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## A healthy Nordic diet and physical performance in old age: findings from the longitudinal Helsinki Birth Cohort Study

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### Abstract

Epidemiological studies have shown that a number of nutrients are associated with better physical performance. However, little is still known about the role of the whole diet, particularly a healthy Nordic diet, in relation to physical performance. Therefore, we examined whether a healthy Nordic diet was associated with measures of physical performance 10 years later. We studied 1072 participants from the Helsinki Birth Cohort Study. Participants' diet was assessed using a validated 128-item FFQ at the mean age of 61 years, and *a priori*-defined Nordic diet score (NDS) was calculated. The score included Nordic fruits and berries, vegetables, cereals, PUFA:SFA and *trans*-fatty acids ratio, low-fat milk, fish, red and processed meat, total fat and alcohol. At the mean age of 71 years, participants' physical performance was measured using the Senior Fitness Test (SFT), and an overall SFT score was calculated. Women in the highest fourth of the NDS had on average 5 points higher SFT score compared with those in the lowest fourth ( $P_{\text{for trend}} 0.005$ ). No such association was observed in men. Women with the highest score had 17% better result in the 6-min walk test, 16% better arm curl and 20% better chair stand results compared with those with the lowest score (all  $P$  values < 0.01). In conclusion, a healthy Nordic diet was associated with better overall physical performance among women and might help decrease the risk of disability in old age.

**Key words:** Physical performance: Senior Fitness Test: Nordic diet: Ageing

Physical performance is an important indicator of current health status of ageing individuals. Poor physical performance in old age has serious health consequences as it predisposes to disability, morbidity as well as mortality<sup>(1–4)</sup>. Reduction in physical performance can also lead to loss of independence and increase the need for healthcare and social care<sup>(5–7)</sup>. As the number of people over 65 years is growing rapidly worldwide<sup>(8)</sup>, it is important to understand lifestyle factors that are related to physical performance, and thus enhance older adults' independence and prevent adverse health outcomes<sup>(9)</sup>.

There is strong evidence that physical activity is an important modifiable factor associated with physical performance, whereas evidence on the effect of diet is more limited.

Some observational studies have investigated the associations between single nutrients and physical performance and have reported positive associations with vitamin D<sup>(10–12)</sup>, antioxidants<sup>(13,14)</sup> and *n*-3 fatty acids<sup>(15)</sup>. Relatively little is known about the whole diet and overall physical performance. The few existing studies have shown that people who adhere to the Mediterranean diet have better physical performance<sup>(16)</sup> and a slower decline of mobility when ageing<sup>(17,18)</sup>. In addition, it has been observed that adherence to overall nutrition recommendation is related to better physical performance in old age<sup>(19)</sup>. Most of these studies have assessed physical functioning with questionnaires or tested only selected aspects of physical performance, such as measuring lower-body

**Abbreviations:** NDS, Nordic diet score; SFT, Senior Fitness Test.

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strength using the Short Physical Performance Battery (SPPB). However, it is important to measure all key physiological parameters that are needed for performing normal everyday activities, and thus focus on overall physical functioning.

Although previous studies have shown that the Mediterranean diet is associated with better physical performance, adherence to the Mediterranean diet may be hard to implement globally because of differences in food culture and resources. Therefore, diets that take into account regional food culture and resources are needed. For example, a healthy Nordic diet illustrates the healthier choices of the diet consumed in the Nordic countries and is rich in foods available in the Nordic countries, including apples and berries, roots and cabbages, rye, oats and barley, low-fat milk products, rapeseed oil and fish (salmon and Baltic herring); it is also low in red meat, processed meat products and alcohol<sup>(20,21)</sup>. It has been reported that a healthy Nordic diet contains lower amounts of meat products and sweets and higher amounts of plant food and fish than a diet of Swedish reference population<sup>(20)</sup>. Studies have shown a positive effect of a healthy Nordic diet on several CVD risk factors such as blood pressure<sup>(22)</sup> and inflammation<sup>(23)</sup> as well as all-cause mortality<sup>(24)</sup>. Whether a healthy Nordic diet also predicts overall physical performance in old age is still unknown. Therefore, the purpose of this study was to expand our current understanding of the association between diet and overall physical performance and investigate whether a Nordic diet, which illustrates healthier dietary choices based on foods that are typically grown in the Nordic countries, is related to physical performance 10 years later in older men and women.

## Methods

### Design and study population

The subjects of this study belong to the Helsinki Birth Cohort Study, which includes 4630 men and 4130 women who were born as singletons at the Helsinki University Central Hospital between 1934 and 1944, attended child welfare clinics in the city and lived in Finland in 1971<sup>(25)</sup>. We used random-number tables to select a subset of people who attended a clinical examination during 2001–2004. Of the 2902 invited subjects, 2003 men ( $n$  928) and women ( $n$  1075) participated in the examination<sup>(26)</sup>. In 2011–2013, 1404 participants (627 men and 777 women) were still traceable and were invited to a follow-up clinical examination: 151 had died, 212 had declined participation in subsequent follow-up evaluations and 236 lived abroad or further than 100 km from Helsinki. A total of 1094 participants (478 men and 616 women) attended the clinical examination between 2011 and 2013. Of these, 1072 had adequate information on physical performance tests and food intake and were included in this study.

Those who participated in a follow-up clinical examination were younger at baseline (61.3 *v.* 61.9 years), had lower BMI (27.2 *v.* 28.2 kg/m<sup>2</sup>), had a university degree (23.9 *v.* 18.1%) and were less likely to smoke at baseline (19.2 *v.* 29.2%) compared with those who did not participate ( $P_{\text{for all}} < 0.05$ ). In addition, their energy intake was lower (9.2 *v.* 9.6 MJ) and the Nordic diet score (NDS) was higher (13.0 *v.* 12.4) ( $P_{\text{for all}} < 0.05$ ). Fat, protein, carbohydrate and alcohol intakes were similar in both groups.

Both studies were conducted according to the guidelines laid down in the Declaration of Helsinki, and all the procedures involving human subjects were approved by the Coordinating Ethics Committee of the Hospital District of Helsinki and Uusimaa. Written informed consent was obtained from all the participants.

### Dietary assessment

At the baseline clinical examination, dietary intake information was collected using a validated, self-administered, 128-item FFQ designed to assess average food intake over the previous 12 months<sup>(27,28)</sup>. For each food item and mixed dish, participants indicated their average frequency of consumption over the previous year by checking one of nine frequency categories ranging from 'never or seldom' to 'at least six times a day'. At the clinic, participants completed the FFQ, which was then checked by a research nurse. The final decision regarding the completeness of the FFQ was made by a nutritionist. Exclusions were made because of incompletely filled FFQ and daily energy intake cut-off points corresponding to 0.5% at both ends of the daily energy intake distributions for men and women. The average daily intakes of nutrients and foods were calculated using the national food composition database Fineli<sup>®(29)</sup>.

We used *a priori*-defined NDS, which is also known as the Baltic Sea Diet Score, as a measure of a healthy Nordic diet<sup>(21)</sup>. In brief, the NDS is based on nine components. Favourable food components including fruits and berries (apples, pears and berries), vegetables (tomatoes, lettuce, cucumbers, cabbages, legumes and roots – potatoes excluded), cereals (rye, oats and barley), low-fat milk (fat-free milk and milk with fat content under 2%), fish (salmon, Baltic herring) and a ratio of PUFA:SFA and *trans*-fatty acids were assigned values of 0–3 according to ascending sex-specific quartile ranks. Unfavourable food components including red meat and meat products (beef, pork, processed meat products) and intake of total fat expressed as a percentage of total energy intake were assigned values of 0–3 according to descending sex-specific quartile ranks. In addition, men consuming 20 g or less and women consuming 10 g or less of alcohol per day received 1 point, or else 0 point was assigned. The NDS ranged from 0 to 25, where a higher score indicates greater adherence to the healthy Nordic diet.

### Physical performance

At the follow-up clinical examination, physical performance was assessed using the validated Senior Fitness Test (SFT) battery<sup>(30,31)</sup>. We used a modified test battery that consisted of five measurements of physical fitness: (1) number of chair stands during 30 s to assess lower-body strength, (2) arm curl to assess upper-body strength (curling weight, 2 kg for women and 3 kg for men, through the full range of motion as many times as possible during 30 s), (3) chair sit and reach to assess lower-body (hamstring) flexibility (from sitting position at front of the chair, distance between fingers and toe), (4) back scratch to assess upper-body (shoulder) flexibility (with one hand reaching over the shoulder and one up the middle of the back, distance between extended middle fingers) and (5) 6-min walk

test to measure aerobic endurance (distance walked in 6 min). All the measurements were performed by a team of trained research assistants.

For each test, the scores of the participant were classified with respect to percentile tables of normative data for each 5-year age group<sup>(31)</sup>. A rating from 1 to 20 was given according to each 5-percentile range, with 1 being the worst performance (score below the 5th percentile), 2 the score from the 5th to the 9th percentile and 20 the best performance (in or above the 95th percentile). We then established the overall score, which was the sum of the normalised scores at the five SFT tests. The overall SFT score varied between 5 and 100.

### Covariates

Age, BMI, educational status, physical activity, smoking status and total energy intake were all considered as potential confounders of the association between the NDS and physical capacity. During the baseline clinical examination, height was measured to the nearest 0.1 cm and weight to 0.1 kg. BMI was calculated as weight in kilograms divided by the square of height in metres. Energy intake was measured using an FFQ as an average intake (in MJ/d). On the basis of the questionnaires, the level of educational attainment was classified as elementary school, vocational school, senior high school and university degree. For smoking status, participants were categorised into never-smokers, former smokers and current smokers. Participants' physical activity was assessed using a questionnaire. At the baseline clinical examination, participants completed a validated exercise questionnaire (Kuopio Ischaemic Heart Disease Risk Factor Study (KIHD) 12-month leisure-time physical activity (LTPA) history)<sup>(32)</sup>. This questionnaire was used to assess duration, frequency and intensity of the most common forms of LTPA, including indoor and outdoor activities performed during the previous 12 months. For each intensity grade, activity-specific metabolic equivalent values were used. Total exercise includes various types of leisure-time activities, from house cleaning and gardening to, for example, jogging and resistance training, during leisure time.

### Statistical methods

The relationship between the NDS and physical performance was examined visually and with a linear regression analysis. We tested for interactions between the NDS and sex on overall SFT score ( $P=0.01$ ). As the interaction was significant, women and men were analysed separately. Models were adjusted for possible confounding factors: model 1 was adjusted for age and model 2 for age, BMI, educational attainment, physical activity, smoking status and total energy intake. In addition, we analysed associations between the NDS and SFT components and associations of each NDS component with overall SFT score, adjusting for the same potential confounders. All the statistical analyses were carried out using SPSS Statistics version 22 for Windows® (SPSS Inc.); significance level was set at  $P<0.05$ .

### Results

The final analysis included 600 women and 472 men. Tables 1 and 2 show the baseline characteristics of women and men

according to quartiles of the NDS. Women with the highest score for the NDS were on average slightly older, more educated, more physically active and less likely to be current smokers than those with the lowest NDS. Men with higher NDS were more physically active and less often current smokers compared with those with a low score (all  $P$  values  $<0.01$ ). Men and women with higher NDS had higher intake of total energy, carbohydrates and fibre and lower intakes of total fat, SFA and MUFA compared with those with a low score (all  $P$  values  $<0.001$ ). Mean intakes of  $\beta$ -carotenes, folate and vitamins B<sub>6</sub>, C, D and E differed significantly across the NDS quartiles, such that higher intakes were associated with a higher NDS (all  $P$  values  $<0.001$ ).

We observed a statistically significant association between the NDS and the overall SFT score in women (Table 3). In a fully adjusted model, the overall SFT score was 0.55 (95% CI 0.22, 0.88) points higher per 1 unit increase in the NDS. Women in the highest fourth of the NDS had on average 5 points higher overall SFT score compared with the lowest fourth of the NDS ( $P_{\text{for trend}} 0.005$ ). Among men, the NDS was not associated statistically significantly with the overall SFT score. Regarding single SFT components, in a fully adjusted model with the NDS as a continuous variable, 1 point higher NDS was associated with 0.16 (95% CI 0.06, 0.26) unit higher 6-min walk test score, 0.18 (95% CI 0.09, 0.28) unit higher arm curl and 0.11 (95% CI 0.03, 0.19) unit higher chair stand test results. The 6-min walk test score was on average 17% higher among those women with the highest NDS compared with those with the lowest score ( $P_{\text{for trend}} 0.002$ ). A similar statistically significant association was observed in men after adjusting for age. However, in a fully adjusted model, the association was no longer statistically significant in men. In addition, women with the highest NDS had 16% better arm curl test results and 20% better chair stand test results compared with those with the lowest score (all  $P$  values  $<0.01$ ). There were no significant associations between the NDS and upper-body (shoulder) flexibility or lower-body (hamstring) flexibility either in women or in men (Table 3). LTPA was not statistically significantly associated with SFT after adjustment for age, BMI, educational attainment and smoking status in women ( $P=0.087$ ) or in men ( $P=0.12$ ).

To better understand the individual role of each NDS component, we examined the associations between each NDS component and the overall SFT score (Table 4). In women, high consumption of fruit and berries, cereals and alcohol were positively related to the overall SFT score, whereas intake of total fat and consumption of red and processed meat were inversely associated with the SFT score. In men, high consumption of cereals and low consumption of low-fat milk were significantly associated with better overall SFT score.

### Discussion

In this study of ageing women and men, we found that among women a higher adherence to a healthy Nordic diet at baseline was associated with better physical performance 10 years later, even after controlling for physical activity. A healthy Nordic diet was especially associated with better results in the 6-min walk,

**Table 1.** Lifestyle factors and nutrient intakes according to the Nordic diet score (NDS) quartiles in women (*n* 600) at baseline (Mean values with their standard errors or proportions)

	NDS quartiles							
	1 (NDS < 10)		2 (NDS 10–12)		3 (NDS 13–14)		4 (NDS > 14)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Age (years)	60.9	0.2	61.2	0.2	61.7	0.3	61.4	0.2
Height (cm)	162.9	0.4	163.6	0.4	163.5	0.5	163.7	0.5
Weight (kg)	72.7	1.0	73.5	1.0	72.7	1.0	70.6	1.1
BMI (kg/m <sup>2</sup> )	27.4	0.4	27.5	0.4	27.2	0.4	26.3	0.4
Current smokers (%)	28.7		16.7		11.8		10.8	
LTPA (MET-h/year)*	1881	104	2033	120	1979	104	2205	121
Education (%)†	17.2		21.5		20.1		25.6	
Nutrient intake								
Energy (MJ) ‡	7.4	0.2	8.5	0.2	8.7	0.3	9.3	0.2
Carbohydrate (E%)‡	46.9	0.4	50.2	0.5	51.3	0.4	54.1	0.4
Sucrose (E%)‡	9.3	0.3	10.1	0.3	10.2	0.2	10.3	0.3
Fibre (g)§	22.0	0.4	25.5	0.4	28.9	0.6	36.4	0.9
Protein (E%)‡	17.5	0.2	17.0	0.2	17.5	0.2	17.3	0.2
Fat (E%)‡	35.6	0.3	32.8	0.4	31.2	0.4	28.6	0.3
SFA (E%)‡	13.7	0.2	12.2	0.1	10.9	0.1	9.6	0.2
MUFA (E%)‡	11.7	0.1	10.7	0.2	10.4	0.2	9.4	0.1
PUFA (E%)‡	5.1	0.1	5.1	0.1	5.4	0.1	5.2	0.1
NaCl (g)§	8.0	0.1	7.9	0.1	8.1	0.1	8.0	0.1
β-Carotene (mg)§	3.5	0.1	3.9	0.2	5.1	0.3	6.4	0.4
Vitamin B <sub>6</sub> (mg)§	2.3	0.04	2.3	0.04	2.6	0.06	2.7	0.06
Vitamin B <sub>12</sub> (µg)§	8.8	0.3	8.6	0.4	9.0	0.4	8.9	0.4
Folate (µg)§	345.0	5.5	361.3	5.5	389.4	6.9	440.7	8.4
Vitamin C (mg)§	177.4	6.2	200.0	7.1	229.4	8.8	286.9	13.5
Vitamin D (µg)§	7.9	0.3	8.5	0.4	9.8	0.7	9.5	0.4
Vitamin E (mg)§	12.1	0.2	12.7	0.2	14.0	0.3	14.5	0.3

LTPA, leisure-time physical activity; MET, metabolic equivalent; E%, percentage of total energy intake.

\* 12-month history of LTPA.

† University degree.

‡ Adjusted for age.

§ Adjusted for age and daily energy intake.

arm curl and chair stand tests, reflecting better aerobic endurance and upper- and lower-body strength. Our results suggest that a healthy diet such as a healthy Nordic diet may help decrease the burden of functional limitations among older individuals.

Our study has important strengths including the use of a large study population consisting of both men and women. In addition, a long follow-up time provides an opportunity to explore the long-term influences of diet on physical performance. A further strength of our study is that we measured the overall physical performance instead of single aspects of it. SFT is validated and developed to measure especially older adults' physical capacity to perform normal everyday activities<sup>(31)</sup>. In contrast to the widely used SPPB, the SFT provides detailed information needed for evaluating specific physical functions such as aerobic endurance and flexibility. It has also been speculated<sup>(33)</sup> that the SPPB contains items that have been found to be too easy (side-by-side balance test) or too difficult (five-times chair stand) to be effective performance discriminators for older, especially community-residing, people<sup>(1,34)</sup>.

There are some potential limitations that need to be considered when interpreting the results. First, as diet was assessed using an FFQ, participants might have overestimated the consumption of healthy food and under-reported the intake of food that is considered unhealthy<sup>(28)</sup>. However, the used FFQ was validated and it measures the entire diet and ranks subjects reasonably well

according to their dietary intakes<sup>(27,28)</sup>. Second, even though we were able to adjust for a wide range of potential confounders including physical activity, we cannot exclude the possibility of residual confounding or effect modifications caused by other unmeasured covariates. In the present study, educational attainment was used as proxy of socio-economic status. We acknowledge that socio-economic status was higher among those with a high NDS than those with a lower score. In addition, individuals who had high NDS were more physically active than those with a low NDS. Therefore, even though the observed associations were robust to adjustment for socio-economic status and physical activity, future intervention studies may be particularly useful in determining whether a Nordic diet has also causal effects rather than serving as a marker of better overall quality of life. Third, individuals who participated in the follow-up clinical examination were younger, thinner, more educated and had a healthier diet at baseline compared with those who did not participate. Therefore, participants may not be fully representative of all older people living in Helsinki. Further, selective attrition over time may also introduce potential bias. These restrictions, however, rather underestimate than increase our ability to detect statistically significant associations between diet and overall physical performance. Finally, our study population came from an ethnically and culturally homogeneous Finnish population, which might limit the generalisability of our results to other populations or ethnicities.



**Table 2.** Lifestyle factors and nutrient intakes according to the Nordic diet score (NDS) quartiles in men (*n* 472) at baseline (Mean values with their standard errors or proportions)

	NDS quartiles							
	1 (NDS < 10)		2 (NDS 10–12)		3 (NDS 13–14)		4 (NDS > 14)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Age (years)	61.1	0.2	61.3	0.2	61.1	0.2	61.5	0.3
Height (cm)	176.6	0.5	177.4	0.5	177.9	0.6	177.2	0.6
Weight (kg)	84.6	1.1	84.9	1.0	86.8	1.1	86.0	1.3
BMI (kg/m <sup>2</sup> )	27.1	0.3	27.0	0.3	27.4	0.3	27.3	0.4
Current smokers (%)	31.2		18.6		18.3		10.9	
LTPA (MET-h/year)*	1657	94	1951	144	1881	95	2270	132
Education (%)†	19.9		28.7		37.0		31.5	
Nutrient intake								
Energy (MJ)‡	9.5	0.3	10.1	0.3	11.1	0.3	10.8	0.3
Carbohydrate (E%)‡	47.6	0.5	49.9	0.5	51.4	0.6	54.7	0.5
Sucrose (E%)‡	8.8	0.3	8.8	0.3	9.5	0.3	9.0	0.3
Fibre (g)§	20.8	0.5	25.9	0.5	29.1	0.6	35.2	1.1
Protein (E%)‡	16.5	0.2	16.7	0.2	17.0	0.2	16.9	0.2
Fat (E%)‡	35.9	0.4	33.4	0.4	31.6	0.4	28.5	0.4
SFA (E%)‡	13.5	0.2	12.0	0.2	10.9	0.2	9.4	0.2
MUFA (E%)‡	12.1	0.2	11.3	0.2	10.7	0.2	9.5	0.2
PUFA (E%)‡	5.1	0.1	5.3	0.1	5.4	0.1	5.0	0.1
NaCl (g)§	9.9	0.1	9.9	0.2	10.2	0.2	10.1	0.2
β-Carotene (mg)§	2.9	0.2	3.6	0.2	4.2	0.3	4.8	0.4
Vitamin B <sub>6</sub> (mg)§	2.5	0.04	2.7	0.05	3.1	0.07	3.1	0.05
Vitamin B <sub>12</sub> (µg)§	10.5	0.4	10.5	0.3	12.8	0.5	12.0	0.7
Folate (µg)§	359.7	6.6	393.9	6.6	435.3	8.4	456.0	8.4
Vitamin C (mg)§	148.9	6.0	189.9	7.3	235.1	10.6	238.5	11.7
Vitamin D (µg)§	9.3	0.3	10.8	0.4	13.4	0.7	13.4	0.7
Vitamin E (mg)§	13.4	0.2	14.9	0.3	16.2	0.4	16.5	0.4

LTPA, leisure-time physical activity; MET, metabolic equivalent; E%, percentage of total energy intake.

\* 12-month history of LTPA.

† University degree.

‡ Adjusted for age.

§ Adjusted for age and daily energy intake.

To our knowledge, the present study is the first to focus on a healthy Nordic diet and its role on overall physical performance among older persons. However, previous studies have observed positive associations between the Mediterranean diet and adherence to nutrition recommendation and physical performance as well as frailty among older individuals<sup>(16–19,35)</sup>. A healthy Nordic diet resembles the Mediterranean diet, as the concept of the Mediterranean diet has been the inspiration for the concept of a healthy Nordic diet. Accordingly, both diets are rich in fruits, vegetables, whole grains, fish and low-fat dairy products. However, caution should be taken when comparing the results of a healthy Nordic diet with the Mediterranean diet as foods in these diets refer to different variants – for example, whole grains in the Mediterranean diet mostly come from dark wheat bread and pasta, whereas in a healthy Nordic diet whole grains mostly come from rye bread. However, both these diets show that a healthy diverse diet can be constructed from locally available foods. A healthy Nordic diet may be easier to implement in Nordic countries than a Mediterranean diet, as it takes into account local food resources and culture. It is known that local well-known foods that are part of the food culture are better adapted to the diet compared with foreign foods. In addition, a diet that contains locally available foods is also environmentally friendly.

We observed that a healthy Nordic diet was related to better overall physical performance in old women but not in men.

Similar sex differences were demonstrated by Martin *et al.*<sup>(36)</sup> when they investigated the associations between single nutrients and foods and physical performance. There are several possible explanations for the observed sex differences. For example, our study included more women than men, which may limit the statistical power to detect significant associations among men. In addition, the life expectancy of women is longer than men, which could result in greater healthy survivor effects among men than women in our study population. Furthermore, studies have shown consistent sex-related behavioural differences in food choices – for example, it is known that men consume higher amounts of processed meat and lower amounts of fruits<sup>(37,38)</sup>. Therefore, as the NDS was based on sex-specific quartiles, men with high NDS could consume lower amounts of favourable foods and higher amounts of unfavourable foods than women.

There are likely to be several mechanisms underlying the observed association. For example, several studies have shown that oxidative stress and inflammation may play a key role in the decrease of skeletal muscle strength and mass as well as overall physical performance, as proposed in a review by Semba *et al.*<sup>(39)</sup>. Previous epidemiological studies support this hypothesis by showing positive associations between antioxidants and physical performance<sup>(13,14)</sup>. In the present study, we observed that among those who had the highest

**Table 3.** Participants' overall Senior Fitness Test (SFT) scores and points of SFT components according to the Nordic diet score (NDS) quartiles (Mean values with their standard errors; regression coefficients and 95% confidence intervals)

	NDS quartiles								Regression coefficient*	95% CI	P†
	1		2		3		4				
	Mean	SE	Mean	SE	Mean	SE	Mean	SE			
<b>Women</b>											
SFT score											
Model 1‡	43.4	1.3	45.5	1.4	48.7	1.4	51.8	1.7	0.81	0.48, 1.15	<0.001
Model 2§	45.0	1.2	45.7	1.2	48.3	1.2	49.6	1.7	0.55	0.22, 0.88	0.005
Chair stand											
Model 1‡	5.9	0.3	6.2	0.3	6.6	0.3	7.4	0.4	0.13	0.05, 0.20	0.001
Model 2§	6.1	0.3	6.2	0.3	6.5	0.3	7.3	0.4	0.11	0.03, 0.19	0.006
6-min walk											
Model 1‡	9.0	0.4	10.0	0.4	10.6	0.4	12.0	0.5	0.26	0.16, 0.36	<0.001
Model 2§	9.6	0.3	10.1	0.4	10.5	0.4	11.2	0.5	0.16	0.06, 0.26	0.002
Arm curl											
Model 1‡	9.1	0.3	9.9	0.4	11.1	0.4	11.3	0.5	0.22	0.13, 0.31	<0.001
Model 2§	9.5	0.3	9.9	0.4	10.9	0.4	11.0	0.5	0.18	0.09, 0.28	0.001
Chair sit and reach											
Model 1‡	9.7	0.4	9.5	0.5	9.7	0.4	10.7	0.6	0.12	0.01, 0.23	0.18
Model 2§	10.1	0.4	9.5	0.5	9.6	0.4	10.4	0.6	0.06	-0.06, 0.18	0.68
Back scratch											
Model 1‡	9.6	0.4	10.0	0.5	10.8	0.5	10.5	0.6	0.10	-0.01, 0.21	0.09
Model 2§	9.9	0.4	10.1	0.4	10.7	0.4	9.9	0.5	0.04	-0.07, 0.14	0.58
<b>Men</b>											
SFT score											
Model 1‡	41.8	1.3	42.4	1.6	43.4	1.6	42.9	1.6	0.16	-0.19, 0.52	0.51
Model 2§	42.7	1.2	42.4	1.5	43.2	1.5	42.0	1.6	-0.01	-0.36, 0.35	0.87
Chair stand											
Model 1‡	5.6	0.3	6.0	0.3	5.8	0.3	5.7	0.3	0.01	-0.07, 0.07	0.92
Model 2§	5.8	0.3	6.0	0.3	5.7	0.3	5.5	0.3	-0.03	-0.10, 0.04	0.43
6-min walk											
Model 1‡	10.0	0.5	10.6	0.5	10.8	0.5	11.6	0.6	0.14	0.02, 0.26	0.03
Model 2§	10.4	0.4	10.6	0.4	10.7	0.5	11.3	0.5	0.08	-0.04, 0.19	0.19
Arm curl											
Model 1‡	8.7	0.4	9.4	0.5	10.1	0.4	9.3	0.5	0.09	-0.01, 0.19	0.17
Model 2§	8.9	0.4	9.5	0.4	10.0	0.4	9.0	0.5	0.04	-0.07, 0.15	0.60
Chair sit and reach											
Model 1‡	7.8	0.5	7.4	0.5	7.4	0.5	6.9	0.6	-0.05	-0.17, 0.07	0.25
Model 2§	7.8	0.5	7.4	0.5	7.4	0.5	6.7	0.6	-0.08	-0.21, 0.05	0.13
Back scratch											
Model 1‡	10.0	0.5	9.0	0.5	9.4	0.6	9.6	0.6	-0.02	-0.15, 0.10	0.70
Model 2§	10.0	0.4	8.9	0.5	9.5	0.6	9.7	0.6	-0.01	-0.14, 0.12	0.82

\* Regression coefficient for change in SFT scores or points of SFT components for 1 point higher NDS.

† P for a linear trend across fourths, tested by linear regression analyses.

‡ Adjusted for age.

§ Adjusted for age, energy intake, BMI, smoking status, educational attainment and physical activity.

score to a healthy Nordic diet had higher intake of several antioxidants including  $\beta$ -carotene and vitamins C and E, compared with those with the lowest score. In addition, the dietary patterns associated significantly with better overall physical performance were higher intakes of fruits, berries and cereals, which all are linked with reduced oxidative stress and inflammation<sup>(40)</sup>, and lower intakes of fat and red and processed meat. In contrast to fruits and cereals, intake of fat and red and processed meat have been shown to be related to increased oxidation as well as inflammation<sup>(40)</sup>. In addition, a healthy Nordic diet has been found to reduce the expressions of genes related to inflammation<sup>(23)</sup> and to be associated with lower plasma levels of biomarkers of inflammation<sup>(41)</sup>. Therefore, we suggest that a healthy Nordic diet may prevent oxidative stress and inflammation, and thus have beneficial effects on overall physical performance.

We did not find significant associations between a healthy Nordic diet and upper- or lower-body flexibility, although flexibility is an important determinant of physical performance, and reduced flexibility can result in impaired mobility<sup>(42,43)</sup>. To our knowledge, previous studies have not investigated the association between the whole diet and flexibility in older adults. On the basis of our observations, we suggest that the role of diet on flexibility is minor, whereas other than dietary factors physical activity<sup>(44)</sup> particularly plays a key role in determining flexibility.

From a public health point of view, our results are encouraging and introduce specific opportunities to promote physical performance in older age with better adherence to a healthy Nordic diet. It is known that even small improvements in physical performance have major impacts on a person's ability to live independently, and thus subsequently may decrease healthcare costs. In addition to

**Table 4.** Participants' adjusted overall Senior Fitness Test score according to the Nordic diet score (NDS) component quartiles\* (Mean values with their standard errors)

	Quartile intakes of NDS components								P†
	1		2		3		4		
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	
<b>Women</b>									
Cereals	45.1	1.3	45.4	1.2	49.7	1.3	47.6	1.4	0.034
Vegetables	45.3	1.3	48.1	1.3	48.7	1.3	45.7	1.4	0.73
Fruit and berries	44.0	1.2	46.4	1.3	49.8	1.3	47.6	1.4	0.010
Low-fat milk	45.2	1.4	46.0	1.3	49.6	1.2	46.8	1.3	0.15
Fish	45.9	1.3	46.9	1.4	48.3	1.2	46.5	1.5	0.55
Fat ratio‡	47.3	1.3	46.3	1.3	47.0	1.4	47.1	1.4	0.99
Fat (E%)	49.2	1.4	47.3	1.2	47.3	1.2	44.0	1.4	0.006
Red and processed meat	49.7	1.2	47.3	1.3	46.0	1.3	44.7	1.4	0.001
Alcohol§	46.3	0.7	50.2	1.7					0.029
<b>Men</b>									
Cereals	40.5	1.5	42.3	1.5	43.0	1.3	44.5	1.4	0.036
Vegetables	43.5	1.4	42.5	1.4	41.5	1.6	42.7	1.3	0.57
Fruit and berries	43.0	1.4	41.8	1.4	41.7	1.5	43.8	1.5	0.67
Low-fat milk	44.5	1.3	44.4	1.7	41.4	1.4	40.0	1.4	0.009
Fish	43.0	1.5	41.9	1.4	42.3	1.4	43.1	1.5	0.87
Fat ratio‡	44.3	1.4	42.1	1.5	41.1	1.4	42.8	1.5	0.40
Fat (E%)	42.7	1.4	42.8	1.6	42.4	1.3	42.4	1.5	0.85
Red and processed meat	44.8	1.5	42.5	1.4	40.0	1.4	43.0	1.5	0.16
Alcohol§	42.6	0.8	42.5	1.5					0.96

E%, percentage for total energy intake.

\* Adjusted for age, energy intake, BMI, smoking status, education and physical activity.

† P for a linear trend across fourths, tested by linear regression analyses.

‡ Ratio of PUFA:SFA + trans-fatty acids.

§ Women who consumed <10 g of alcohol and men who consumed <20 g of alcohol were in the lowest quartile.

physical performance, a healthy Nordic diet has other health benefits as it improves the blood lipid profile and insulin sensitivity, lowers blood pressure and inflammation and is linked with a smaller waist circumference<sup>(22,23,45,46)</sup>. Thus, a healthy Nordic diet seems to enhance physical performance as well as cardiovascular and overall health.

In conclusion, our study indicates that among women a healthy Nordic diet predicts better physical performance, and especially better aerobic endurance and upper- and lower-body strength 10 years later. In particular, high consumption of Nordic cereals and fruit and berries and low consumption of red and processed meat and total fat are related to better overall physical performance. Therefore, a healthy Nordic diet may subsequently decrease the risk of disability in old age. Future longitudinal studies are, however, needed to determine whether the beneficial associations of a healthy Nordic diet on physical performance are also found in other Nordic countries and closer regions.

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