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Review article

Association between adherence to the Nordic diet and frailty in older adults: A systematic review of observational studies

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ABSTRACT

Background: The Nordic or Baltic Sea diet is a healthy plant-based dietary pattern composed of foods originating from Nordic countries, closely related to the Mediterranean diet. Adherence to the Mediterranean diet has been found to be associated with a reduced risk of frailty. Although adherence to the Nordic diet has been associated with health benefits, little is known about its association with frailty.
Objectives: To investigate the evidence from observational studies regarding the association between the Nordic/Baltic Sea diet and frailty among older adults.
Design: Systematic review.
Methods: Three databases (Medline/Ovid, Embase/Ovid, and Scopus) were systematically searched in February 2023 for observational studies examining the association between adherence to the Nordic diet and frailty among adults $\geq$60 years. The two authors independently assessed the full text of the papers for eligibility of studies and risk of bias.
Results: Three studies (the results of which were reported across 6 papers) met the inclusion criteria, among which one study (2 papers) included only women. Greater adherence to the Nordic diet was associated with a reduced risk of frailty measured by modified Fried criteria in women (one study). Moreover, greater adherence to the Nordic diet was associated with improved muscle (handgrip/leg) strength (one study) and physical performance (two studies), but these differences were seen only in women, with no significant results in men in two studies. Greater adherence to the Nordic diet was also associated with a lower risk of mobility limitations and improved ability to carry out self-care tasks (one study) and a borderline non-significant difference in Activities of Daily Living (one study). A meta-analysis was not performed due to heterogenous outcomes. Although all studies were of good quality, the results should be carefully interpreted due to methodological limitations.
Conclusions: Adherence to the Nordic diet could be promising in reducing frailty risk, but more robust studies with equal gender representation and frailty-specific outcomes are needed.

1. Background

The increasing average life expectancy [1] means that individuals reach older age with a significant disease burden that has a negative effect on their quality of life [2]. Older people are often affected by frailty, a syndrome characterised by a deterioration in biological reserves and mechanisms associated with normal organ function, and increased vulnerability to stressors [3]. Frail older adults have reduced functional capacity and are at higher risk of falls, fractures, disability, hospital admissions and death [4].

As weight loss is one of the characteristics of frailty, nutrition could be a modifiable risk factor for the prevention and management of frailty [5]. An increased dietary protein intake has been suggested to help combat anabolic resistance and preserve muscle mass, strength and function [6–8]. Protein and specific amino acid supplementation have also been studied in relation to frailty, with mixed evidence where some randomised controlled trials (RCTs) have demonstrated improvements in functional performance with protein supplementation, while other studies only showed anthropometric measurement improvements with amino acid supplements [9]. A meta-analysis has shown that protein

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supplementation solely does not considerably enhance muscle function among pre-frail and frail older adults [10]. Nutritional supplements alone might not be effective in managing frailty [11], thus a multi-component approach incorporating structured exercise besides nutritional interventions should be considered [7]. Other antioxidant nutrients (carotenoids and vitamin E) [12 and vitamin D [13] have been investigated, showing promising effects.

However, considering dietary patterns overall could be more reasonable, as people consume whole meals comprising individual nutrients that interact with each other [5,7]. Adherence to the Mediterranean diet (MedDiet) has been associated with a reduced risk of various chronic conditions [15,16], and frailty [17–19]. However, essential ingredients of the MedDiet such as olive oil can be inaccessible and unaffordable in several regions around the world, leading to modifications or deviations from the MedDiet [20]. Adherence to other traditional dietary patterns has also been associated with health benefits in older age [21,22].

The Nordic diet (ND), also called Baltic Sea diet (BSD), is a healthy dietary pattern composed of food items originating from Nordic countries: Denmark, Finland, Iceland, Norway, Sweden, Faroe Islands, Greenland, and Åland [23]. It emphasizes the consumption of seasonal and regional foods including lean and fatty fish from lakes, plant-based foods like fruits (wild berries, apples, pears), cruciferous and root vegetables, mushrooms, reduced-fat dairy products, meats from free-range, wild animals, and sources of unsaturated fats including canola and rapeseed oils (Fig. 1) [23,24]. The ND has emerged as a healthy local plant-based dietary pattern closely related to the MedDiet [25]. Both patterns include ample amounts of whole grains, fruits/vegetables, and fish, while limiting red, processed meats, and other sources of saturated fats [24]. In fact, the main difference between them is that the ND incorporates rapeseed and canola oil as a source of unsaturated fats, while the MedDiet is based on olive oil [24]. Adherence to the healthy ND has been associated with health benefits including reduced risk of hypertension, heart disease, inflammation, and improved blood lipid profile [26–28].

To our knowledge, few observational studies have examined the association between the Nordic/Baltic Sea diet (N/BSD) and frailty risk among older adults, and neither RCTs nor systematic reviews have been conducted to date. The aim of this systematic review is to present evidence from observational studies examining the association between adherence to the N/BSD and frailty among community-dwelling older adults.

2. Methods

2.1. Data source and search strategy

A protocol was set according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [29]. Literature searches were initially carried out on March 17th, 2022, and were subsequently updated on February 1st, 2023. With the help of a librarian, a structured search strategy was created combining the following key concepts: frailty, older people, Nordic diet, and Baltic Sea diet. The search strategy was implemented in three electronic databases: Medline/Ovid, Embase/Ovid, and Scopus. The search strategies for Medline and Embase are presented as Supplementary material. Studies were restricted to English language only. A reference list search was also conducted on the included studies to find other relevant papers.

2.2. Study selection

One reviewer (SH) screened titles and abstracts, and two reviewers (SH and CA) independently screened full-text articles and selected the studies meeting the pre-set inclusion criteria. Any disagreements between the reviewers were discussed and resolved.

Studies were selected according to the following inclusion criteria: (1) observational (prospective cohort and cross-sectional) studies, (2) involving community-dwelling older adults (mean age ≥ 60 years), (3) assessing adherence to the N/BSD using validated tools (e.g., Nordic Diet Score (NDS), Baltic Sea Diet Score (BSDS), etc.), (4) measuring frailty as a main outcome using an original or modified version of validated criteria, such as: physical characteristics of frailty (weight loss, exhaustion, weakness (low grip strength), slow walking speed (gait speed), low physical activity) or change in frailty index; additional

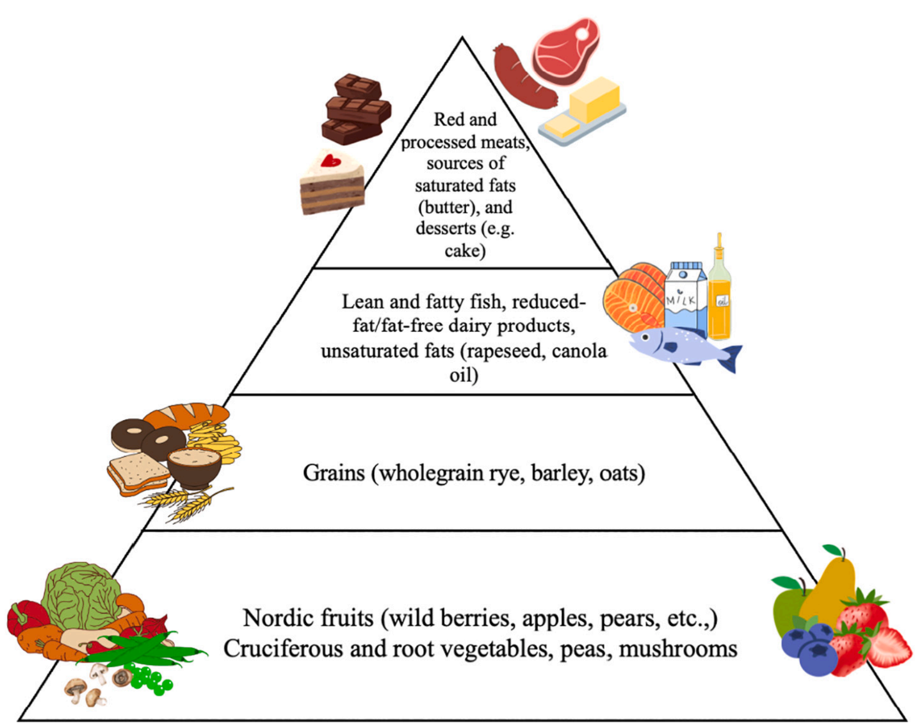

Fig. 1. Nordic/Baltic Sea diet food pyramid.

outcomes: physical performance, functioning, and other relevant clinical outcomes.

Studies were excluded if they: (1) were reviews, editorials, interventional RCTs, or conference abstracts; (2) could not be retrieved in full-text and English language; (3) were animal studies.

2.3. Data extraction

The first author (SH) extracted the following data from the eligible studies: first author, year of publication, country, study design, sample size, percentage of female participants, mean age, and age range, follow-up period, tools used to measure adherence to the N/BSD, outcome measures and main findings. The second author (CA) checked the extracted data against the content of the original papers.

2.4. Methodological quality assessment

The risk of bias was independently assessed by two reviewers (SH and CA) using the 8-item Newcastle-Ottawa Scale (NOS) for cohort studies [30] and a 7-item NOS modified for cross-sectional studies [31]. A minimum overall quality score of 5 for the studies was considered as adequate methodological quality.

2.5. Data synthesis and presentation

We anticipated to conduct a meta-analysis if feasible, however, due to the heterogeneity of the outcome measures within the selected studies, only a narrative synthesis was performed.

2.6. Study registration

The protocol for this study was registered on PROSPERO (International prospective register of systematic reviews) website (PROSPERO 2022 CRD42022336952) [32].

3. Results

3.1. Selection process

The PRISMA flowchart of the literature selection process is presented in Fig. 2. A total of 3443 articles were retrieved from searches, with additional 22 articles from reference list screening. After excluding duplicates ($n = 572$), 2893 titles and abstracts were screened, of which 2858 were excluded for being irrelevant. A total of 35 articles were included for full-text review, where 29 articles were excluded for the following reasons: conference abstract (1), reviews/editorials (6), different exposures and outcome measures (4), different exposures (15), different population age and exposures (2) and different outcome measure (1). A total of three studies met the inclusion criteria, one of which was described in 3 publications, and another was described in 2 publications. Publications reporting data from the same cohort were considered under the same study sample. Therefore 6 papers (reporting data from three studies) were included in the review.

3.2. Study characteristics

The characteristics and findings of the included studies are summarized in Tables 1 and 2. Out of the three studies included, cross-sectional analysis was presented in one paper [33] and both cross-sectional and prospective analysis in another paper from the same study population [34], and the other two were cohort studies [35–38]. A total of 3916 older adults were recruited in the selected studies, originating from Finland and Sweden, and were followed-up on average for 7.7 years.

All studies used specific validated tools to measure adherence to the

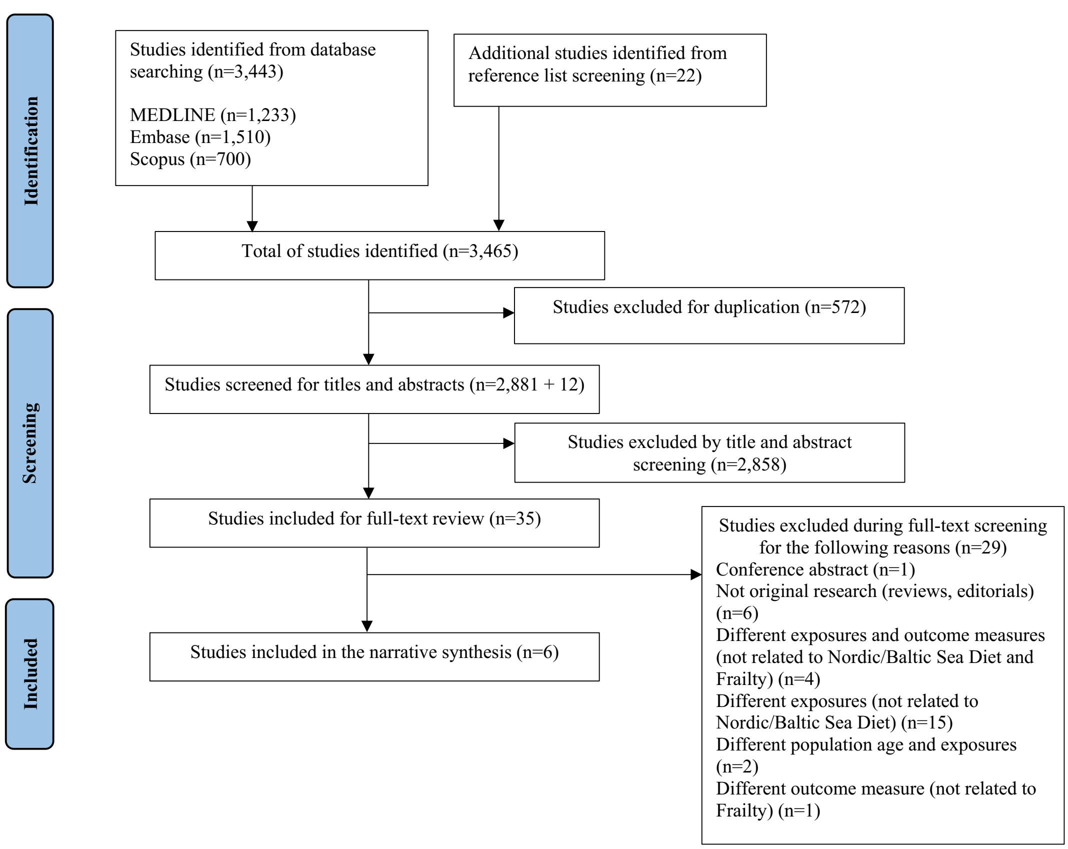

Fig. 2. PRISMA flowchart.

Table 1
Description of the characteristics of studies included in the review.

Author, year	Country	Study design	Sample size (n)	Female (%) Age, mean (range)	Follow-up (years)	N/BSD measurement	Outcome measures
Alaghehband et al., 2021 [33]	Finland	Cross-sectional	440	F 100 % 67.8 (65–72)	3 years	BSD score	Frailty score using the modified Fried frailty phenotype
Isanejad et al., 2018 [34]	Finland	Cohort (cross-sectional analysis)	554	F 100 % 67.8 (65–72)	3 years	BSD score	Physical performance including handgrip strength, N of chair rises in 30s, ability to squat, knee extension, maximal walking speed 10 m (m/s), and one leg stance performance for 30s. SPPB
Perälä et al., 2019 [35]	Finland	Cohort	962	F 54.4 % 61.6 (no age range identified)	10 years	NDS	Incident disability defined as mobility limitations and difficulty to perform self-care activities using the Finnish validated version of the RAND 36-Item Health Survey 1.0
Perälä et al., 2017 [36]	Finland	Cohort	1072	F 56 % 61 (no identified age range)	10 years	NDS	Muscle strength using isometric hand grip and leg strength (knee extension)
Perälä et al., 2016 [37]	Finland	Cohort	1072	F 56 % 61 (no identified age range)	10 years	NDS	Physical performance using SFT battery
Wu et al., 2021 [38]	Sweden	Cohort	2290	F 60.8 % 70.8 (≥60)	Up to 12 (average 10 years)	NPDP index	Physical disability defined as dependence in at least one of the six ADLs using the Katz index

BSD = Baltic Sea Diet, N/BSD=Nordic/Baltic Sea Diet, NPDP = Nordic Prudent Dietary Pattern, NDS = Nordic Diet Score, ADL = Activities of Daily Living, SFT = Senior Fitness Test, DSM- IV = Diagnostic and Statistical Manual of Mental Disorders, fourth edition, SPPB = Short Physical Performance Battery, OR = Odds Ratio, CI = Confidence Interval, HR = Hazard Ratio, RC = Regression Coefficient.

N/BSD. Of those tools, one study used the Nordic Diet Score (NDS) including 9 favourable and unfavourable food items with a score ranging from 0 to 25 [35–37]. Two studies [33,34] used a modified Baltic Sea Diet Score (BSDS), where the components were calculated slightly differently than the original NDS/BSDS due to software limitations. However, the included 9 components and score range were like the above study. Another study used the Nordic Prudent Dietary Pattern (NPDP) Index that incorporated 15 different foods and drinks, with a score range of 7–62 [38]. With all the different tools used, higher scores indicate higher N/BSD compliance.

The outcomes used within the selected articles were considered either as main measures of frailty or as a proxy for defining frailty. One study used a modified frailty score from the Fried frailty phenotype incorporating 5 components (weight loss, life satisfaction score presenting exhaustion, walking speed, hand-grip strength divided by body mass index (BMI) indicating weakness, and physical activity level) [33]. Another study measured ADL functioning using the Katz index [38]. Another study used the Finnish validated Research and Development (RAND) 36-Item Health Survey 1.0 to assess mobility limitations and difficulties in performing self-care tasks [35]. Physical performance outcomes examined in different studies included: hand grip [34] and leg strength to determine muscle strength [34,36]; a validated and modified Senior Fitness Test (SFT) battery comprising 5 measures of physical performance (number of chair stands/30 s, arm curl, chair sit and reach, back scratch, and 6-min walk test) [37]; and walking speed 10 m, chair rises 30s, and one leg stance (for Short Physical Performance Battery (SPPB)), as well as knee extension, handgrip strength and squat [34].

3.3. Risk of bias assessment

All the included papers had an overall score of 7 or above (out of a maximum of 9 points) from the NOS for cohort and modified for cross-sectional studies, indicating the presence of medium-low risk of bias. Risk of bias assessment scores are shown in Table 3.

3.4. Participants

All study participants were older adults aged ≥60 years, with more females (n = 2547) recruited than males (n = 1369). In Alaghehband et al. [33] and Isanejad et al. [34], participants were recruited from the OSTPRE-FPS study from Kuopio, Finland, and participants were exclusively females. In total 554 women participated in the Isanejad study, who were randomised to either receive vitamin D and calcium (n = 272) or no supplement (n = 282). Researchers found no significant interaction by intervention arm, they therefore did a pooled prospective analysis adjusting for the intervention, but they also presented a separate prospective analysis in the control group only [34].

Wu et al. recruited participants from the Swedish National Study on Ageing and Care-Kungsholmen (SNAC-K), from Stockholm, Sweden [38]. Perälä et al. [35–37] recruited participants from the Helsinki Birth Cohort Study in Finland. Only two papers specified that they recruited healthy older adults at baseline, free of any physical [35,38] or mental disability [38].

3.5. Outcomes

3.5.1. Frailty phenotype

Frailty was defined by modified Fried frailty phenotype criteria [39] in one study that included women only [33]. Highest adherence to ND/BSD (third BSDS tertile) was associated with lower risk of frailty when compared to lowest BSDS tertile [33] both in an unadjusted and an adjusted model. Yet, the overall trend of the association between BSDS tertile and frailty was only significant when confounders were not adjusted for. Intake of vegetables within the ND/BSD was significantly lower in frail than pre-frail and robust participants [33].

3.5.2. Physical performance and mobility

Physical performance and mobility were an outcome in three studies [34,35,37]. Increased adherence to the ND showed a significant association with physical performance in women only in one study [37]. Women in the highest quartile of the NDS had on average 5 points higher overall SFT score compared with the lowest quartile of the NDS [37]. Examining each component of the SFT separately, every unit increase in NDS was significantly associated with 0.16, 0.18, and 0.11 units higher 6-min walk test score, arm curl and chair stand test results respectively. Women with the highest NDS had on average 17 % higher 6-min walk

Table 2
Description of the findings of studies included in the review.

Author, Year	Country	Main Findings
Alaghehband et al., 2021 [33]	Finland	1. No significant association between continuous BSD score and frailty (p = 0.209). 2. Every SD-unit increase in BSD was associated with decreased probability of frailty (β = 0.623, SE = 0.249, and p = 0.057) (borderline non-significant) 3. In unadjusted (β = 0.246, 95 % CI 0.076 – 0.794, P = 0.019*)* and adjusted[a] (β = 0.273, 95 % CI 0.081– 0.917, p = 0.036) models, BSD third tertile (highest adherence) had lower risk of frailty as compared to referent BSD tertile. 4. BSD tertile was significantly associated with frailty only in an unadjusted model (β = −0.104, 95 % CI = −0.030 – −0.001) (p = 0.042). 5. Vegetable intake was lowest in frail (31.5 ± 36.0 g/day) (p = 0.041) than pre-frail (37.1 ± 42.0 g/day) and healthy women (48.6 ± 40.7 g/day) (p = 0.024).
Isanejad et al., 2018 [34]	Finland	1. At baseline (cross-sectional analysis) women[h] in higher quartiles of BSD score at baseline had significantly faster walking speed 10m (p = 0.006), longer one leg stance performance (p = 0.005), and higher SPPB score (p = 0.034) than those in lower quartiles. 2. At baseline (cross-sectional analysis) there was a borderline non-significant association between BSD score and lower mobility disability (OR = 1.64, p = 0.051). 3. There was a positive cross-sectional association between BSD score (as continuous variable) and walking speed, and SPPB. 4. Over 3-year follow-up (prospective analysis), in the separate analysis in the control group, women in highest BSD quartile score showed highest improvement in SPPB (p = 0.041) and had 55 % higher squat test completion (OR = 0.45, 95 % CI: 0.11–0.98) as compared to women in lowest quartile. 5. There was a positive association between higher total fruit and vegetable (except potato) intakes and walking speed (mean difference ≥ 0.08, p ≤ 0.049). 6. There was a negative association between alcohol consumption and walking speed 10m at baseline (mean difference = − 0.3, p = 0.034).
Perälä et al., 2019 [35]	Finland	1. In models 1[b] and 2[c], highest NDS tertile had decreased probability of having mobility limitations (model 1: OR 0.42, 95 % CI 0.23 – 0.76, model 2: OR 0.42, 95 % CI 0.22 – 0.80) and difficulties in performing self-care tasks (model 1: OR 0.39, 95 % CI 0.16 – 0.93, model 2: OR 0.38, 95 % CI 0.15 – 0.94) as compared to those in the lowest NDS tertile. In model 3[d], highest NDS tertile had a significant decreased probability of having mobility limitations (OR = 0.42 (95 %CI 0.21–0.84). 2. Significant association between increased consumption of fat (OR = 4.13, 95 %CI 1.33–12.84) and increased probability of having difficulties in performing self-care activities. 3. Non-significant association between decreased intake of cereals (OR = 0.64, 95 % CI 0.27–1.5) and increased probability of having difficulties in performing self-care activities. 4. Significant association between increased alcohol consumption and decreased probability of having mobility limitations (OR = 0.48, 95 %CI 0.25–0.91).
Perälä et al., 2017 [36]	Finland	1. In women only, there were a 1.83N (95 %CI 0.14–3.51; p = 0.034) and 1.44N (95 %CI 0.04–2.84, p = 0.044) greater leg and hand-grip strength respectively with every unit increase in NDS. 2. In women, 20.0N (model 1[e]: 95 %CI 0.01–3.20, model 2[f]: 95 %CI 0.14–3.51) and 14.2N (model 1: 95 %CI 0.08 – 2.37, model 2: 95 % CI 0.04 – 2.84) greater knee extension and hand-grip strength respectively were depicted in highest NDS quartile as compared to their counterparts. Leg strength was positively associated with Nordic cereals (RC 6.34, 95 %CI 0.02–12.7, p = 0.049) and alcohol consumption (RC 8.27, 95 %CI 2.21–14.33, p = 0.008); hand-grip strength was negatively associated with red and processed meat (RC - 9.17, 95 % CI -14.72 – −3.62, p = 0.001) and positively associated with alcohol intake (RC 7.28, 95 % CI 2.24–12.31, p = 0.005).
Perälä et al., 2016 [37]	Finland	1. In women, in a fully adjusted model[g], NDS was significantly associated with SFT score, where every unit increase in NDS was associated with 0.55 more points in SFT (95 %CI 0.22–0.88) score. 2. Compared to women on the lowest fourth of NDS, women on the highest fourth scored 5 points higher in SFT (p = 0.005). 3. There was 0.16 (95 %CI 0.06–0.26), 0.18 (95 %CI 0.09–0.28), and 0.11 (95 %CI 0.03–0.19) unit higher 6-min walk test score, arm curl and chair stand test respectively with every point increase in NDS. 4. Women with highest adherence to NDS had a 17 % higher 6-min walk test score (p = 0.002), 16 % improved arm curl and 20 % improved chair stand test as compared to counterparts (p<0.01). 5. In women, SFT scores positively correlated with increased consumption of fruits and berries (p = 0.01), cereals (p = 0.034), and alcohol (p = 0.029), and negatively correlated with processed and red meat intake (p = 0.001). 6. No significant results in a fully adjusted model in men. 7. In men, SFT scores positively correlated with higher intake of cereals (p = 0.036) and negatively correlated with lower intake of reduced-fat milk (p = 0.009).
Wu et al., 2021 [38]	Sweden	1. Borderline significant association between every unit increase in NPDP index and likelihood of survival free of dementia and physical disability (HR = 1.02, 95 %CI 1.01–1.02).

BSD = Baltic Sea Diet, N/BSD = Nordic/Baltic Sea Diet, NPDP = Nordic Prudent Dietary Pattern, NDS= Nordic Diet Score, ADL = Activities of Daily Living, SFT = Senior Fitness Test, DSM- IV = Diagnostic and Statistical Manual of Mental Disorders, fourth edition, SPPB = Short Physical Performance Battery, OR = Odds Ratio, CI = Confidence Interval, HR = Hazard Ratio, RC = Regression Coefficient.

[a] Adjusted for age, energy intake, smoking status, living and marital status, and calcium and vitamin D supplementation intervention group.

[b] Adjusted for sex and age.

[c] Adjusted for b and BMI, educational achievement, smoking status, physical activity, energy intake, presence of chronic conditions and depression.

[d] Adjusted for c and impaired cognitive function.

[e] Adjusted for age and energy intake.

[f] Adjusted for e and BMI, educational achievement, physical activity, and smoking status.

[g] Adjusted for age, energy intake, BMI, smoking status, educational achievement, and physical activity.
[h] Adjusted for e and smoking, total physical activity, hormone therapy, osteoporosis, rheumatoid arthritis, coronary heart disease, income per month and fat mass percentage.

test score, 16 % improved arm curl test and 20 % improved chair stand test compared to the lowest. However, in men, and with full adjustments, there were no significant associations.

Examining the effect of ND food components on physical performance, this study found that higher SFT score was associated with higher intake of fruits and berries, alcohol, and cereal, and associated with lower intake of red and processed meats in women, and with a higher intake of cereal and lower intake of reduced-fat milk in men [37].

In another study [34], women in the highest BSD quartiles had longer one leg stance and higher SPPB score at baseline. In the prospective analysis of all women (among whom half of these i.e. those in the intervention arm also received vitamin D and calcium) using BSD score as continuous variable, higher adherence to BSD was positively associated with walking speed and SPPB. In the prospective analysis including only women in the control group, women in the highest BSD quartile showed the highest improvement in SPPB and 55 % higher squat test completion [34].

Finally, in another study [35] the highest NDS tertile was associated with significantly lower probability of self-reported mobility limitations, compared to the lowest NDS tertile, and high alcohol consumption was significantly associated with lower probability of having mobility limitations [35].

3.5.3. Muscle strength

This was studied as an outcome in one study [36], described as hand grip and leg strength, where it was found that in women there was 1.83 N greater leg strength, and 1.44 N greater grip strength with each 1-unit increase in the NDS. In comparison to women in the lowest NDS quartile, women in the highest NDS quartile had on average 20.0 N and 14.2 N greater knee extension and grip strength respectively, while no significant association was shown in men. While leg strength was positively associated with cereal and alcohol intake adapted from the ND components specifically, grip strength was negatively associated with consumption of red and processed meat and positively associated with alcohol intake [36].

Hand grip strength was also examined as an outcome in another study [34], where no significant association was found between BSD quartile at baseline or at 3-year follow-up.

3.5.4. Ability to perform ADLs

This was studied as an outcome in two studies [35,38] which studied the association between higher compliance with the ND and reduced risk of difficulties in performing self-care activities [35] and dependence in ADLs [38]. In one study [38] adherence to the ND using the NPDP Index showed a borderline significantly increased likelihood of survival free of physical disability with increase in every unit in NPDP score.

In another study [35] participants with highest adherence to the ND were less likely to develop difficulties performing self-care activities compared to those with lowest adherence. Upon further investigation of the effect of specific food components within the ND, an association was found between increased fat intake and increased difficulty in perfoming self-care activities.

Table 3
Risk of bias assessment for the included studies.

Cohort study	Selection				Comparability	Outcome			
	Representativeness of the cohort	Selection of the non-exposed cohort from the same source as exposed cohort	Ascertainment of exposure	Outcome of interest was not present at start of study	Comparability of cohorts	Ascertainment of outcome	Follow-up long enough for outcomes to occur	Adequacy of follow-up of cohorts	Quality score
Wu et al., 2021	Somewhat representative ★	Yes ★	Structured interview ★	Yes ★	★★	★	Yes ★	★	9
Perälä et al., 2019	Somewhat representative ★	Yes ★	Structured interview ★	Yes ★	★★	Written self-report	Yes ★	★	8
Perälä et al., 2017	Somewhat representative ★	Yes ★	Structured interview ★	No	★★	★	Yes ★	★	8
Perälä et al., 2016	Somewhat representative ★	Yes ★	Structured interview ★	No	★★	★	Yes ★	★	8
Isanejad et al., 2018 (regarding prospective analysis)	Somewhat representative ★	Yes ★	Written self report	No	★★	★	Yes ★	★	7

Cross-sectional study	Representativeness of the sample	Sample size	Non-respondents	Ascertainment of exposure	Comparability	Ascertainment of outcome	Statistical test	Quality score
Alaghehband et al., 2021	Somewhat representative ★	Included sample size calculated from the original trial but not for the cross-sectional study	★	Written self-report	★★	★★	★	7
Isanejad et al., 2018 (regarding cross-sectional analysis)	Somewhat representative ★	Included sample size calculated from the original trial but not for the cross-sectional study	★	Written self-report	★★	★★	★	7

4. Discussion

In this systematic review 6 papers were identified reporting data from 3 observational studies, with 3802 community-dwelling older adults followed for 7.7 years on average. Results have shown that increased compliance to the ND was associated with reduced frailty risk measured by modified Fried criteria in one study that included only women [33]. Greater adherence to the ND was associated with improved hand grip strength and leg strength in women in one study [36], with no significant results in men, whereas the association between ND and grip strength was non-significant in another study with women only [34]. Similarly, adherence to the ND showed a significant association with several measures of physical performance but only in women, with no significant differences in men [37], and with improved physical performance in women in another study that recruited only women [34]. Moreover, greater adherence to the ND was associated with reduced risk of self-reported mobility limitations and ability to carry out self-care tasks in one study [35]. Finally, a borderline non-significant difference in ADL functioning was found in one study [38].

The association between other healthy dietary patterns and risk of frailty has been reported in the literature. Compliance with the MedDiet, apart from a reduced risk of cardiovascular disease, diabetes, cancer, and obesity [14–16], has also been associated with a lower risk of incident frailty [17] and improved muscle strength, walking speed, and physical activity [18,40,41]. Similarly, the Japanese dietary pattern has been associated with reduced risk of frailty and physical disability [21], potentially associated with specific antioxidant capacity food items [42]. Interestingly, higher adherence to other dietary patterns such as the Dietary Approaches to Stop Hypertension (DASH) diet and the Alternative Healthy Eating Index-2010 (AHEI-2010) were also associated with a significantly lower frailty risk [43].

While one cohort study did not demonstrate an association between vegetable consumption and frailty [44], a systematic review showed opposite results where fruit and vegetable intake was associated with decreased frailty risk [45]. Similar results were yielded in this review where fruit consumption, as part of the ND, was associated with better physical functioning. The relationship between dietary protein intake and frailty has been widely investigated, yielding heterogenous results [46]. Some studies have shown a positive association between higher protein/protein rich food intake and decreased incident frailty and improved physical performance and capacity [47–50], while other studies found no association between higher protein intake and muscle mass, strength, and function [46,51]. Diet quality [52,53] and variety [54] are also important factors. Ultra-processed foods, despite their low dietary quality, tend to be consumed excessively due to their convenience, tastiness, and high caloric content [52], and their consumption can predict frailty [15,55]. On the contrary, long-term adherence to an overall varied, good quality diet, rich in fruits and grains, has been associated with reduced frailty risk [53,54].

The association between N/BSD and frailty can be explained by several mechanisms. It is known that oxidative stress and pro-inflammatory reactions are part of the ageing process, exacerbating the risk of developing physical disabilities, frailty, and muscle strength loss [33,36]. Adopting the ND was found to decrease obesity risk, a significant condition leading to muscle mass and functional decline [36]. In specific, consumption of fruits and vegetables which are associated with numerous health benefits including decreased risk of cardiovascular conditions and obesity, is a major component of the healthy N/BSD pattern [33]. Furthermore, their antioxidant properties can delay frailty progression, mitigate inflammation, and protect against chronic conditions [56].

Interestingly, in several of the studies included in this review, alcohol consumption was associated with positive health outcomes (mobility [35], muscle strength [36], physical performance [37]), which seems like an unexpected result. A previous systematic review found that non-drinkers were more likely than those with low alcohol consumption to develop frailty, whereas no evidence was found for an association between high levels of alcohol consumption and becoming frail. This review however found that people who did not consume any alcohol were more likely to be prefrail rather than robust and had poorer cognition and more comorbidities at baseline, which could explain the findings [57]. In a retrospective cohort study, after adjustment for potential confounders, non-hazardous alcohol use and hazardous alcohol use were associated with lower incidence of frailty compared to no alcohol use, which might be due to reverse causality or residual confounding [58].

The main strength of our review is that to date, it is the first systematic review examining the association between N/BSD and frailty. Two independent reviewers were involved in article selection process and risk of bias assessment, using a rigorous methodology. Limitations related to the review include that grey literature was not searched for, and that a meta-analysis was not conducted due to heterogeneity of the outcomes of the included papers.

Nevertheless, there are some limitations related to methodological challenges of the included studies. Only one study directly assessed risk of frailty using an original or modified tool developed to define frailty, while the others included components of frailty as their main outcomes. However, it is worth mentioning that the lack of consensus regarding the definition of frailty [59] has inevitably led to variation in frailty-related outcome measures.

In addition, in most of the studies, details about blinding of researchers were not given. Food intake was assessed using self-reported methods (information on diet obtained either via structured interview or written self-report), posing the risk of recall and selection bias. Moreover, although all studies adjusted for several factors including age, sex, lifestyle factors, and BMI, residual confounders cannot be entirely excluded. Finally, in the cross-sectional studies sample size calculation was undertaken only for the original RCT.

Interestingly, two papers demonstrated results attributed to sex differences. Perälä 2016 detected significant associations among women only [37] that could be explained by the fact that more women were recruited than men (potentially lacking the power to detect associations among men), or that women usually live longer, or that there are differences in food choices between men and women, where men usually consume more processed meats and less fruits. As for the sex differences observed in Perälä 2017 [36], one explanation could be that muscle strength tends to decrease in women earlier than men due to menopause-related hormonal changes. Two other studies [33,34] recruited only women.

The above highlight that high-quality research is needed with a robust methodology that clearly describes blinding processes and select non-frail participants at baseline. In addition, adequate power size calculation, objective assessment of dietary intake, and assessment of frailty using validated criteria should be considered. Finally, further consensus is required regarding agreed definition of frailty and appropriate frailty-specific outcomes.

The findings of this review have important clinical implications. Adherence to the healthy N/BSD may improve physical function and muscle strength. Based on the evidence available, the Nordic population are given the opportunity to explore their dietary patterns and inform their healthy eating guidelines. From a public health perspective, this review introduces the need to encourage older adults to adopt the healthy ND that could contribute to improved physical performance and muscle strength. Finally, healthy eating guidelines should be coupled with physical activity advice, especially when it comes to managing frailty.

5. Conclusion

Adherence to the N/BSD may be promising in preventing frailty among older adults. There is some evidence examining the direct association between adherence to this dietary pattern and improvement in frailty-associated measures in a few studies, although studies have overall included more women than men, and from this small number of studies there appear to be gender differences. More good quality research from large population-based studies with representation of both genders and more frailty-specific definition of outcomes is needed to establish these associations.

Contributors

Sarah Hanbali did systematic searches, performed screening of titles and abstracts, screening of full text, risk-of-bias assessment, data extraction, and drafted the manuscript.

Christina Avgerinou had the concept of the study, reviewed the search strategy, performed screening of full text, risk-of-bias assessment, checked the extracted data, reviewed and redrafted parts of the manuscript.

Both authors saw and approved the final version and no other person made a substantial contribution to the manuscript.

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Declaration of competing interest

The authors declare that they have no competing interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.maturitas.2024.107923.

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