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The healthy Nordic diet predicts muscle strength 10 years later in old women, but not old men

Abstract

Background: a number of nutrients have been found to be associated with better muscle strength and mass, however, the role of the whole diet on muscle strength and mass remains still unknown.

Objective: to examine whether the healthy Nordic diet predicts muscle strength, and mass 10 years later among men and women.

Methods: 1072 participants belong to the Helsinki Birth Cohort Study, born 1934–44. Diet was assessed with a validated food-frequency questionnaire during 2001–2004. The Nordic diet score (NDS) was calculated. The score included Nordic fruits, vegetables, cereals, ratio of polyunsaturated to saturated fatty acids, low-fat milk, fish, red meat, total fat and alcohol. Higher scores indicated better adherence to the healthy Nordic diet. Hand grip strength, leg strength (knee extension), and muscle mass were measured during the follow-up, between 2011 and 2013.

Results: In women, each 1-unit increase in the NDS was related to 1.83 N greater leg strength (95% confidence interval [CI] 0.14–3.51; P=0.034), and 1.44 N greater hand grip strength (95% CI 0.04–2.84; P=0.044). Women in the highest quartile of the NDS had on average 20.0 N greater knee extension results, and 14.2 N greater hand grip results than those in the lowest quartile. No such associations were observed among men. The NDS was not significantly related to muscle mass either in men or women.

Conclusions: adherence to the healthy Nordic diet seems to protect from weaker muscle strength in old women. Therefore, the healthy Nordic diet may help to prevent disability.

Introduction

Skeletal muscle strength and mass decrease progressively with older age [1]. Poor muscle strength in later life is associated with several health consequences such as poor functioning and a greater risk of falls, disability and premature death and is related to significant health care costs [2, 3]. Lifestyle factors, such as exercise, have been shown to slow down the rate of decline in muscle strength and mass in older age [4]. However, less is known about the effect of other lifestyle factors, such as nutrition, which potentially can influence the rate of decline in muscle strength and mass and thus prevent disability.

Some nutrients have been shown to be linked with muscle strength and mass, including protein, vitamin D and the antioxidants β-carotene, vitamin E and vitamin C [5-11]. As the diet contains several foods and nutrients that interact with each other, the results of the associations between single nutrient and functioning may be confusing and difficult to interpret. Therefore, the interest has moved towards the whole diet instead of single nutrients for the last decade. Only a few studies have, however, investigated the role of the whole diet on muscle strength and mass. In these studies, a prudent diet was associated with better hand grip strength [9] and adherence to the Healthy Eating Index [12] and Mediterranean diet [13] was related to better muscle strength and physical functioning as well as decreased risk of mobility limitations in ageing individuals [14-16].

It is well known that local foods that are part of the food culture are better adapted to the diet compared to foreign foods. Therefore, the Mediterranean diet may not be easily adopted by other communities including the Nordic countries due to differences in food culture and resources. Thus, diets that take into account regional food culture and resources are needed. For example, the healthy Nordic diet is based on healthy, common local Nordic food items, characterised by high consumption of Nordic fruits, vegetables, whole-grain products, fish, and rapeseed oil and low consumption of red meat, and alcohol [17, 18]. Adherence to the healthy Nordic diet has been shown to be associated with better physical capacity in old age as well as smaller waist circumference, better insulin sensitivity, less low-grade inflammation, and hypertension [19-22]. However, it is still unknown whether the healthy Nordic diet has positive influences on muscle strength and mass as well. We therefore examined the associations between adherence to the healthy Nordic diet and muscle strength, and mass 10 years later among 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 at Helsinki University Central Hospital between 1934 and 1944 [23]. Using random-number tables, a sample of 2902 participants was invited to a clinical examination during 2001–2004. Of these, 2003 men and women participated. In 2011–2013, 1404 men and women were still traceable and were invited to a follow-up clinical examination. A total of 1094 men and women participated. Both clinical studies were approved by the Coordinating Ethics Committee of the Hospital District of Helsinki and Uusimaa. Written informed consent was obtained from each subject.

Dietary assessment

At the baseline clinical examination, the food intake over the previous 12 months was assessed by a validated, 128-item food-frequency questionnaire (FFQ) [24]. The average use of each food-item and mixed dish was recorded by nine frequency categories ranging from never or seldom to at least six times a day. The portion sizes were fixed, e.g. a glass or a slice of bread. At the clinic, participants completed the FFQ, which was then checked by a research nurse. Exclusions were made due to 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 with the national food composition database, Fineli®.

The details of the Nordic diet score (NDS), also known as the Baltic Sea Diet Score [18], has been described elsewhere. In brief, it is based on nine components: high intake of Nordic fruits (apples, pears, and berries); Nordic vegetables (tomatoes, cucumber, leafy vegetables, roots, cabbages and peas); Nordic cereals (rye, oat, and barley); low-fat and fat-free milk; Nordic fish (salmon and freshwater fishes); ratio of polyunsaturated fatty acids to saturated fatty acids and trans-fatty acids; low intake of red and processed meat; total fat; and moderate or low intake of alcohol. The NDS components were divided using sex-specific quartiles of average daily intakes, and for each dietary component, except alcohol, points from 0 to 3 were assigned according to the predictable impact on health. In addition, participants received 1 point if alcohol intake was moderate (≤20 g/day alcohol for men and ≤10 g/day alcohol for women) and 0 if above. The NDS ranged from 0 to 25, where a higher score indicates better adherence to the healthy Nordic diet.

Muscle strength and mass measurements

At the follow-up clinical examination, maximal isometric hand grip strength and leg strength (knee extension) were measured in a sitting position using an adjustable dynamometer chair (Good Strength, Metitur Oy, Jyväskylä, Finland) [25]. Isometric hand grip strength was measured on the dominant hand by fixing the arm to the armrest of the chair with the elbow flexed at an angle of 90°. Isometric leg strength was measured on dominant leg at a knee angle of 60° from full extension. The contraction was maintained for 2–3 s. The participants were allowed one practice followed by three measurements. The best result was chosen for the analysis. Total lean body mass was measured by bioelectrical impedance analysis using the InBody 3.0 eight-polar tactile electrode system (Biospace Co., Ltd, Seoul, Korea). All measurements were performed by a team of trained research assistants.

Covariates

During the baseline clinical examination, height was measured to the nearest 0.1 cm and weight to 0.1 kg. Body mass index (BMI) was calculated as (weight (kg)/height (m)^2). Energy intake was measured with an FFQ as an average intake (in MJ per day). Based on the questionnaires, the level of educational attainment was categorised into three groups according to the number of years in school: basic (≤9 years of education); secondary (10–12 years), and higher (≥13 years). For smoking status, participants were classified as never, former, or current smokers. Participants' physical activity was measured by using a validated exercise questionnaire [26] which assessed duration, frequency and intensity of the most common forms of leisure time physical activity, including indoor and outdoor activities performed during the previous 12 months. For each intensity grade, activity-specific metabolic equivalent values were used.

Statistical analyses

A total of 1072 participants had adequate information on both muscle strength and mass and food intake. There were significant interactions between sex and the NDS on the muscle strength and mass and therefore men and women were analysed separately (P-value for all <0.05). The associations between the NDS and muscle strength, and mass were analysed by linear regression analyses. The models were adjusted for potential confounding variables, which included age and energy intake (Model 1), while Model 2 was further adjusted for BMI, smoking status, educational attainment, and physical activity.

If the NDS was significantly related to the muscle strength or mass, we tested which of the NDS components contributed the most to the observed association. All statistical analyses were done using the SPSS Statistics version 23 for Windows® (SPSS Inc., Chicago, IL, USA). Significance was defined as P<0.05.

Results

The final analysis included 472 men and 600 women. Participants with higher adherence to the NDS were slightly older, more educated, less often smokers, and physically more active (**Table 1**). In women, each 1-unit increase in the NDS was related to 1.83 N greater leg strength (95% confidence interval [CI] 0.14–3.51; P=0.034), and 1.44 N greater hand grip strength (95% CI 0.04–2.84; P=0.044) (**Table 2**). Women in the highest quartile of the NDS had on average 20.0 N greater knee extension results, and 14.2 N greater hand grip results compared to those in the lowest quartile. No such statistically significant associations were observed in men. There were no significant associations between the NDS and muscle mass either in men or women (**Table 2**).

Table 3 shows associations between single NDS component and muscle strength by quartiles of NDS among women. Nordic cereals and alcohol intake were positively related to leg strength. In addition, red and processed meat was inversely and intake of alcohol was positively related to hand grip strength.

Discussion

This study shows that adherence to the healthy Nordic diet predicts greater hand grip and leg muscle strength 10 years later among women but not among men. We observed that hand grip strength was on average 5% and leg strength 7% greater among those women who had the highest adherence to the healthy Nordic diet compared to those with the lowest adherence. It has been shown that muscle strength declines approximately 10-15% per decade in old age [27]. Therefore, we suggest that a healthy diet, such as the healthy Nordic diet may have a major impact on a person's physical functioning and may contribute to the prevention of disability among older women. To the best of our knowledge, this is the 1st study investigating the association between the healthy Nordic diet and muscle strength and mass in older men and women.

We have recently reported that the healthy Nordic diet is related to better physical capacity in old women [21]. In the present study, we provide novel information by showing that adherence to the healthy Nordic diet predicts greater muscle isometric strength but not muscle mass. Thus, we propose that the association of the healthy Nordic diet with physical capacity is mostly the result of Nordic diets positive effect on muscle isometric strength whereas muscle mass has only a minor role.

Our results confirmed previous findings that suggest beneficial effects of the Mediterranean diet and Healthy Eating Index on muscle strength [12-16]. Even though foods in these diets refer to different variants there are several similarities between these diets, e.g. all diets are rich in fruits, vegetables, whole grains, fish and low-fat dairy products. Several mechanisms could mediate the positive effects that the healthy Nordic diet had on muscle strength. For example, the healthy Nordic diet has been shown to decrease the likelihood of obesity [22], a factor which is closely related to decline of muscle strength and mass [28]. In addition, adherence to the healthy Nordic diet is related to high intake of several antioxidants, including β-carotene and vitamin C and E [21]. Several studies have reported associations between low antioxidants level and greater risk of developing poor muscle strength [5-11]. We also observed that antioxidants rich Nordic cereals were positively and red and processed meat that increase oxidation and inflammation were inversely associated with greater muscle strength. It is well known that both oxidative stress and inflammation have a crucial role on the development of declines of muscle strength and mass [28]. Therefore, we suggest that the association between the healthy Nordic diet and muscle strength may be partly explained by its beneficial effect on oxidative stress and inflammation.

We observed that the NDS was not statistically significantly related to muscle mass in this study. To the best of our knowledge, previous studies have not investigated the association between the whole diet and muscle mass in older age. According to studies focusing upon single nutrients, there is strong evidence that protein intake has a beneficial effect on muscle mass whereas more evidence is needed about the effect of other nutrients on muscle mass [29]. In addition, it has been shown that muscle strength declines faster than muscle mass with older age [29]. Therefore, it could be that the association between diet and muscle strength may be detected earlier than the association between diet and muscle mass.

In our study, the NDS was related to greater muscle strength in women but not in men. We have previously shown that the NDS was related to better physical capacity in women but not in men [21]. This finding is also in line with a previous study in which a significant association between diet and muscle strength was observed only in women [7]. The reason for observed sex differences is still unknown. However, it is known that muscle strength declines earlier in women than in men, which is mostly the result of changes in hormonal status during menopause [30]. Therefore, differences in sex hormones could partly explain observed sex differences. We also suggest that sex differences in life expectancy may, at least partly, explain these findings because the life expectancy of women is longer than men. This could result in greater healthy survivor effects among men than women in our study cohort. In addition, the NDS was based on sex-specific quartiles, thus, men with the high NDS consumed lower amounts of favourable foods and higher amounts of unfavourable foods than women, as seen in Table 1. It has also been speculated that adult lifestyles, including diet and physical activity, may have important effect on physical performance especially among older women [7].

Strengths of this study include the use of a large study population consisting of both men and women. We also objectively measured both upper-body and lower-body muscle strength. In addition, we investigated the whole diet instead of focusing upon single nutrients. As the diet contains several food items and each food-item contains several nutrients that interact with each other, the results of the associations between single nutrient and muscle strength and mass may be confusing and difficult to interpret. Studies investigating the whole diet may be easy for the public to understand and therefore, results may be more easily applied to public health settings. This study also has some potential limitations. The diet and the physical activity were assessed only at baseline; therefore, any changes in the diet or physical activity during the 10 year follow-up were not captured. In addition, when the diet is assessed by an FFQ, participants may overestimate healthy and underestimate unhealthy food consumption [25] which may lead to some misclassifications in the NDS quartiles. However, we used a validated FFQ that measured the entire diet and ranks subjects reasonably well according to their dietary intakes [24, 25]. Our observed associations were robust to adjustment for physical activity and socioeconomic status, however, intervention studies are needed to be certain that the Nordic diet has causal effects rather than serving as a marker of better overall quality of life. Those who participated in the follow-up clinical examination were younger, thinner, more educated, and had healthier diet at baseline compared with those who did not participate as reported earlier [21]. Hence, we cannot disregard the possibility of selection bias influencing observed associations. These restrictions, however, are likely to underestimate than increase our ability to detect statistically significant associations between diet and muscle strength.

Conclusion

Our results demonstrate that in women the adherence to the healthy Nordic diet was associated with greater muscle strength measured 10 years later. Therefore, a healthy diet, such as the healthy Nordic diet, may slow down the decrease in muscle strength in older people and may have positive effects on later life physical functioning. However, further longitudinal prospective studies are needed to confirm the associations between the healthy Nordic diet and muscle strength in other Nordic countries.

Key points:

- Adherence to the healthy Nordic diet predicts better hand grip and leg muscle strength in old women.
- The healthy Nordic diet may have positive impact on physical functioning in old age and thus may help protect to disability.
- The healthy Nordic diet is not associated with muscle mass.

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Table 1. Baseline characteristics and food intakes according to the Nordic diet score quartiles in women and men

	Women					Men				
	Nordic diet score quartiles					Nordic diet score quartiles				
	1	2	3	4		1	2	3	4	
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	P [c]	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	P [c]
n	171	163	145	121		139	130	109	94	
Age (years)	60.9 (2.8)	61.2 (3.1)	61.7 (3.1)	61.4 (2.7)	0.059	61.1 (2.7)	61.3 (2.6)	61.1 (2.5)	61.5 (2.6)	0.41
BMI (kg/m^2)	27.4 (4.9)	27.5 (4.6)	27.2 (4.5)	26.3 (4.4)	0.065	27.1 (3.5)	27.0 (3.5)	27.4 (3.5)	27.3 (3.5)	0.41
Smokers (%)					<0.001					0.011
Never	47	62	65	72		15	29	31	38	
Former	24	21	23	17		44	52	51	51	
Current	29	17	12	11		31	19	18	11	
Education (%)[a]					0.015					0.40
≤9 years	52	42	33	36		40	33	33	29	
10-12 years	12	18	22	15		16	19	12	19	
≥13 years	36	39	45	49		44	48	55	52	
MET (h/years) [b]	1881 (1365)	2033 (1526)	1979 (1250)	2205 (1333)	0.081	1657 (1104)	1950 (1647)	1881 (991)	2270 (1283)	0.001
NDS	7.8 (2.1)	12.0 (0.8)	15.0 (0.8)	18.6 (1.7)	<0.001	7.6 (2.1)	11.9 (0.8)	15.1 (0.9)	18.5 (1.6)	<0.001
NDS component										
Cereals (g)	35.0 (26.9)	53.3 (27.8)	60.4 (31.8)	84.7 (29.3)	<0.001	37.9 (26.0)	56.3 (28.1)	68.1 (29.9)	97.0 (54.2)	<0.001
Vegetables (g)	292.8 (288.7)	476.1 (313.2)	619.1 (300.4)	727.2 (305.6)	<0.001	227.6 (233.0)	384.6 (318.6)	440.4 (336.2)	591.7 (320.9)	<0.001
Fruits (g)	78.7 (78.7)	132.8 (119.3)	189.9 (201.4)	277.5 (223.8)	<0.001	44.9 (47.5)	92.3 (126.9)	153.4 (139.0)	198.9 (176.5)	<0.001
Low-fat milk (g)	108.9 (176.7)	147.2 (188.3)	209.6 (216.3)	253.4 (236.0)	<0.001	136.8 (197.2)	226.1 (292.5)	259.1 (257.3)	334.5 (279.3)	<0.001

Fish (g)	25.2 (17.3)	40.5 (44.7)	51.3 (77.7)	55.2 (41.0)	<0.001	36.4 (25.7)	52.0 (32.7)	73.0 (56.4)	71.2 (50.3)	<0.001
Fat ratio	0.37 (0.10)	0.42 (0.12)	0.49 (0.15)	0.54 (0.14)	<0.001	0.38 (0.10)	0.44 (0.11)	0.49 (0.13)	0.54 (0.13)	<0.001
Fat (E%)	35.6 (4.2)	32.8 (4.5)	31.2 (4.2)	28.6 (3.7)	<0.001	35.9 (4.8)	33.4 (4.6)	31.6 (4.6)	28.4 (4.0)	<0.001
Red meat (g)	104.5 (67.7)	88.6 (63.3)	82.8 (69.5)	63.5 (46.0)	<0.001	174.5 (138.4)	142.6 (109.8)	128.4 (102.7)	95.5 (59.5)	<0.001
Alcohol (g)	6.6 (8.1)	5.4 (8.1)	5.2 (6.6)	4.5 (5.8)	0.014	14.9 (17.4)	15.1 (15.3)	12.8 (13.3)	13.9 (16.4)	0.42

SD, standard deviation; BMI, body mass index; MET, metabolic equivalent NDS, Nordic diet score; E%, per cent of total energy intake.

[a] Number of years in school.

[b] Leisure time physical activity.

[c] P value was determined using linear regression for continuous variables and χ^2 test for categorical variables. Significance testing was at P<0.05.

Table 2. Participants' muscle strength and mass according to the Nordic diet score quartiles

	Nordic diet score quartiles					
	1	2	3	4		
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Regression coefficient (CI) [a]	P
Women						
Hand grip strength (N)						
Model 1 [b]	262.4 (67.3)	271.5 (67.2)	264.5 (61.8)	276.9 (69.6)	**1.41 (0.08–2.73)**	**0.037**
Model 2 [c]	262.5 (67.4)	272.1 (66.9)	264.2 (62.9)	276.7 (69.2)	**1.44 (0.04–2.84)**	**0.044**
Leg strength (N)						
Model 1 [b]	283.4 (82.4)	288.4 (82.4)	280.9 (74.1)	302.1 (79.8)	**1.60 (0.01–3.20)**	**0.049**
Model 2 [c]	283.3 (82.4)	287.8 (82.8)	280.8 (74.5)	303.3 (79.9)	**1.83 (0.14–3.51)**	**0.034**
Lean body mass (kg)						
Model 1 [b]	45.8 (5.4)	46.7 (5.5)	46.2 (5.2)	45.8 (5.9)	0.03 (-0.08–0.14)	0.59
Model 2 [c]	45.8 (4.4)	46.4 (4.9)	46.2 (4.4)	46.2 (4.8)	0.06 (-0.04–0.16)	0.22
Men						
Hand grip strength (N)						
Model 1 [b]	511.8 (125.3)	520.4 (105.3)	534.2 (126.6)	497.2 (112.7)	0.18 (-2.41–2.78)	0.89
Model 2 [c]	509.2 (125.8)	522.2 (104.8)	534.1 (126.1)	499.1 (114.7)	0.57 (-2.17–3.31)	0.68
Leg strength (N)						
Model 1 [b]	461.8 (112.7)	460.2 (114.7)	464.4 (102.0)	465.3 (107.3)	0.17 (-2.23–2.58)	0.89
Model 2 [c]	462.4 (110.5)	463.3 (111.0)	463.9 (102.1)	460.8 (108.4)	-0.35 (-2.85–2.15)	0.78

Lean body mass (kg)						
Model 1 [b]	62.4 (8.2)	63.1 (6.7)	63.9 (6.9)	63.8 (8.1)	0.14 (-0.03–0.31)	0.10
Model 2 [c]	62.5 (7.1)	63.2 (5.8)	63.7 (5.8)	63.8 (6.7)	0.11 (-0.04–0.26)	0.16

SD, standard deviation; CI, confidence interval

[a] Regression coefficient for change in muscle strength or mass for 1 point higher Nordic diet score, statistically significant associations ($P<0.05$) are bolded.

[b] Model 1: Adjusted for age and energy intake.

[c] Model 2: Adjusted for age, energy intake, body mass index, educational attainment, physical activity, and smoking status.

Table 3. Relationship between the Nordic diets score component and muscle strength among women

Components	Hand grip strength (N) Regression coefficient (CI) [a]	P [b]	Leg strength (N) Regression coefficient (CI) [a]	P [b]
Cereals	4.38 (-0.88–9.64)	0.10	**6.34 (0.02–12.7)**	**0.049**
Vegetables	-1.30 (-6.55–3.96)	0.63	-2.07 (-8.40–4.26)	0.52
Fruits	1.56 (-3.72–6.83)	0.56	2.99 (-3.34–9.32)	0.35
Low-fat milk	0.90 (-4.17–5.97)	0.73	3.32 (-2.78–9.43)	0.29
Fish	2.93 (-2.37–8.23)	0.28	5.32 (-1.02–11.67)	0.10
Fat ratio	1.23 (-3.72–6.18)	0.63	3.99 (-1.94–9.91)	0.19
Fat	-3.89 (-8.91–1.13)	0.13	-4.59 (-10.63–1.45)	0.14
Red meat	**-9.17 (-14.72– -3.62)**	**0.001**	-2.77 (-9.49–3.95)	0.42
Alcohol	**7.28 (2.24–12.31)**	**0.005**	**8.27 (2.21–14.33)**	**0.008**

Notes: Models adjusted for age, energy intake, body mass index, educational attainment, physical activity, and smoking status.

[a] Regression coefficient for change in muscle strength for each Nordic diet score component quartile.

[b] P value for the linear trend across quartiles, statistically significant associations (P<0.05) are bolded.