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The Nordic diet and cognition – The DR's EXTRA Study

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ABSTRACT

The rapid increase in the prevalence of dementia associated with aging populations has stimulated interest in identifying modifiable lifestyle factors which could prevent cognitive impairment. One such potential preventive lifestyle factor is the Nordic diet which has been shown to reduce the risk of cardiovascular disease; however its effect on cognition has not been studied. The aim of this study was to estimate cross-sectional and longitudinal associations of the baseline Nordic diet with cognitive function at baseline and after a four-year follow-up in a population-based random sample (1140 women and men, age 57-78) as secondary analyses of the Finnish Dose-Responses to Exercise Training study. The Nordic diet score was created based on reported dietary components in four-day food records. Cognition was assessed by the Consortium to Establish a Registry for Alzheimer's Disease (CERAD) neuropsychological battery and the Mini-Mental State Examination (MMSE). The baseline Nordic diet score was positively associated with Verbal Fluency [β 0·08 (95% CI 0·00, 0·16), P=0·039] and Word List Learning [0·06 (0·01, 0·10), P=0·022] at four-years but not with CERAD-total score or MMSE at four-years, after adjustment for baseline cognitive scores, demographic and health-related factors. After excluding individuals with impaired cognition at baseline, the baseline Nordic diet score was positively associated also with the CERAD-total score [0·10 (0·00, 0·20), P=0·042] and MMSE [0·03 (0·00, 0·06), P=0·039] at four-years. These associations disappeared after further adjustment for energy intake. In conclusion, the Nordic diet might have a positive association with the cognition in individuals with normal cognition.

The Clinical Trial Registration Number ISRCTN45977199.

INTRODUCTION

Maintenance of cognitive function has a crucial role in well-being when an individual ages. As our understanding of the pathophysiology of dementia increases, this has stimulated interest in identifying modifiable lifestyle factors which could reduce, or at least delay, the cognitive impairment associated with aging[1]. The Mediterranean diet is the most extensively studied dietary pattern related to cognition; it has been found to reduce the rate of cognitive decline with aging and to lower the risk of developing Alzheimer's disease[2] in addition to improving global cognitive function[3]. Due to differences in food culture and available resources, it is important to study whether other dietary patterns, typical of certain populations, are associated with cognition. One such potential dietary pattern is the Nordic diet, a typical healthy Northern diet following the Nordic Nutrition Recommendations[4]. The traditional Nordic diet is based on commonplace local Scandinavian food items, characterised by a high consumption of vegetables, fruit and berries, fish and whole grain products as well as low-to-moderate consumption of meat and alcohol, and rapeseed oil being the recommended source of fat[5]. The Nordic diet primarily differs from Mediterranean type diets in that it has different sources of vegetables, grain products and dietary fat, consisting of products readily available in the Nordic countries. In brief, the Nordic diet is characterised by a wide selection of berries, providing a variety of polyphenols, antioxidants and other bioactive compounds. The major sources of grain products are rye, oat and barley being eaten in bread and porridge, i.e. products which have high fibre contents. An important source of unsaturated fatty acids is rapeseed oil which contains essential fatty acids linolic acid and α-linolenic acid two- and twenty-fold amounts, respectively, as compared to olive oil, a major food component in the Mediterranean diet. Previously, the Nordic diet has shown to be associated with reduced cardiovascular risk factors[5,6], however no data are available on its impact on cognition. Since a better cardiovascular risk profile is associated with a lower risk of vascular dementia[7] it seemed reasonable to postulate that the Nordic diet could reduce the rate of cognitive decline with aging. In addition, the majority of the components of the Nordic diet have previously been associated with preserved cognition. For example, extensive consumptions of vegetables and fish as well as a high intake of polyunsaturated fatty acids have been postulated to protect against cognitive decline[8,9] whereas the amounts of saturated fatty acids consumed are inversely associated with cognition[8]. Further, omega-3 fatty acids have beneficial effects on mild cognitive impairment[10] and low-to-moderate alcohol use has been associated with a reduced risk of dementia[11].

In the present study, we examined both cross-sectional and longitudinal associations of the baseline Nordic diet with cognitive function at baseline and after a four-year follow-up in a randomly selected population-based sample of older men and women.

METHODS

Study population

The data presented here represent secondary analyses from the Dose-Responses to Exercise Training Study (the DR's EXTRA), which is a population-based, randomised, controlled four-year trial on the health effects of regular physical exercise and diet (ISRCTN45977199, http://isrctn.org). This report describes observational data collected over the four years of monitoring the subjects. Since the aim of the present study was to examine the association of the Nordic diet with cognition, the study intervention groups were pooled in the analyses and thus study design can be considered to represent a four-year follow-up. However, the original study group assignment was adjusted for as a covariate in the analyses.

Subjects were identified from the Finnish Population Register (Figure 1) as described previously[(12)]. Altogether 1479 men and women participated in baseline examinations conducted in 2005-2006. Due to exclusion criteria (health conditions that impair safe exercise training, malignancies, and conditions preventing co-operation e.g. existing dementia, as judged by a physician) or other reasons (i.e. moving elsewhere or refusal) 69 individuals were excluded, and 1410 were randomised into an intervention group (aerobic exercise, resistance exercise, diet, aerobic exercise+diet or resistance exercise+diet) or to the reference group. A total of 1199 individuals of original participants completed the four-year follow-up in 2009-2011. There were 211 (15·0 %) drop-outs during the intervention. In the present study, after excluding 59 individuals with missing or insufficient data on baseline diet (n=8), cardiorespiratory fitness tests (n=46) or both (n=2), or four-year cognition assessment (n=3) complete data was available for 1140 individuals (567 men, 573 women). The complete data on the four-year changes in diet and cognition was available for 1132 individuals. Those individuals excluded from the analyses (211 drop-outs and 59 with missing data) were older [mean (SD) 68·3 (5·7) vs. 66·1 (5·2) years, P<0·001], had lower scores in CERAD-total score [78·7 (10·5) vs. 83·5 (8·6) points, P<0·001] and in the Mini-Mental State Examination [27·0 (3·0) vs. 28·0 (2·0) points, P<0·001], reported more depressive symptoms [10·3 (6·6) vs. 8·3 (6·3) points, P<0·001], were less educated [10·4 (3·9) vs. 11·3 (3·8) years, P<0·001], had higher body mass index (BMI) [28·6 (5·4) vs. 27·5 (4·3) kg/m^2, P<0·001], lower cardiorespiratory fitness [20·9 (5·9) vs. 24·2 (6·2) ml/kg/min, P<0·001] and lower energy intake [6·4 (1·8) vs. 7·1 (1·9) MJ, P<0·001] at baseline than those who completed all of the analyses. This study was conducted according to the guidelines laid down in the Declaration of Helsinki. The study protocol was approved by the Research Ethics Committee of the Northern Savo Hospital District. Written informed consent was obtained from all study participants.

Assessment of diet

Dietary intake was assessed at baseline and at the four-year follow-up evaluation by a four-day food record which was predefined to include three weekdays and one weekend day as described previously[13]. The participants were given detailed written and verbal instructions on how to complete the food record. All food records were reviewed and checked for completion by either a clinical nutritionist or a trained nurse. Portion sizes were estimated by the subjects using a picture booklet[14], household gauges or actual weighing. Data from food records were analysed using the MicroNutrica® nutrient calculation software for group analysis, version 2·5 (recipes updated in 2007)[15].

The Nordic diet score was obtained by a modification of the method of Kanerva et al[5]. This Nordic diet score consists of the following eight variables: consumption of fish (g/day; including fatty and lean fish and processed fish products), vegetables (g/day; including roots, non-root vegetables, mushrooms, legumes and nuts, but not potatoes), fruit and berries (g/day), whole grain bread (g/day), meat (g/day; including beef, pork, poultry, game, sausage and giblets) and alcohol (g/day), and intake of α-linolenic acid (g/day; to represent the consumption of rapeseed oil), and unsaturated fatty acids-to-total fat ratio. Changes were made to the original Nordic diet score[5] due to either limited data availability or in an attempt to refine the quality of the score. The original Nordic diet score included low-fat milk products whereas in the present study, all milk products were excluded from the score. Due to the data given by the nutrient calculation software, we were not able to separate milk products according to their fat-content. The original variables regarding fat intake (total fat and PUFA-SFA –ratio in the original score) were also changed. Nowadays, quality of fat is considered more important than the amount of fat[16], thus, we did not include total fat intake into the score. We have decided to describe the quality of dietary fat by estimating the unsaturated fatty acids-to-total fat intake –ratio and this was included into the score because in the Finnish nutrition guideline, the recommended proportion of unsaturated fatty acids is at least 2/3. In addition, rapeseed oil is a common and recommended source of fat in the Nordic diet. However, we did not have data available about the consumption of rapeseed oil. Thus, the intake of α-linolenic acid as a surrogate marker of the consumption of rapeseed oil was included in the modified score. In addition, nuts were included in the vegetable group, in contrast to their classification in the original score. In the nutrient calculation software, legumes and nuts are categorized as one food group, and they could not be separated. The Nordic diet score was calculated according to the gender-specific quartiles of each dietary component (with the exception of alcohol). For each component (fish, vegetables, fruit and berries, whole grain bread, α-linolenic acid and unsaturated fatty acids-to-total fat ratio), the lowest quartile was coded as 0, the two middle quartiles as 1 and 2 and the highest as 3. For meat, the highest quartile was coded as 0, the two middle quartiles as 1 and 2 and the lowest as 3. Consumption of alcohol was two-point scale based on specific cut-points in accordance with the Dietary Guidelines for Americans[17]. Non-alcohol drinkers (<1 g of alcohol/day) as well as heavy alcohol consumers [>24 g/day in men and >12 g in women] received 0 points. Mild-to-moderate drinkers (1-24 g/day in men and 1-12 g in women) received 1 point. Hence, the total Nordic diet score ranged from 0 to 22 points, with higher points indicating better adherence to a desirable Nordic diet. The gender-specific medians were used to dichotomise the score. Men with poor adherence had 0-11 points and men with good adherence scored 12-21 points. Similarly, women with poor adherence had 1-10 points and women with good adherence 11-21 points.

Assessment of cognitive function

Cognitive function was assessed using the standardised Finnish version of Consortium to Establish a Registry for Alzheimer's Disease (CERAD) neuropsychological battery[18] and the Mini-Mental State Examination (MMSE)[19] at baseline and after two and four years (only the baseline and four-year results are reported in the present study). Trained nurses performed the assessments under the supervision of a neuropsychologist. Tests were performed in the same order on every study visit. The CERAD total score (CERAD-TS) was calculated, as previously described, including Verbal Fluency, Modified Boston Naming Test, Word List Learning, Constructional Praxis, Word List Recall and Word List Recognition Discriminability[20]. The score ranged from 0 to 100 points, with a higher score indicating better performance and thus an individual scoring ≤70 points was classified as being impaired cognition[21].

Other assessments

Symptoms of depression were assessed with the Center for Epidemiological Studies Depression Scale (CES-D)[22]. Cardiorespiratory fitness was assessed as maximal oxygen uptake (VO_{2max}, ml/kg/min) measured by the VMax respiratory gas analyser (SensorMedics, Yorba Linda, CA) during a maximal symptom-limited, exercise stress test on an electrically braked cycle ergometer (Ergoline, Biz, Germany). Prevalent use of medications, smoking status and education were assessed from a self-administered questionnaire, and BMI was calculated from height and weight.

Statistical analyses

Statistical analyses were performed using the IBM SPSS statistics for Windows, version 19·0 (IBM Corp., Armonk, NY). Associations with a P<0·05 were considered as statistically significant. Differences between the groups and between baseline and four-year examinations were analysed using t-test, Mann Whitney's U-test, Wilcoxon Signed-Ranks test or χ^2–test as appropriate. These values are presented as mean (standard deviation, SD) for normally distributed variables and as median (interquartile range, IQR) for non-normally distributed variables. The assumption of normality was verified using the Kolmogorov-Smirnov test and visual inspection of histograms, with the latter receiving greater emphasis. Analysis of covariance (ANCOVA) was used to assess the association of the baseline Nordic diet with the CERAD-TS, its subtests and MMSE at four-years among all individuals and among those with normal cognition at baseline. The Nordic diet score was used as a continuous variable. Interactions between the Nordic diet and gender on CERAD-TS and MMSE were analysed via an interaction term in all models. A hierarchical approach was used to reveal the effect of confounding factors to the association between the Nordic diet and cognition. Covariates were chosen based on the current knowledge of factors associated with cognitive function during aging. Model 1 included adjustments for basic demographic factors (age, gender, education), and baseline cognitive scores and study group. Model 2 was additionally adjusted for different lifestyle factors including smoking, cardiorespiratory fitness (maximal oxygen uptake, ml/kg/min), medications (antihypertensive, lipid lowering and antidiabetic) and symptoms of depression. Model 3 was additionally adjusted for energy intake.

RESULTS

Baseline characteristics are presented in Table 1, and food consumption and nutrient intake in Table 2. At baseline, 8·6% (n=98) displayed evidence of impaired cognition. These individuals were older [mean (SD) 69·4 (5·1) vs. 65·8 (5·1) years, P<0·001], less educated [9·0 (3·0) vs. 11·5 (3·8) years, P<0·001], reported more depressive symptoms [median (IQR) 9·0 (9·0) vs. 7·0 (8·0) points, P=0·028] and had a lower energy intake [mean (SD) 6·8 (1·9) vs. 7·2 (1·9) MJ, P=0·050], as well as using more antihypertensive medication (52·0 vs. 39·0 %, P=0·012) and antidiabetic medication (13·3 vs. 6·0 %, P=0·005) than those with normal cognition. The Nordic diet score [median (IQR) 10·0 (5·0) vs. 11·0 (6·0) points, P=0·076] and BMI [mean (SD) 27·8 (3·8) vs. 27·5 (4·3) kg/m^2, P=0·522] did not differ between individuals with impaired or normal cognition.

During four years, the cohort's CERAD-TS improved from [mean (SD)] 83·4 (8·5) to 84·4 (10·0) points (P<0·001). The total Nordic diet score did not change [median (IQR) 11·0 (6·0) points at baseline and 11·0 (5·0) points after four years, P=0·367]. However, increased consumption was observed in the amounts of fruit and berries [from median (IQR) 207 (187) to 231 (193) g/day, P<0·001], fish [from median (IQR) 37·5 (60·8) to 42·2 (56·3) g/day, P=0·019], and in α-linolenic acid [from mean (SD) 1·7 (0·9) to 1·9 (1·0) g/day, P<0·001] whereas declines were noted in the consumption of alcohol [from median (IQR) 0·9 (8·0) to 0·0 (5·0) g/day, P<0·001] and in the unsaturated fatty acids-to-total fat ratio [from mean (SD) 0·58 (0·07) to 0·53 (0·07), P<0·001].

The Nordic diet and cognition

At baseline, the adherence to the Nordic diet was not associated with CERAD-TS in the total study cohort [β 0·10 (95 % CI -0·02, 0·22), P=0·114] or in individuals with normal cognition [0·05 (-0·05, 0·15), P=0·300] after adjustment for age, gender, education and study group. In addition, at baseline the Nordic diet score was not associated with either the MMSE or with the individual cognitive domains in the CERAD-TS (data not shown). However, the Nordic diet score at baseline was positively associated with the CERAD-TS at four-years in the total cohort and in individuals with normal baseline cognition in Model 1 (Table 3). In Model 2, these associations became weakened but remained statistically significant (P<0·05) in individuals with normal cognition but not in the entire cohort. After further adjustment for energy intake, these associations were no longer statistically significant. Similar associations were observed between the baseline Nordic diet and the MMSE at four-years (Table 3). Age [β -0·33 (95% CI -0·41, -0·25), P<0·001], gender [women vs. men 1·69 (95% CI 0·64, 2·75), P=0·002], education [0·12 (0·02, 0·23), P=0·002] and baseline CERAD-TS [0·81, (0·76, 0·85), P<0·001] were the only covariates associated with CERAD-TS at four years in Model 3 in all individuals. Similar associations of covariates were observed with MMSE. In addition, no interaction was observed between the Nordic diet score and gender with respect to CERAD-TS or MMSE either in the entire cohort or in those with normal baseline cognition (P>0·05 in all Models).

The Nordic diet score at baseline was positively associated with the Verbal Fluency at four-years in all individuals in Model 1 [β 0·10 (95% CI 0·03, 0·18), P=0·009] and in Model 2 [0·08 (0·00, 0·16), P=0·039] but not in Model 3 [0·04 (-0·04, 0·13), P=0·308]. Similarly, a positive association was found in individuals with normal cognition in Model 1 [0·10 (0·03, 0·18), P=0·010] and in Model 2 [0·09 (0·01, 0·17), P=0·033], but not in Model 3 [0·05 (-0·04, 0·14), P=0·270]. Furthermore, the Nordic diet score at baseline was positively associated with the Word List Learning at four-years in the entire group in Model

1 [0·07 (0·02, 0·12), P=0·004] and in Model 2 [0·06 (0·01, 0·10), P=0·022] but not in Model 3 [0·04 (-0·02, 0·09), P=0·172]. A similar positive association was found in individuals with normal cognition in Model 1 [0·06 (0·02, 0·11), P=0·009] and in Model 2 [0·05 (0·00, 0·10), P=0·044] but not in Model 3 [0·03 (-0·02, 0·09), P=0·205]. Finally, there were no associations detected between the Nordic diet score at baseline and the other subtests of the CERAD-TS (i.e. Modified Boston Naming Test, Constructional Praxis, Word List Recall and Word List Recognition Discriminability) at four-years (data not shown).

DISCUSSION

The present study revealed that better adherence to the baseline Nordic diet was associated with higher scores in global cognition and also in two subtests, i.e. those assessing memory and language, which are the earliest domains to reveal problems in cognition(23), over the four-year study period after adjustment for demographic and lifestyle factors in individuals with normal cognition. However, after adjustment for dietary energy intake, none of the associations found between the Nordic diet and cognition remained statistically significant. This may reflect the overall importance of different kinds diets, i.e. ensuring that an individual consumes a sufficient amount of energy to maintain energy balance and prevent malnutrition, and in that way to reduce the cognitive decline which can occur during aging.

However, there are sources of bias in the adjustment for energy intake which need to be considered before one can draw any final conclusions. Underreporting of energy intake is a common source of error in nutritional assessments(24), and this was also evident in our study. In addition, undereating (so called “Anorexia of aging”) tends to increase with age and this is reflected in nutrition assessments as a lower energy intake(25). In the present study, the energy intake was lower among individuals with impaired cognition in comparison to those with normal cognition; this is likely to be due to both underreporting and undereating.

The statistically significant association between the Nordic diet score and global cognition, before adjustment for the energy intake, was observed only in individuals with normal cognition. We postulated that a stronger association would be found between the Nordic diet score and cognition in the analysis involving all individuals. Partly these differences may reflect the dietary misreporting in participants with impaired cognition. In addition, the fact that associations between the Nordic diet and the change in cognition were weakened, or in the case of global cognition disappeared, after adjustment for lifestyle factors may reflect the accumulation of beneficial factors in a healthy lifestyle. However, no clinically significant differences in the extent of the functional cognitive decline could be detected in these analyses.

Limited data is available about the association between consumption of a Nordic diet and the level of cognition. Most of the studies examining the effect of dietary patterns on cognition have investigated the Mediterranean diet, characterised by its high consumption of plant foods (vegetables, fruit, legumes, cereals, nuts and seeds), moderate consumption of fish and dairy products, relatively low consumption of red meat, low-to-moderate consumption of alcohol, particularly in the form of red wine, and with olive oil being the principal source of fat[(26)]. In prospective observational studies, the Mediterranean type diet has been shown to decrease the risk of experiencing a cognitive decline[(27-29)] and Alzheimer's disease[(30)]. However, not all studies have found positive associations[(31,32)]. Only a few observational studies have been conducted in the actual Mediterranean countries[(27,31)], most studies originate from the United States. In a randomised trial conducted in Spain, consumption of a Mediterranean diet with added extra-virgin olive oil or nuts was associated with better cognitive function in comparison to the control diet[(3)]. A limitation of this trial was that cognitive function was assessed only at the end of the intervention, thus the effect of the intervention on the actual change in cognition could not be estimated. With respect to other dietary patterns, prospective observational studies have revealed both positive[(29,33)] and neutral[(28)] findings related to cognitive decline and dementia. All these dietary patterns, including the Nordic diet, emphasise the importance of high consumption of vegetables and fruit. Most, but not all, also recommend high consumption of fish and whole grain products and low-to-moderate consumption of meat and high-fat dairy products. There may be some differences in the definitions of dietary fat quality but the tendency has been to prefer unsaturated fatty acids over saturated fatty acids. Hence, although the recommended dietary patterns share some similarities, there are also significant differences. In other words, a diverse and healthy diet can be constructed in many ways. The above-mentioned dietary patterns, including the Nordic diet, are all descriptions of a healthy diet with different nuances attributable to local food culture, preferences and resources. Since the adherence to dietary patterns is usually estimated with population-based cut point values (e.g. medians), even the same dietary pattern will not be directly comparable in different countries and populations. In addition, a diet consisting of familiar and widely available food items will be easier to adopt and therefore the practical effectiveness of health promotion actions can be improved when they emphasise the benefits of this kind of diet. Therefore it is important to study the effects of different dietary patterns in different populations.

No clear mechanism to explain the beneficial effects of healthy diets on cognitive function has been formulated as yet[34]. However, it is likely that a healthy diet and its components can influence cognition via their beneficial effects on vascular risk factors, inflammation and oxidative stress. High consumption of fish[35] and high levels of circulating omega-3 fatty acids[36] have been associated with a lower prevalence of subclinical infarcts and white matter abnormalities. In addition, certain nutrients (omega-3 fatty acids, B-vitamins and antioxidants) present in healthy diets have been proposed to interfere with the processing of beta-amyloid in the brain[37].

The improvement in cognitive function during four-year study period was small but unexpected in this age group. In these kinds of longitudinal studies, the changes in cognitive function are typically minor[38] and cognition may even improve[39]. One potential explanation in the present study is that the actual participation into the intervention study led to improvements in the lifestyle factors as well as providing social and mental stimulation. The cognitive tests were performed three times during the study, thus a learning effect might account for the better performance in the tests similarly as found in other studies[38,39]. The retest effect may have conferred some bias in our results by underestimating the age-related cognitive decline. It should also be borne in mind that the progression from normal cognition to dementia may require several decades[23], thus there may be limitations on our capabilities to detect clinically relevant changes in cognition over a four-year period. Since changes in cognition may be minor, it also may be difficult to link then with the effects of diet. Thus, even a small association showing that an improvement in cognition could be related to diet may be clinically relevant.

The strength of the study is the large representative population-based sample of older men and women. A four-day food record is an open-ended dietary assessment method filled in at the time when food is being eaten, thus it does not rely on memory and in that way is superior to the more commonly used retrospective food frequency questionnaires or recalls[40]. The accuracy of these methods is highly dependent of the respondents' motivation and their ability and willingness to report their actual food consumption. A cognitive impairment may lead to a decline in the ability to perceive and process the relevant information[41], which in turn probably impairs the ability of an individual to record his/her food intake, independent of the methodology used. Thus, as mentioned earlier, underreporting is a common source of error in food records, especially in older individuals[24]. Seasonal variations in diet may not have been captured at an individual level; however, as the surveys in the present study population were spread out over 1·5 years, it is most unlikely that this is a source of bias. Cognitive function was evaluated using the CERAD neuropsychological battery, which is recognized for its good interviewer and test-retest reliability[18]. The CERAD-TS is an accurate measure of global cognitive status in normal aging and in the early stages of dementia[21]. It should also be kept in mind that responses to the diet may vary between individuals due to genotype[42], a factor for which we were unable to control.

The Nordic diet score has some limitations; it was not possible to assess the impact of the contents of food groups incorporated in the diet score, because they were estimated by nutrient calculation software (MicroNutrica®)[15]. Problematic food groups were fish and whole grain bread, which were classified as being healthy, while non-recommended food items, e.g. processed fish products and biscuits, were also included. Despite the fact that meat was classified as a non-recommended food group, it is an important source of good quality protein, especially in elderly people and it can be viewed as part of a healthy diet, if consumed in moderate amounts. Although the analyses were adjusted for the randomised study group, we cannot exclude the possibility that changes in lifestyle factors during the intervention may have affected the observed associations. In addition, the adjustments for potential confounders were performed only at baseline, thus we cannot exclude the possibility of residual confounding. The drop-out rate during the study was low (15%), despite the long and demanding intervention period. The non-participants and drop-outs were older and had more cardio-metabolic risk factors and worse CERAD-TS scores than the study participants. This may have diluted our ability to reveal the potential effect of the Nordic diet on cognition in the entire population.

In conclusion, based on this present large sample of middle-aged and elderly men and women, consumption of a Nordic diet appears to display a positive association with cognition in individuals with normal levels of cognition.

CONFLICT OF INTEREST None

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AUTHORSHIP The study was planned and designed by RR, PK, RM, US and MK. The acquisition of data was implemented by RM, PK, HMH, KS, MH and RR. The data were analysed and interpreted by RM, PK, US, KS, MH, TH and RR. The original manuscript was written by RM, and subsequently all of the other authors have critically revised the manuscript. All authors have read and approved the final manuscript.

Table 1. Baseline characteristics of all participants and according to adherence to the Nordic diet.

	All (n=1140)		Adherence to the Nordic diet* Poor (n=593)		Adherence to the Nordic diet* Good (n=547)		
	Mean, median[†] or %	SD or IQR[†]	Mean, median[†] or %	SD or IQR[†]	Mean, median[†] or %	SD or IQR[†]	P value
Age (years)	66·1	5·2	66·4	5·4	65·7	5·0	0·020
Education (years)	11·3	3·8	10·9	3·8	11·8	3·8	<0·001
CERAD total score	83·3	8·7	82·6	9·2	84·1	8·1	0·002
MMSE score	28·0[†]	2·0[†]	28·0[†]	3·0[†]	28·0[†]	2·0[†]	0·014[‡]
CES-D (points)	7·0[†]	8·0[†]	8·0[†]	9·0[†]	7·0[†]	8·0[†]	0·024[‡]
BMI (kg/m^2)	27·5	4·3	28·1	4·2	26·9	4·3	<0·001
VO_{2max} (ml/kg/min)	24·2	6·2	23·6	6·2	24·8	6·3	0·001
Smoking status, never/ past/current (%)	55·3/34·7/ 10·0		53·3/33·7/ 13·0		57·4/35·8/ 6·8		0·002
Antidiabetic medication (%)	6·6		7·6		5·5		0·152
Antihypertensive medication (%)	40·1		42·5		37·5		0·084
Lipid lowering medication (%)	34·8		34·7		34·9		0·949

CERAD, the Consortium to Establish a Registry for Alzheimer's Disease. IQR, interquartile range. MMSE, the Mini-Mental State Examination. CES-D, the Center for Epidemiological Studies Depression Scale. BMI, body mass index. VO_{2max}, maximal oxygen uptake. *Men with the poor adherence had 0-11 points in the Nordic diet score and men with the good adherence 12-21 points. Women with the poor adherence had 1-10 points and women with good adherence 11-21 points. [†]Median and interquartile range are used for non-normally distributed variables. P values are from t-test, [‡]Mann-Whitney's U test or χ^2–test, and refer to the difference between groups of poor and good adherence to the Nordic diet.

Table 2. Baseline food consumption and nutrient intake of all participants and according to adherence to the Nordic diet.

			Adherence to the Nordic diet*				
	All (n=1140)		Poor (n=593)		Good (n=547)		
	Mean or median†	SD or IQR†	Mean or median†	SD or IQR†	Mean or median†	SD or IQR†	P value
Nordic diet score	11·0†	6·0†	8·0†	3·0†	14·0†	4·0†	<0·001ǂ
Vegetables§ (g/day)	174	100	134	76	217	106	<0·001
Fruit and berries (g/day)	206†	187†	159†	141†	257†	185†	<0·001ǂ
Fish (g/day)	37·5†	60·6†	20·2†	48·3†	55·6†	54·5†	<0·001ǂ
Whole grain bread (g/day)	107	63	91	53	124	67	<0·001
Meat (g/day)	121	71	131	71	109	70	<0·001
Alcohol (g/day)	0·9†	8·0†	0·0†	9·0†	1·5†	7·0†	0·910ǂ
Energy (MJ)	7·1	1·9	6·7	1·8	7·6	1·9	<0·001
Protein (E%)	18·1	2·9	18·1	2·9	18·1	2·8	0·683
Carbohydrates (E%)	46·8	7·2	45·9	7·9	47·9	6·4	<0·001
Fat (E%)	30·8	5·8	31·2	6·3	30·3	5·3	0·009
SFA (E%)	11·5	3·0	12·4	3·1	10·5	2·6	<0·001
MUFA (E%)	10·3	2·5	10·3	2·5	10·4	2·4	0·374
PUFA (E%)	5·5	1·5	5·1	1·3	6·1	1·5	<0·001
α-linolenic acid (g/day)	1·7	0·9	1·4	0·6	2·1	1·0	<0·001
UFA / total fat –ratio	0·58	0·07	0·55	0·06	0·61	0·06	<0·001
Dietary fibre (g/4·18 MJ)	13·8	4·0	12·5	3·5	15·1	4·0	<0·001

IQR, interquartile range. E%, percentage of energy. SFA, saturated fatty acids. MUFA, monounsaturated fatty acids. PUFA, polyunsaturated fatty acids. UFA, unsaturated fatty acids, including mono- and polyunsaturated fatty acids. *Men with the poor adherence had 0-11 points in the Nordic diet score and men with the good adherence 12-21 points. Women with the poor adherence had 1-10 points and women with good adherence 11-21 points. †Median and interquartile range are used for non-normally distributed variables. P values are from t-test or ǂMann-Whitney's U test, and refer to the difference between groups of poor and good adherence to the Nordic diet. §Including roots, non-root vegetables, mushrooms, legumes and nuts, but not potatoes.

Table 3. Association of the baseline Nordic diet score with the CERAD total score and MMSE after the four-year follow-up.

	All (n=1140)			Normal cognition at baseline (n=1042)*		
	β	95% CI	P value	β	95% CI	P value
CERAD total score						
Model 1	0·12	0·02, 0·22	0·020	0·12	0·03, 0·22	0·013
Model 2	0·10	-0·01, 0·20	0·062	0·10	0·00, 0·20	0·042
Model 3	0·08	-0·03, 0·19	0·160	0·08	-0·02, 0·19	0·121
MMSE						
Model 1	0·03	0·00, 0·06	0·028	0·03	0·00, 0·06	0·029
Model 2	0·03	-0·00, 0·06	0·063	0·03	0·00, 0·06	0·039
Model 3	0·02	-0·01, 0·05	0·199	0·02	-0·01, 0·05	0·108

Values are from ANCOVA· Model 1: Age, gender, education, study group and baseline CERAD total score or MMSE. Model 2: Model 1 + symptoms of depression, smoking, VO_{2max} (ml/kg/min), antihypertensive medication, lipid lowering medication and antidiabetic medication. Model 3: Model 2 + energy intake. *Individuals with impaired cognition (CERAD total score ≤70 points) at baseline were excluded.

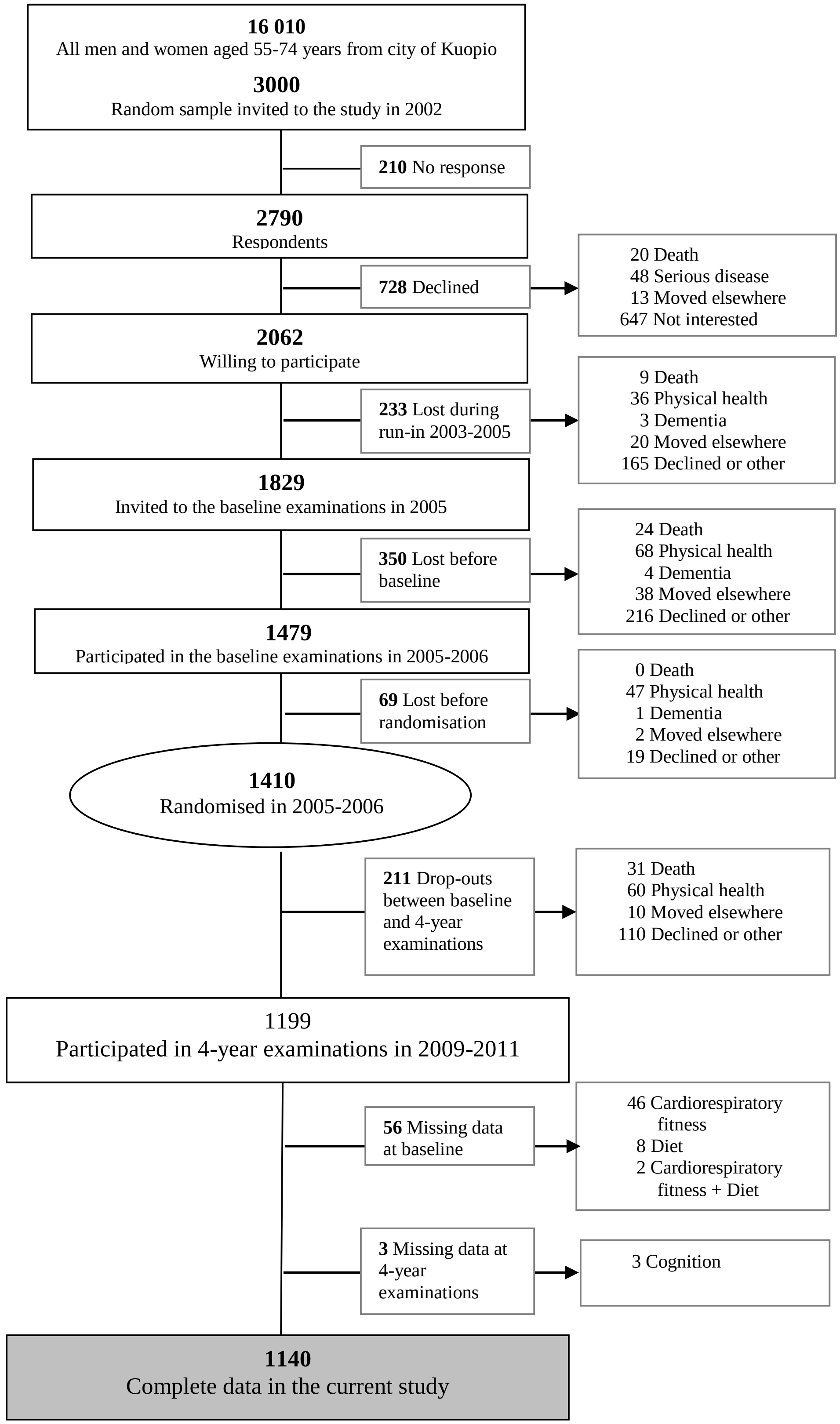

Figure 1. DR's EXTRA flow chart in the present study

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