively, was explained by the model. The inability to explain a higher percentage of the variance in wholegrain products intake may be due to several factors, including difficulties inherent in the assessing of wholegrain products and an inability to measure unknown factors relevant to the intake of wholegrain products.

In conclusion, the present results suggest that consumption of wholegrain products is associated with other individual dietary factors and dietary patterns, healthier lifestyle habits and higher socio-economic status. This could contribute to the associations observed between wholegrain products intake and risk of various chronic diseases. Future epidemiological studies on the intake of wholegrain products and disease risk need to take into account possible confounding by other dietary and lifestyle-related parameters when examining the relationship between wholegrain products intake and risk of diseases.

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Appendix 1

Principal components and corresponding scoring coefficients for dietary variables among 28 545 women in the Diet, Cancer and Health cohort study

Principal component	Positive scoring coefficients	Negative scoring coefficients	Variance explained (%)
PC1	Fish (0·45) Red meat (0·43) Poultry (0·32) Processed meat (0·32) Lean dairy products (0·17) Fatty dairy products (0·16) Fruits (0·32) Vegetables (0·35) Cakes (0·20) Refined-grain products (0·29)		20
PC2	Red meat (0·27) Processed meat (0·43) Fatty dairy products (0·12) Cakes (0·38) Refined-grain products (0·38)	Fish (−0·20) Poultry (−0·28) Lean dairy products (−0·09) Fruits (−0·33) Vegetables (−0·46)	16
PC3	Fatty dairy products (0·39) Fruits (0·29) Vegetables (0·17) Cakes (0·50) Refined-grain products (0·34)	Fish (−0·09) Red meat (−0·37) Poultry (−0·15) Processed meat (−0·40) Lean dairy products (−0·21)	11
PC4	Poultry (0·02) Lean dairy products (0·63) Fruits (0·06) Cakes (0·32) Refined-grain products (0·24)	Fish (−0·08) Red meat (−0·18) Processed meat (−0·11) Fatty dairy products (−0·62) Vegetables (−0·06)	10
PC5	Processed meat (0·14) Vegetables (0·02) Lean dairy products (0·59) Fatty dairy products (0·44) Fruit (0·26)	Fish (−0·00) Red meat (−0·02) Poultry (−0·54) Vegetables (−0·06) Cakes (−0·13) Refined-grain products (−0·25)	10
PC6	Fish (0·26) Poultry (0·34) Lean dairy products (0·36) Fatty dairy products (0·42) Refined-grain products (0·13)	Red meat (−0·22) Processed meat (−0·20) Fruits (−0·63) Vegetables (−0·08) Cakes (−0·04)	8
PC7	Poultry (0·55) Processed meat (0·17) Lean dairy products (0·16) Fatty dairy products (0·24) Fruits (0·21)	Fish (−0·73) Red meat (−0·02) Vegetables (−0·05) Cakes (−0·06) Refined-grain products (−0·01)	7
PC8	Fish (0·20) Poultry (0·24) Processed meat (0·05) Fatty dairy products (0·03) Fruits (0·07) Cakes (0·59)	Red meat (−0·04) Lean dairy products (−0·04) Vegetables (−0·31) Refined-grain products (−0·67)	7
PC9	Red meat (0·36) Lean dairy products (0·09) Fatty dairy products (0·00) Vegetables (0·62) Cakes (0·30)	Fish (−0·33) Poultry (−0·17) Processed meat (−0·14) Fruits (−0·40) Refined-grain products (−0·27)	6
PC10	Fish (0·03) Processed meat (0·65) Vegetables (0·38) Cakes (0·06)	Red meat (−0·62) Poultry (−0·05) Lean dairy products (−0·08) Fatty dairy products (−0·06) Fruits (−0·15) Refined-grain products (−0·06)	5

PC, principal component.

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Appendix 2

Principal components and corresponding scoring coefficients for dietary variables among 26 175 men in the Diet, Cancer and Health cohort study

Principal component	Positive scoring coefficients	Negative scoring coefficients	Variance explained (%)
PC1	Fish (0·43) Red meat (0·43) Poultry (0·36) Processed meat (0·25) Lean dairy products (0·12) Fatty dairy products (0·12) Fruits (0·31) Vegetables (0·43) Cakes (0·22) Refined-grain products (0·29)		19
PC2	Red meat (0·22) Processed meat (0·47) Fatty dairy products (0·22) Cakes (0·40) Refined-grain products (0·40)	Fish (−0·17) Poultry (−0·30) Lean dairy products (−0·10) Fruits (−0·28) Vegetables (−0·38)	15
PC3	Fatty dairy products (0·32) Fruits (0·41) Vegetables (0·12) Cakes (0·47) Refined-grain products (0·27)	Fish (−0·15) Red meat (−0·40) Poultry (−0·10) Processed meat (−0·42) Lean dairy products (−0·22)	11
PC4	Lean dairy products (0·69) Fruits (0·14) Cakes (0·27) Refined-grain products (0·22)	Fish (−0·14) Red meat (−0·16) Poultry (−0·04) Processed meat (−0·01) Fatty dairy products (−0·57) Vegetables (−0·09)	11
PC5	Fish (0·04) Red meat (0·02) Processed meat (0·18) Lean dairy products (0·49) Fatty dairy products (0·51) Fruits (0·37)	Poultry (−0·43) Vegetables (−0·04) Cakes (−0·13) Refined-grain products (−0·34)	9
PC6	Fish (0·19) Poultry (0·41) Lean dairy products (0·42) Fatty dairy products (0·47) Cakes (0·03) Refined-grain products (0·13)	Red meat (−0·27) Processed meat (−0·21) Fruits (−0·51) Vegetables (−0·12)	8
PC7	Red meat (0·01) Poultry (0·43) Processed meat (0·24) Lean dairy products (0·07) Fatty dairy products (0·18) Fruits (0·15) Vegetables (0·15) Refined-grain products (0·11)	Fish (−0·78) Cakes (−0·24)	7
PC8	Fish (0·20) Poultry (0·43) Processed meat (0·40) Fruits (0·32) Cakes (0·18)	Red meat (−0·37) Lean dairy products (−0·16) Fatty dairy products (−0·05) Vegetables (−0·49) Refined-grain products (−0·29)	7
PC9	Red meat (0·33) Poultry (0·14) Lean dairy products (0·06) Fatty dairy products (0·01) Vegetables (0·11) Cakes (0·60)	Fish (−0·25) Processed meat (−0·15) Fruits (−0·18) Refined-grain products (−0·62)	7
PC10	Fish (0·03) Processed meat (0·47) Vegetables (0·60) Cakes (0·14)	Red meat (−0·52) Poultry (−0·17) Lean dairy products (−0·04) Fatty dairy products (−0·05) Fruits (−0·29) Refined-grain products (−0·13)	6

PC, principal component.

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