Moderate Consumption of Healthy Nordic Foods is Associated with Reduced Mortality in the Norwegian Women and Cancer Study: a Prospective Cohort Study

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Abstract

Background

High adherence to healthy Nordic diets may enhance longevity. However, optimal intake levels of healthy Nordic foods are not known. Hence, in a large prospective cohort of women in Norway we examined all-cause mortality in relation to intake of five food groups that are part of a healthy Nordic diet: Nordic fruits and vegetables, fatty fish, lean fish, wholegrain products, and low-fat dairy products.

Methods

A total of 87 899 women who completed a food frequency questionnaire between 1996 and 2004 were followed for mortality until the end of 2018. Cox proportional hazards regression models were used to examine the associations between consumption of the Nordic food groups and all-cause mortality. The food groups were examined as categorical exposures, and all but wholegrain products also as continuous exposures in restricted cubic spline models.

Results

A total of 9 168 women died during the 20-year follow-up. Nordic fruits and vegetables, fatty fish and low-fat dairy products were not linearly associated with mortality ($p < 0.05$). The optimal intake levels and hazard ratios (HR) and 95% confidence intervals (CI) associated with these intakes were approximately 200 grams/day of Nordic fruits and vegetables (HR 0.84 (95% CI: 0.77–0.90)), 10–20 grams/day of fatty fish (HR 0.98 (95% CI: 0.92–1.03)) and 200 grams/day of low-fat dairy products (HR 0.94 (95% CI: 0.89–0.99)) compared to no consumption. High consumption of fatty fish (≥ 70 grams/day) was associated with increased mortality. Intake of wholegrain products of >120 grams/day was associated with lower mortality (HR 0.92 (95% CI: 0.85–0.99)) compared to < 60 grams per day. Lean fish consumption was not associated with mortality. After stratification by smoking status, the observed association for Nordic fruits and vegetables was only significant in ever smokers with the optimal intake level at 250 grams/day (HR 0.78 (95% CI: 0.71–0.86)).

Conclusion

Moderate intake of healthy Nordic foods seems to be better than low or high intake, and high consumption either does not add any beneficial effects or can compromise longevity. Stronger inverse associations for Nordic fruits and vegetables were observed in former and current smokers.

Background

Over the past decade there has been a movement towards health-promoting regional and environmentally friendly diets (1). A healthy Nordic diet, associated with properties beneficial in prevention of cardiovascular diseases, type 2 diabetes and colorectal cancer, has been recommended (1–6). The evidence is largely founded on studies of indices constructed in line with dietary guidelines with emphasis on varieties of foods traditionally used and cultivated in the Nordic region (7, 8). An index can be described as a constructed indicator measuring the cumulative effects of several components combined. In the case of dietary indices, the components included can be single foods, food groups, nutrients, and ratios between such (9).

The Healthy Nordic Food Index and the Baltic Sea Diet Score are indices that have been developed to measure level of adherence to a healthy Nordic diet (7, 8). High adherence to these indices is linked to longevity in populations across Nordic countries including Denmark, Sweden, Finland and Norway (5, 7, 10–12). The Healthy Nordic Food Index values higher intake of fish, rye bread, oatmeal, root vegetables, cabbages and apples/pears, and the Baltic Sea Diet Score values higher consumption of Nordic fruits and vegetables, Nordic wholegrains, fish, low-fat dairy and rapeseed oil, and lower consumption of red and processed meat, saturated fat and alcohol. Both indices are constructed with the use of population-based cut-off values to score intake levels of included components.

An advantage of such indices compared to single foods is that a larger part of the total diet is considered, but there are some dilemmas concerning the interpretation of the results. Firstly, to assume that such indices follows a linear scale can be problematic, as dose–response relationships for nutrients are likely non-linear (13). The relationship between the food intake and morbidity or mortality is often U-shaped, with an increased risk with both low and high intake (14). Secondly, when comparing results across studies, the cut-off values for index components vary considerably from study to study. For example, the cut-off value for assigning points to the index component “fish” in the Healthy Nordic Food Index varies from > 41 grams per day in one population (7) to ≥ 103 grams per day in another population (5). This is common for all indices that use population-based cut-off values (15).

The public health message from these studies is a general and unspecified advice to increase the consumption of healthy Nordic foods, but the optimal intake levels for long-term health are uncertain.

Olsen et al. concluded that healthy Nordic food items should be considered in public health recommendations, but we need to know more about risk associated with specific intake levels of foods that are part of a healthy Nordic diet (7). Hence, to evaluate the association of food groups central in a healthy Nordic diet and long-term health, the aim of this study is to examine the association between Nordic fruits and vegetables, fatty fish, lean fish, wholegrain products, and low-fat dairy products with all-cause mortality.

Materials And Methods

Study design and setting

The population for this paper has been described previously (16). In short, the Norwegian Women and Cancer Study (NOWAC) is a nationwide study with approximately 172 000 participants. The women were recruited in waves from 1991 to 2007 and were randomly drawn from the National Population Registry.

Information on vital status and cancer incidence was obtained by linkage to the National Population Registry and the Cancer Registry of Norway, using the unique 11-digit identity number assigned to all Norwegian citizens.

Participants completed a mailed self-administered questionnaire including questions about anthropometric, sociodemographic, reproductive and lifestyle factors. Most of the questionnaires included four pages of food frequency questions. The questionnaire used has previously been published elsewhere (17). Follow-up questionnaires were mailed approximately every sixth year after recruitment.

A study on external validity of the NOWAC found no major source of selection bias (18).

Study participants

The baseline for this paper is partly the first NOWAC mailing from 1996 to 1997 and 2003 to 2004 (response rate of 57% and 48%, respectively), and partly the second mailing (follow-up questionnaire) from 1998 to 1999 to those enrolled in 1991 to 1992 who had not been given the food frequency questions at enrolment (response rate of 81%). In total 101 316 women aged 41–76 at baseline were considered eligible for inclusion. Women who had emigrated ($n = 3$) and women with no follow-up ($n = 13$) were excluded. We further excluded women with implausible daily energy intake ($< 2\,500$ kJ ($n = 1\,033$) or $> 15\,000$ kJ ($n = 141$)), and women with missing information on the following variables: Body mass index (BMI) ($n = 2\,272$), physical activity ($n = 8\,548$) and smoking habits ($n = 1\,407$), leaving a total number of 87 899 women for the present analysis.

Dietary assessment

Diet was assessed using a semi-quantitative food frequency questionnaire (FFQ). The FFQ was designed to measure the typical diet during the past year with special emphasis on fish consumption. The response options were given with four to seven frequency categories ranging from never/seldom to six or more per week. Questions about portion size were included for some food items as natural units, such as number of carrots, or household units, such as tablespoons.

The FFQ used in NOWAC has been validated in several studies. Hjartåker et al. reported that the FFQ's ability, when compared to information from repeated 24-hour dietary recalls, was good to rank women for foods eaten frequently and fairly good for macronutrients (19). Another validation study that compared the relation between fish consumption registered by the FFQ and fatty acids composition in serum phospholipids concluded that habitual intake of fish in high-consuming populations was reflected in serum phospholipids (20). In a study of the reproducibility of the FFQ, there were some indications of seasonal reporting bias, but the overall results were in line with what has been found in studies on similar self-administered FFQs developed to assess habitual diet (21).

The Norwegian Weight and Measurement Table with standardised portion sizes and weights was used to convert the consumption of food items to grams (22), and information about the nutrient content in foods was obtained from the Norwegian Food Composition Database (23). The calculations of daily intake of food items, energy and nutrients were made using a statistical program for SAS (SAS Institute Inc., Cary, NC, USA) developed at the Department of Community Medicine, University of Tromsø, for the NOWAC cohort. Missing frequency values were treated as no consumption, and missing portion sizes were set to the smallest portion size asked for.

Exposures

We included five Nordic food groups that can be extrapolated to our dietary guidelines in the analysis. The questions in the FFQ that formed the basis for the construction of the food groups has been described previously (24). Based on the criteria set by Olsen et al., we have included fruits and vegetables produced in the Nordic climate without the use of external energy and that were available from the FFQ: broccoli/cauliflower, cabbage, carrots, swede, mixed vegetables (commonly a frozen mix of carrots, broccoli and cauliflower) and apples/pears (7). Consumption of Nordic fruits and vegetables was divided into four categories (grams/day): < 100 , $100\text{--}199$, $200\text{--}299$, ≥ 300 .

We analysed lean and fatty fish separately because they are specified in our dietary guidelines, and are sources of specific essential nutrients such as vitamin D and omega-3 fatty acids from fatty fish, and iodine from lean fish (14). Fatty fish was classified as fish with $\geq 4\%$ fat in the meat (salmon, trout, herring, mackerel), and was categorised in four categories (grams/day): < 5 , $5\text{--}14$, $15\text{--}29$, ≥ 30 . Lean fish was classified as fish containing $< 4\%$ fat in the meat (cod, haddock, plaice) but excluding products like fish cakes, fish balls, fish spread and stew, and was categorised in four categories (grams/day): < 15 , $15\text{--}29$, $30\text{--}44$, ≥ 45 .

Low-fat dairy products, comprised of semi-skimmed milk ($\leq 1.5\%$), skimmed milk (0.1% fat) and yoghurt ($\leq 3.4\%$ fat). It was chosen to include this food group as it is part of the Baltic Sea Diet Score, and because it is the main source of iodine in the Norwegian diet. Consumption was categorised into four categories: non-consumers, ≤ 200 , $201\text{--}400$, > 400 grams/day.

Wholegrain products included wholegrain bread and breakfast cereals and was categorised into four categories (grams/day): < 60 , $60\text{--}119$, $120\text{--}179$, ≥ 180 .

Confounders

Covariates included in the analysis were chosen based on literature and selected with the use of Directed Acyclic Graphs (DAGs). DAGs are a tool that can help in selecting confounding factors to include in the statistical analysis when the purpose is to study causal relationships (25). The selection of confounding factors through DAGs are based on the assumption of causation between included variables in the DAG, hence wrong assumptions could lead to misspecified models. The strength is however that possible colliders are also identified in a DAG, reducing the risk of introducing bias in the statistical models. The

following confounders were included in the analysis: physical activity, body mass index (BMI), smoking status and intake of energy, alcohol and processed meat.

Physical activity

Physical activity level was included based on self-report on a ten-point scale estimating physical activity at home, at work, exercising and walking. A validation study showed that self-reporting was able to rank women according to their level of physical activity (26). Physical activity was categorised as low (1–4 points), medium (5–6 points) or high (7–10 points).

BMI

BMI was calculated based on self-reported height and weight (kg/m^2), and was categorised in four categories: < 20 , $20\text{--}24.9$, $25\text{--}29.9$, $\geq 30 \text{ kg}/\text{m}^2$. Self-reported weight and height has been found to provide valid ranking of BMI in NOWAC (27).

Smoking status

The smoking variable was computed by combining information on smoking status (never, former and current), with age at smoking initiation for those who have ever smoked. For current smokers who started smoking before the age of 20 we also included information about pack-years (number of cigarettes smoked per day, divided by 20, multiplied by number of years smoked). Twenty or more pack-years was defined as heavy smoking, and 0–19 pack-years was defined as moderate. Further adjustments for pack-years did not change the confounding effect of smoking. Smoking exposure was then divided into six categories: never smoker, current heavy smoker early starter (age at start smoking < 20), current moderate smoker early starter, current smoker late starter (age at start smoking ≥ 20), former smoker early starter, former smoker late starter.

Intake of energy, alcohol, and processed meat

The calculations of daily intake of nutrients, food items and energy has been described in the dietary assessment segment above. More specifically, the calculated total energy intake was based on approximately 85 food frequency questions that cover the habitual diet of the women. Energy intake was computed as a continuous variable (kJ per day) excluding energy from alcohol.

Intake of alcohol was calculated based on three questions about intake of alcoholic beverages and was computed as a categorical variable to get a group of non-consumers, and categories representing lower and higher intake (grams/day): non-consumers, 0–5, > 5 .

Intake of processed meat included three to four questions on intake of meatballs, hamburgers, sausages and sandwich meats (liver pâté), and is computed as four categories (grams/day): < 15 , $15\text{--}29$, $30\text{--}44$, ≥ 45 (28).

Outcome

The women were followed from return of the FFQ and until death or censoring, which was the date of emigration or end of follow-up on 31 December 2018.

Statistical methods

Population characteristics and dietary factors by healthy Nordic food group categories were analysed using χ^2 tests for categorical covariates and Kruskal–Wallis tests for continuous covariates. Distribution of covariates is presented across consumption categories of the Nordic food groups as mean (and standard deviation) for age, as median intake (and 10th–90th percentile) for energy, and percentages (%) for the covariates expressed categorically.

Spearman's rank-order correlation was used to test the association between the Nordic food groups and is presented as the correlation coefficient (r_s).

Cox proportional hazards regression models with age as the underlying time scale were used to examine the associations between consumption of the five Nordic food groups and all-cause mortality. Estimates from the Cox regression models are presented as age-adjusted and multivariable-adjusted estimates. The Nordic food groups were mutually adjusted for in the multivariable-adjusted model, and the results were also adjusted for: physical activity, BMI group, smoking status, alcohol intake, estimated intake of energy and processed meat. Both models examined the Nordic food groups expressed as categorical exposures, and four of the Nordic food groups were further examined in the multivariable-adjusted model as continuous exposures in restricted cubic splines. The wholegrain products variable, which is only based on two FFQ frequency questions, was not examined in restricted cubic splines, as the distribution of values could not be approximated to a continuous variable.

Number of knots in the restricted cubic splines was determined by testing and comparing models with three, four and five knots by the Akaike and Bayesian information criteria. This test was chosen because unlike the likelihood-ratio test and Wald testing procedures, the models do not have to be nested to compare how well the different models fit the data. Models with the smallest AIC value were judged to fit the data better, resulting in three knots at fixed percentiles (10, 50, 90) of the distribution (29). The p-value for non-linearity in the restricted cubic spline analysis was calculated by performing Wald testing, which tests the null hypothesis that the coefficient of the second spline is equal to zero. Proportional-hazards assumptions were tested with a Schoenfeld residuals test.

All models were stratified by subcohorts ($n = 5$), which were constructed by grouping together the FFQs that are most similar regarding the food frequency questions included, and which were completed closest together in time, as the data were collected over a period of almost ten years. We explored potential interactions between the Nordic food groups and smoking habits by adding a product term in the mutually adjusted models. If a statistically significant interaction effect was observed, we performed analyses stratified by never and ever smokers.

Results

During a median of 20 (range 0.2–23) years of follow-up, 9 168 women died, mainly from cancer (n = 4 719) and cardiovascular diseases (n = 1 668).

Table 1 shows the total population distribution and number of deaths by consumption categories of the Nordic food groups, and the median intake within the categories.

Table 1. Population distribution and intake of healthy Nordic food groups by intake categories

From: Moderate consumption of healthy Nordic foods is associated with reduced mortality in the Norwegian Women and Cancer study: a prospective cohort study

Healthy Nordic food groups	Nordic fruits and vegetables intake				Wholegrain products intake				Fatty fish intake				Lean fish intake				Low-fat dairy intake	
	Low		High		Low		High		Low		High		Low		High		Low	
Category range (grams/day)	< 100	100–199	200–299	≥ 300	< 60	60–119	120–179	≥ 180	< 5	5–14	15–29	≥ 30	< 15	15–29	30–44	≥ 45	Non-consumers	
Median intake by intake categories	65	149	237	368	34	100	121	180	0	10	21	42	6	22	36	61	0	
Number of women	21 667	34 096	19 876	12 260	15 527	25 716	16 890	29 766	25 059	27 128	23 116	12 596	29 616	23 521	15 532	19 230	12 972	
Number of deaths	2 730	3 434	1 917	1 087	1 527	2 875	1 673	3 093	2 695	2 694	2 252	1 527	2 716	2 144	1 565	2 743	1 687	

The correlation matrix (Table 2) shows that lean and fatty fish were most strongly correlated of the five food groups, but the correlation was still quite low ($r_s = 0.21$).

Table 2. Spearman correlation coefficients between intake of healthy Nordic food groups

From: Moderate consumption of healthy Nordic foods is associated with reduced mortality in the Norwegian Women and Cancer study: a prospective cohort study

Healthy Nordic food groups	Nordic fruits and vegetables intake	Wholegrain intake	Fatty fish intake	Lean fish intake	Low-fat dairy intake
Nordic fruits and vegetables intake	1				
Wholegrain intake	0.05	1			
Fatty fish intake	0.19	0.01	1		
Lean fish intake	0.15	0.09	0.21	1	
Low-fat dairy intake	0.03	0.15	0.02	0.07	1

Table 3 gives the distribution of included covariates across consumption categories of the Nordic food groups. The oldest women were in the high-consumption group of lean fish, and the greatest age span across intake categories was within this food group (ranging from 51.0 years old in low consumers to 53.5 in high consumers). Similar tendencies were seen within the food group fatty fish, where mean age ranged from 51.0 in low consumers to 53.2 years in high consumers. Within the other Nordic food groups the age differences across intake categories were minimal. We see a general tendency of women in the high-consuming categories within the Nordic food groups being more physically active, and more likely to be never smokers except among high consumers of lean and fatty fish. Across all food groups, energy intake was higher in the higher-consumption categories. The proportions of women reporting overweight (BMI 25.0–29.9 kg/m²) and obesity (BMI ≥ 30 kg/m²) were higher among high consumers of Nordic fruits and vegetables and lean fish, whereas the opposite was observed within the wholegrain products group.

Due to the high number of participants, even marginal differences in the distribution of covariates across consumption categories of the healthy Nordic food groups were statistically significant ($p < 0.05$).

Table 3. Baseline information according to intake categories of healthy Nordic food groups

From: Moderate consumption of healthy Nordic foods is associated with reduced mortality in the Norwegian Women and Cancer study: a prospective cohort study

Covariates	Nordic fruits and vegetables intake				Wholegrain products intake				Fatty fish intake				Lean fish intake
	< 100	100–199	200–299	≥ 300	< 60	60–119	120–179	≥ 180	< 5	5–14	15–29	≥ 30	< 15
Age, mean (SD)	51.3 (6.7)	51.7 (6.5)	52.2 (6.5)	52.3 (6.0)	52.2 (6.1)	52.0 (6.5)	52.2 (6.6)	51.2 (6.5)	51.0 (6.6)	51.6 (6.4)	52.1 (6.3)	53.2 (6.5)	51.0 (6.2)
Physical activity % (n)													
Low	33 (7197)	27 (9218)	23 (4514)	21 (2629)	31 (4766)	29 (7538)	24 (3989)	24 (7265)	29 (7374)	27 (7373)	25 (5747)	24 (3064)	29 (8486)
Medium	42 (9028)	44 (15141)	44 (8739)	40 (4953)	41 (6316)	43 (11016)	44 (7391)	44 (13138)	43 (10655)	44 (11927)	44 (10110)	41 (5169)	42 (12283)
High	25 (5442)	29 (9737)	33 (6623)	38 (4678)	29 (4445)	28 (7162)	33 (5510)	32 (9363)	28 (7030)	29 (7828)	31 (7259)	35 (4363)	30 (8847)
BMI % (n)													
< 20	8 (1756)	6 (2160)	6 (1125)	5 (633)	6 (942)	5 (1319)	6 (970)	8 (2443)	7 (1761)	6 (1740)	6 (1432)	6 (741)	7 (2149)
20–24.9	55 (11966)	55 (18615)	53 (10546)	51 (6194)	50 (7831)	52 (13403)	54 (9091)	57 (16996)	53 (13339)	54 (14763)	54 (12553)	53 (6666)	55 (16224)
25–29.9	28 (5995)	30 (10206)	32 (6371)	33 (4079)	33 (5057)	33 (8360)	32 (5349)	27 (7885)	30 (7594)	30 (8094)	31 (7063)	31 (3900)	29 (8564)
≥ 30	9 (1950)	9 (3115)	9 (1834)	11 (1354)	11 (1697)	10 (2634)	9 (2634)	8 (2442)	9 (2365)	9 (2531)	9 (2068)	10 (1289)	9 (2679)
Smoking status % (n)													
Never	31 (6813)	36 (12214)	38 (7606)	38 (4658)	30 (4680)	34 (8677)	39 (6628)	38 (11306)	35 (8726)	37 (9980)	36 (8292)	34 (4293)	35 (10325)
Current heavy smoker early starter	11 (2207)	7 (2238)	5 (926)	4 (533)	10 (1521)	7 (1867)	4 (730)	6 (1786)	7 (1750)	7 (1777)	6 (1446)	7 (931)	8 (2295)
Current moderate smoker early starter	16 (3538)	13 (4494)	11 (2174)	9 (1143)	15 (2274)	13 (3449)	10 (1689)	13 (3937)	10 (3665)	9 (3409)	9 (2770)	12 (1505)	13 (3946)
Current smoker late starter	12 (2625)	10 (3372)	8 (1668)	8 (928)	9 (1436)	10 (2633)	9 (1564)	10 (2960)	21 (2578)	23 (2452)	24 (2150)	11 (1413)	9 (2539)
Former smoker early starter	19 (4130)	22 (7488)	24 (4847)	27 (3354)	26 (3989)	23 (5880)	23 (3841)	21 (6109)	21 (5340)	23 (6179)	24 (5511)	22 (2789)	24 (7190)
Former smoker late starter	11 (2354)	13 (4290)	13 (2655)	13 (1644)	11 (1627)	13 (3210)	14 (2438)	12 (3668)	12 (3000)	12 (3331)	13 (2947)	13 (1665)	11 (3321)
Alcohol % (n)													

Non-consumers	22 (4855)	20 (6922)	20 (3990)	22 (2639)	19 (2962)	19 (4832)	19 (3228)	25 (7384)	28 (6943)	20 (5302)	17 (3910)	18 (2251)	19 (5733)
0–5 (g/d)	53 (11556)	55 (18665)	56 (11022)	56 (6830)	54 (8328)	54 (13808)	57 (9639)	55 (16298)	54 (13562)	57 (15342)	55 (12651)	52 (6518)	54 (15860)
> 5 (g/d)	24 (5256)	25 (8509)	25 (4864)	23 (2791)	27 (4237)	28 (7076)	24 (4023)	20 (6084)	18 (4554)	24 (6484)	28 (6555)	30 (3827)	27 (8023)
Energy P50 (P10– P90) MJ/d	6.1 (4.1– 8.5)	6.7 (4.7– 9.1)	7.2 (5.1– 9.7)	7.5 (5.4– 10.3)	5.5 (3.6– 8.1)	6.1 (4.5– 8.1)	7.0 (5.3– 9.1)	7.9 (6.1– 10.3)	6.4 (4.3– 8.9)	6.7 (4.6– 9.1)	7.0 (4.9– 9.5)	7.5 (5.3– 10.2)	6.4 (4.3– 8.8)
Processed meat intake % (n)													
< 15 (g/d)	20 (4355)	19 (6342)	20 (4008)	25 (3108)	25 (3916)	21 (5333)	23 (3950)	16 (4614)	20 (4944)	19 (5164)	20 (4643)	24 (3062)	23 (6819)
15–29 (g/d)	30 (6470)	30 (10178)	29 (5841)	28 (3437)	30 (4719)	31 (7988)	33 (5518)	26 (7701)	28 (7038)	31 (8333)	30 (6888)	29 (3667)	29 (8574)
30–44 (g/d)	24 (5284)	26 (8976)	26 (5099)	23 (2782)	24 (3641)	26 (6591)	26 (4314)	26 (7595)	25 (6251)	26 (7033)	26 (5965)	23 (2892)	24 (7130)
≥ 45 (g/d)	26 (5558)	25 (8600)	25 (4928)	24 (2933)	21 (3251)	23 (5804)	18 (3108)	33 (9856)	27 (6826)	24 (6598)	24 (5620)	24 (2975)	24 (7093)
Percentage distribution by columns													
<i>SD</i> standard deviation													
<i>g/d</i> grams per day													
<i>MJ/d</i> mega Joule per day													
<i>P50</i> median intake, <i>P10</i> the 10 th percentile, <i>P90</i> the 90 th percentile													

The restricted cubic spline regression showed a significant J-shaped association for the food groups Nordic fruits and vegetables (Fig. 1A), low-fat dairy products (Fig. 1B) and fatty fish (Fig. 1C).

For Nordic fruits and vegetables, the nadir (the intake level associated with lowest mortality) was observed at 200 grams/day (HR 0.84 (95% CI: 0.77–0.90) compared to no consumption (Fig. 1A). We observed a significant interaction between smoking status and Nordic fruits and vegetables, and thus stratified analyses are also presented.

After stratification by never/ever smokers, the observed association was only significant in ever smokers with the nadir at 250 grams/day (HR 0.78 (95% CI: 0.71–0.86), compared to 150–200 grams/day for never smokers (150 grams/day: HR 0.89 (95% CI: 0.78–1.02); 200 grams/day: HR 0.89 (95% CI: 0.76–1.04) (Fig. 2). Furthermore, consumption of Nordic fruits and vegetables > 500 grams/day increased mortality among never smokers, but there were only 33 deaths registered at this consumption level.

For low-fat dairy products the nadir was observed at 200 grams/day (HR 0.94 (95% CI: 0.89–0.99) compared to no consumption, and high consumption (> 800 grams/day) increased mortality (Fig. 1B). For fatty fish the nadir was observed at an intake level of 10–20 grams per day (20 grams/day: HR 0.98 (95% CI: 0.92–1.03)), but this was not significantly better than not consuming fatty fish at all (Fig. 1C). Excessive consumption on the other hand was associated with increased mortality from 70 grams/day (HR 1.09 (95% CI: 1.01–1.17)). Consumption of lean fish was neutral in relation to mortality (Fig. 1D).

Table 4 gives the results when the intake is categorised into consumption groups. These confirmed the findings presented in Fig. 1. In addition, we note that the intake of wholegrain products, both of 120–179 grams/day and of ≥ 180 grams/day compared to < 60 grams per day, was associated with lower mortality (HR 0.92 (95% CI: 0.85–0.99)) (Table 4).

Table 4. Hazard ratios (HR) and all-cause mortality according to intake categories of healthy Nordic food groups

From: Moderate consumption of healthy Nordic foods is associated with reduced mortality in the Norwegian Women and Cancer study: a prospective cohort study

Healthy Nordic food groups	Intake categories (grams/day)	Total N	No. of deaths	All-cause mortality	
				Age-adjusted*	Multivariable-adjusted model **
				HR (95% CI)	HR (95% CI)
Nordic fruits and vegetables	< 100	21 667	2 730	1.00	1.00
	100–199	34 096	3 434	0.80 (0.76–0.84)	0.92 (0.87–0.97)
	200–299	19 876	1 917	0.77 (0.73–0.81)	0.95 (0.89–1.01)
	≥ 300	12 260	1 087	0.78 (0.73–0.84)	0.98 (0.91–1.06)
Wholegrain products	< 60	15 527	1 527	1.00	1.00
	60–119	25 716	2 875	0.91 (0.85–0.97)	0.97 (0.91–1.04)
	120–179	16 890	1 673	0.78 (0.73–0.83)	0.92 (0.85–0.99)
	≥ 180	29 766	3 093	0.84 (0.79–0.90)	0.92 (0.85–0.99)
Fatty fish	< 5	25 059	2 695	1.00	1.00
	5–14	27 128	2 694	0.95 (0.90–1.00)	1.00 (0.95–1.06)
	15–29	23 116	2 252	0.92 (0.87–0.97)	0.99 (0.93–1.05)
	≥ 30	12 596	1 527	0.99 (0.93–1.06)	1.05 (0.98–1.12)
Lean fish	< 15	29 616	2 716	1.00	1.00
	15–29	23 521	2 144	0.92 (0.87–0.97)	0.95 (0.90–1.01)
	30–44	15 532	1 565	0.93 (0.87–0.99)	0.98 (0.92–1.05)
	≥ 45	19 230	2 743	0.95 (0.90–1.01)	0.96 (0.90–1.01)
Low-fat dairy products	Non-consumers	14 659	1 687	1.00	1.00
	≤ 200	36 566	3 321	0.79 (0.75–0.84)	0.90 (0.85–0.95)
	201–400	19 085	2 013	0.77 (0.72–0.82)	0.94 (0.88–1.00)
	> 400	17 589	2 147	0.83 (0.78–0.89)	0.96 (0.90–1.03)
<i>HR</i> hazard ratio, <i>CI</i> confidence interval					
* Age-adjusted with age as underlying timescale and stratified by subcohorts (n = 5)					
** Age-adjusted and mutually adjusted for the healthy Nordic food groups, BMI < 20, 20–24.9, 25–29.9, ≥ 30 (kg/m ²), physical activity (low, medium, high), smoking status (never, current heavy smoker early starter, current moderate smoker early starter, current smoker late starter, former smoker early starter, former smoker late starter), intake of energy (kJ/day continuous), alcohol (non-consumer, 0–5, > 5 grams/day), and processed meat (< 15, 15–29, 30–44, ≥ 45 grams/day)					

In the stratified analysis, the median consumption of Nordic fruits and vegetables was 173 grams/day in never smokers and 159 grams/day in ever smokers (Table 5). An intake between 100–199 grams/day compared to < 100 grams/day was associated with reduced mortality among never smokers in similar strength as in the unstratified analysis (HR 0.90 (95% CI 0.81–0.99)). However, for ever smokers intake above 100 grams/day was beneficial (Table 6).

Table 5. Population distribution and intake of Nordic fruits and vegetables stratified by never and ever smokers

From: Moderate consumption of healthy Nordic foods is associated with reduced mortality in the Norwegian Women and Cancer study: a prospective cohort study

Smoking status	Total N	No. of deaths	Nordic fruits and vegetables intake Median intake (grams/day)	Nordic fruits and vegetables intake categories (grams/day)			
				< 100	100–199	200–299	≥ 300
Never smokers	28 684	2 607	173	68	150	237	366
Ever smokers	50 047	6 561	159	63	148	236	369

Table 6. Hazard ratios (HR) and all-cause mortality according to intake categories of Nordic fruits and vegetables stratified by never and ever smokers

Intake categories of Nordic fruits and vegetables (grams/day)	All-cause mortality					
	Never smokers			Ever smokers*		
	Total N	No. of deaths	HR (95% CI)	Total N	No. of deaths	HR (95% CI)
< 100	6 813	630	1.00	14 854	2 100	1.00
100–199	12 214	978	0.90 (0.81–0.99)	21 882	2 456	0.91 (0.86–0.97)
200–299	7 606	649	1.02 (0.91–1.14)	12 270	1 268	0.87 (0.81–0.94)
≥ 300	4 658	350	1.05 (0.92–1.21)	7 602	737	0.88 (0.80–0.96)
<i>HR</i> hazard ratio, <i>CI</i> confidence interval						
Age-adjusted and mutually adjusted for the healthy Nordic food groups, BMI < 20, 20–24.9, 25–29.9, ≥ 30 (kg/m ²), physical activity (low, medium, high), intake of energy (kJ/day continuous), alcohol (non-consumer, 0–5, > 5 grams/day), and processed meat (< 15, 15–29, 30–44, ≥ 45 grams/day)						
* additionally, adjusted for pack-years						

To minimise the chance of reverse causation we performed sensitivity analysis, starting follow-up two years after enrolment. Results did not change (Supplementary Figure 1), except that the association with low-fat dairy products and reduced mortality was slightly attenuated in the restricted cubic spline regression model due to a wider confidence interval believed to be caused by loss of cases (Supplementary Figure 1B). As findings for Nordic fruits and vegetables in part could reflect the influence of the consumption of other fruits and vegetables (24), we made further adjustments including other fruits and vegetables in the multivariable-adjusted model, but this did not influence the results (Supplementary Figure 2).

Discussion

Moderate consumption of Nordic fruits and vegetables and low-fat dairy products were associated with reduced all-cause mortality, while excessive intake of low-fat dairy products was associated with increased mortality during follow-up. Intake of wholegrain products estimated to be approximately in line with current recommendations for wholegrains of 70–90 grams/day was associated with reduced mortality, as was higher consumption. Consumption of both lean and fatty fish in line with dietary guidelines was within a non-significant beneficial range, but excessive consumption of fatty fish was associated with increased mortality during follow-up. In contrast, lean fish consumption level had no impact on total mortality.

Thus, there was a J-shaped trend with Nordic fruits and vegetables, fatty fish and low-fat dairy products and mortality, implicating that risk changes might not be linear with increasing intake of some healthy Nordic food groups.

The maximum benefit of consuming Nordic fruits and vegetables was achieved at around 200 grams/day, which is below the recommended intake of all fruits and vegetables of five servings per day (30–33). Non-linear inverse associations of fruit and vegetable intake with total mortality have recently been shown in two meta-analyses (34, 35). While the maximum benefit was observed at higher consumption levels in both studies (≥ 5 servings per day), the effect estimates are relatively close to our results on Nordic fruits and vegetables (i.e. Wang et al.: five servings per day compared to two servings per day (HR 0.87 (95% CI 0.85–0.90)) (34), Aune et al.: high versus low (RR 0.82 (95% CI 0.79–0.86)), or per 200 grams increment (RR 0.90 (95% CI 0.87–0.93)) (35). Miller and colleagues also found in the PURE study that optimal health benefits of fruit and vegetable consumption could be achieved at a more modest intake level than currently recommended (around three to four servings per day) (36).

Potentially, subgroups of fruit and vegetable consumption such as the selected Nordic varieties have distinct health effects due to variations between different fruits and vegetables in nutritional properties (33), but other underlying dietary factors could also play a role in variations between dose–response relationships across populations.

The inverse association between Nordic fruits and vegetable consumption and mortality seemed stronger in former and current smokers than in never smokers. Also, the optimal consumption level was estimated to be higher in ever smokers than never smokers. Similar tendencies were reported in the European Prospective Investigation into Cancer and Nutrition which also included a subsample of women from NOWAC (37). In addition, a meta-analysis of prospective cohort studies on the association between consumption of fruits and vegetable and risk of lung cancer found stronger associations with lung cancer among smokers. Potentially antioxidant properties of fruits and vegetables are protective against increased oxidative stress caused by smoking (38).

The observed protective effect of wholegrain products on mortality in the present analysis is supported by meta-analyses of prospective cohort studies including populations from the US, Europe and Asia (39, 40). The present results showed no further benefits of consuming > 180 grams of wholegrain products per day. In the meta-analysis by Aune et al. reductions in risk for whole grains were observed up to an intake of 225 grams per day, but they found a non-linear association with all-cause mortality and a steeper reduction in risk at lower intake levels (40). Compared to our results, a study on Norwegian wholegrain eaters by Jacobs et al. included in the meta-analyses found an inverse association between a calculated wholegrain consumption score and

mortality, with the highest score being most beneficial. This score was calculated based on slices of bread multiplied by percentages of wholegrain and was thus based on more detailed information on wholegrain consumption than we had access to (41).

The impact of dairy intake on mortality has been extensively studied, with contradicting results (42, 43). The divergence between studies could be due to variation between different types of dairy products being investigated (i.e., total dairy, specific categories of dairy such as milk, yoghurt, cheese, low-fat/high-fat dairy), but also the quality of the underlying diet in different populations could affect the association between dairy consumption and mortality. For example, in a population with little access to complete proteins and essential nutrients from other animal sources than dairy, consumption could be differently associated to all-cause mortality compared to in a population with access to such nutrients from multiple food sources. Still, even when comparing results on low-fat milk consumption as a specific dairy category and mortality in Nordic populations, one study finds an increased mortality (44) while another finds no association (45). It is noted that the fat content in yoghurt, which was part of the low-fat dairy products in present study could be up to 3.4 %, and therefore not considered low-fat within the yoghurt subcategory of dairy products. Hence, our results are not directly comparable with these studies. Our analysis showed a non-linear association with low-fat dairy and mortality, much in line with what Ding et al. found for total dairy consumption in three prospective cohort studies in women and men (46).

As in the present analysis, several large cohort studies have not been able to show any reduced mortality linked to frequent fish consumption (47, 48). In line with our results, Engeset et al. found a non-linear trend with fatty fish consumption and mortality in the European Prospective investigation into Cancer and Nutrition cohort, which included a part of our sample (48). Also, a study on fish consumption and mortality in a cohort of Swedish men and women found a U-shaped association between consumption of fish and all-cause mortality, which was more pronounced in women (49). Further, when they considered lean and fatty fish separately, they found no associations between consumption of lean fish and mortality, but a markedly more pronounced association between fatty fish consumption and mortality. We observed that consumption up to the recommended 200 grams of fatty fish/week (29 grams/day) was within a non-significant beneficial range, but when intake reached 70 grams/day there was a significantly increased mortality. In the cohort on Swedish men and women they reported higher mortality amongst women who consumed 80 grams fish per day compared to the median intake level (49).

Even though fish is a good source of essential nutrients, it is also a source of environmental contaminants such as dioxins, which are classified as carcinogens, and accumulates in the adipose tissue (14, 50, 51). While lean fish store fat in the liver, fatty fish store it in the fillet itself, and such contains more of these substances compared to lean fish. One can speculate if this is related to the observed increased mortality with high consumption of fatty fish but not with lean fish. Nevertheless, our findings do not support the part of the dietary guideline underlining that at least 200 grams a week should be fatty fish, as this conveys the impression that consuming more than this is better (14).

The search for optimal intake levels of foods and an ideal composition of the diet should be emphasised in studies on sustainable healthy regional diets, both for health and to reduce the burden of food production on the environment. However, establishing optimal intake levels of foods for health is not straightforward, given the limitations inherent in FFQs to give precise estimates of actual food intake and that the health effect is dependent on the underlying dietary pattern. For example, even though we found that approximately 200 grams/day of Nordic fruits and vegetables and 120–179 grams/day of wholegrain products (in models mutually adjusted for healthy Nordic food groups and energy intake), is optimal for longevity in this study, substituting processed meat with increased intake of these foods and for example lean fish (which was neutrally associated with mortality) could be beneficial for both health and the environment. Nevertheless, public health messages advocating an “increased” intake of certain foods without pointing to specific intake levels gives the impression that the more we can eat of these foods the better health will be, and this might not be the case. To identify optimal food composition of a healthy Nordic diet in a public health perspective, substitutional analyses are highly relevant for further research.

Strengths and limitations

The strengths of this study include a large sample size, a high number of deaths and the long follow-up (median 20 years), providing enough statistical power in the analysis. Linkage to registry is a strength as all deaths are confirmed. Further, the risk of sampling bias is considered low due to the selection of women through the National Registry. Another strength is that a validated questionnaire was used to assess food intake and covariates (19–21, 26, 27).

The study is, however, limited by having only one assessment of diet, as dietary habits probably have changed during follow-up. Recalling the habitual diet with the use of FFQ could lead to recall error and misclassification of dietary exposures, but this is expected to be non-differential. In addition, the FFQ was not designed to measure all foods that are part of a healthy Nordic diet and hence does not capture all relevant food components such as wild berries and vegetables like kale or distinguish between specific varieties of Nordic wholegrains such as rye and barley. Furthermore, precise assessment of dietary exposure is difficult and measurement errors are inevitable in nutritional epidemiology. Also, even though we adjusted for possible confounding factors that were unevenly distributed across intake categories of the Nordic food groups, residual confounding due to imprecise assessment of these factors as well as unmeasured factors is likely.

In particular, these results must be interpreted with caution as the moderate consumers are probably more representative of what most people eat, while both low and high consumers can be different in many ways (e.g., extreme dieters, vegans, people with allergies).

Conclusion

Moderate consumption of foods that are part of a healthy Nordic diet is either significantly better for or does not compromise longevity, compared to low or high intake, among middle-aged and older women. Consumption of Nordic fruits and vegetables was most beneficial in women that were either current or former smokers, and the optimal intake level seemed to be higher among these women compared to never smokers. These findings implicate that dietary interventions might be especially important for people with higher mortality due to smoking.

Moderate intake of many food groups facilitates a varied diet, which is also part of the dietary guidelines, and this can be good for both health and the environment. Our results indicate that we need to assess linear as well as non-linear associations between food intake and health outcomes.

Abbreviations

NOWAC

the Norwegian Women and Cancer Study

BMI

Body mass index

FFQ

Food frequency questionnaire

DAGs

Directed Acyclic Graphs

HR

Hazard ratio

CI

Confidence interval

PURE study

The Prospective Urban Rural Epidemiology study

REK

The Regional Committee for Medical and Health Research Ethics

Declarations

Ethics approval and consent to participate

The NOWAC cohort has received approval for the collection and storage of questionnaire information. All data are stored and handled according to the permission given by the Norwegian Data Protection Authority (Ref.nr. 07–00030). Participants have given written informed consent, and ethical approval for the NOWAC cohort has been obtained from the Regional Committee for Medical and Health Research Ethics (REK) (Ref.nr. 200300119-5).

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

TEJ: Conception and design, analysis and interpretation of data, writing and revision of the manuscript and supervision of study.

TB: Conception and design, acquisition of data, analysis and interpretation of data, revision of the manuscript.

BKJ: Conception and design, interpretation of data, writing and revision of the manuscript.

GS: Conception and design, acquisition of data, interpretation of data, major contributor in the writing and revision of the manuscript and supervision of study.

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Figures

Figure 1

Intake of healthy Nordic food groups and all-cause mortality by restricted cubic spline regression From: Moderate consumption of healthy Nordic foods is associated with reduced mortality in the Norwegian Women and Cancer study: a prospective cohort study Healthy Nordic food groups modeled by restricted cubic splines with 3 knots at percentiles 10%, 50% and 90% (Nordic fruits and vegetables; 57; 164; 336. Low-fat dairy products; 0; 137; 550. Fatty fish; 0; 12; 35. Lean fish; 0; 24; 68) Black line hazard ratio, grey area 95% confidence interval Mutually adjusted for the healthy Nordic food groups, age (underlying timescale), BMI < 20, 20–24.9, 25–29.9, ≥ 30 (kg/m²), physical activity (low, medium, high), smoking status (never, current heavy smoker early starter, current moderate smoker early starter, current smoker late starter, former smoker early starter, former smoker late starter), intake of energy (kJ/day continuous), alcohol (non-consumer, 0–5, > 5 grams/day), and processed meat (< 15, 15–29, 30–44, ≥ 45 grams/day), stratified by subcohorts (n=5)

Figure 2

Intake of Nordic fruits and vegetables and all-cause mortality by restricted cubic splines stratified by never and ever smokers From: Moderate consumption of healthy Nordic foods is associated with reduced mortality in the Norwegian Women and Cancer study: a prospective cohort study Nordic fruits and vegetables modeled by restricted cubic splines with 3 knots at percentiles 10%, 50% and 90% (Never smokers: 65; 173; 342. Ever smokers: 53; 160; 332). Black line hazard ratio, grey area 95% confidence interval Age-adjusted and mutually adjusted for the healthy Nordic food groups, BMI < 20, 20–24.9, 25–29.9, ≥ 30 (kg/m²), physical activity (low, medium, high), intake of energy (kJ/day continuous), alcohol (non-consumer, 0–5, > 5 grams/day), and processed meat (< 15, 15–29, 30–44, ≥ 45 grams/day) * additionally, adjusted for pack-years

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