

Original Research Article

A randomized, controlled trial of a Nordic, protein-reduced complementary diet in infants: effects on body composition, growth, biomarkers, and dietary intake at 12 and 18 months

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ABSTRACT

Background: High intake of protein and low intake of plant-based foods during complementary feeding can contribute to negative long-term health effects.

Objectives: To investigate the effects of a protein-reduced, Nordic complementary diet on body composition, growth, biomarkers, and dietary intake, compared with current Swedish dietary recommendations for infants at 12 and 18 mo.

Methods: Healthy, term infants ($n = 250$) were randomly allocated to either a Nordic group (NG) or a conventional group (CG). From 4 to 6 mo, NG participants received repeated exposures of Nordic taste portions. From 6 to 18 mo, NG was supplied with Nordic homemade baby food recipes, protein-reduced baby food products, and parental support. CG followed the current Swedish dietary recommendations. Measurements of body composition, anthropometry, biomarkers, and dietary intake were collected from baseline and at 12 and 18 mo.

Results: Of the 250 infants, 82% ($n = 206$) completed the study. There were no group differences in body composition or growth. In NG, protein intake, blood urea nitrogen and plasma IGF-1 were lower compared to CG at 12 and 18 mo. Infants in NG consumed 42% to 45% more fruits and vegetables compared to CG at 12 and 18 mo, which was reflected in a higher plasma folate at 12 and 18 mo. There were no between-group differences in EI or iron status.

Conclusions: Introduction of a predominantly plant-based, protein-reduced diet as part of complementary feeding is feasible and can increase fruit and vegetable intake. This trial was registered at clinicaltrials.gov as NCT02634749.

Keywords: infant feeding, early nutrition, complementary feeding, Nordic diet, infancy, repeated exposure, fruit, vegetables, plant-based food

Introduction

Early human life is a critical period of rapid growth, expanding cognitive and psychomotor functions, and high nutrient requirements [1,2]. Nutrient intake can permanently change organ development, affect metabolic processes, and establish food preferences during the limited period in early life when humans are most malleable [2–5]. The positive effects of breastfeeding are well studied; however, more evidence-based studies of the age-timing effects and nutrient composition during complementary feeding (CF) are needed [6]. A higher daily consumption of fruit and vegetables can prevent

noncommunicable diseases such as cardiovascular disease, obesity, overweight, type-2 diabetes, and some cancer forms [7–9]. Unfortunately, such foods are underconsumed among children and adults worldwide [9–13]. As many food preferences and eating patterns are established in the first years of life and these patterns and preferences may have life-long health effects [14], it is important to study if and how early feeding can be improved [15].

Complementary feeding is the process when breast milk and/or formula feeding alone is no longer sufficient to meet the nutrient requirements of the infant and therefore needs to be complemented with other foods and liquids [16]. The introduction of solid foods between 4

Abbreviations: BIG, baby food in glass jar; BUN, blood urea nitrogen; CF, complementary feeding; CG, conventional group; FR, food record; MCD, milk cereal drink; ND, Nordic diet; NG, Nordic group; NNR, Nordic Nutrition Recommendations; OTIS, optimized complementary feeding study; TBW, total body water.

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to 6 mo involves flavor learning, and combined with different food textures, this determines food preferences and future food choices [17].

A high protein intake during infancy is associated with higher BMI in early childhood and later overweight and obesity [18]. Infants are most vulnerable to high protein exposure during the first 2 y of life [19–21]. High animal protein intake at 12 mo, but not vegetable protein, has been associated with higher serum IGF-1, accelerated growth, and higher BMI at 6 y [22]. In the Nordic countries, protein intake among infants is 2 to 3 times higher than current recommendations [12, 18]. One way to reduce the high animal protein exposure during infancy while allowing the diet to remain isoenergetic is to replace it with plant-based foods [22].

The EAT-Lancet Committee advises a predominantly plant-based diet to endorse a healthy planet as well as for preventing non-communicable diseases [23]. The Nordic diet (ND) consists of mainly

plant-based, seasonal foods such as fruit, vegetables, legumes, and whole grains, and less non-climate-friendly foods such as red meat, meat products, and saturated fat [24,25]. The ND has positive effects on biomarkers of noncommunicable diseases among adults and school-children and on child development from pregnancy until 5 y [26–29], with health benefits comparable to the Mediterranean diet [30]. However, the ND has not been studied in randomized controlled trials among infants.

The aim of the trial was to test if a protein-reduced, Nordic complementary diet compared to the current Swedish recommendations for infants from the introduction of CF to 18 mo would improve body composition, biomarkers of metabolic function, and blood pressure. Secondary outcomes included effects on dietary intake as well as biomarkers of adherence, for example, hemoglobin, iron status, blood urea nitrogen (BUN), and folic acid.

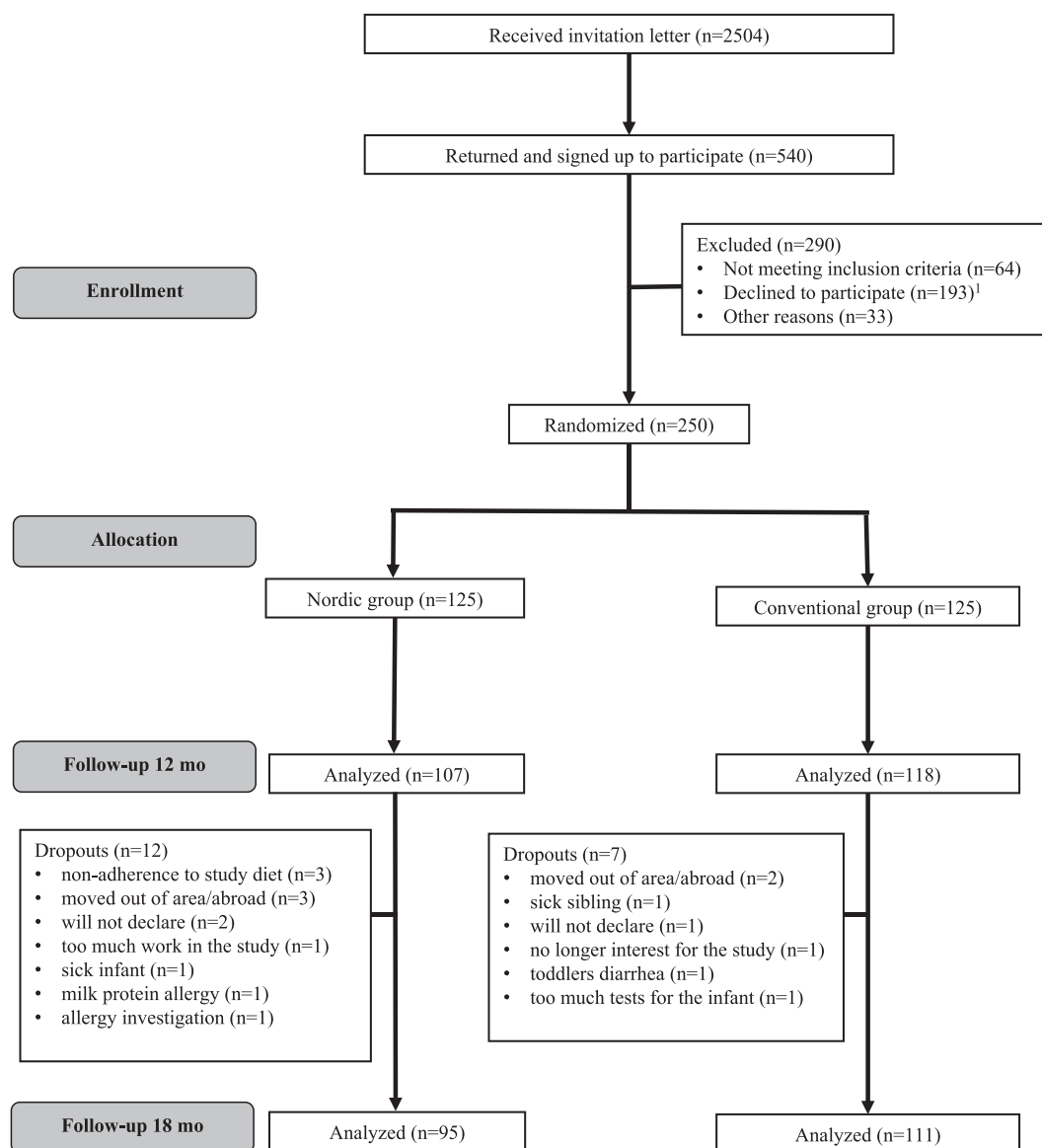


FIGURE 1. Flowchart diagram of OTIS, a randomized controlled trial on the effects of a protein-reduced, Nordic complementary diet on body composition, growth, biomarkers and dietary intake until 18 mo. ¹Reasons to decline participation: 1) too much work in the study; 2) too long study period; 3) will not give their child specific study diet; and 4) the child will start at daycare at an early age. Dropouts between baseline and follow-up age of 9 mo were 14 in NG and 4 in CG, respectively. Dropouts between 9 and 12 mo were 4 in NG and 3 in CG, respectively. CG, conventional group; NG, Nordic group; OTIS, optimized complementary feeding study.

Methods

Participants, design, allocation, and blinding

All parents of healthy, full-term, 4-mo-old singletons from Umeå, Sweden were invited by letter to participate in the OTIS trial (Swedish acronym for optimized complementary feeding study) between April 2015 and January 2018. Of 540 families, 250 were recruited (Figure 1). In the present study, we used a multicomponent design, meaning that we applied several interventions to the same group from study start to 18 mo. A detailed description of the study protocol has been published elsewhere [31]. Inclusion criteria were healthy, singleton 4- to 6-mo-old infants who were exclusively breastfed and/or formula-fed at the time of recruitment, born after >37 weeks of gestation and with birth weight >2500 g, living in Umeå, intending to remain in the study area (Umeå municipality), and not commence childcare outside home during duration of the study. Exclusion criteria were chronic illnesses that would affect nutrient intake or outcomes of the study, iron deficiency, or any other biochemical abnormality at the time of recruitment. When parents considered it appropriate to introduce CF, their infant was randomly allocated to 1 of 2 study groups (Figure 2), that is, the Nordic group (NG, intervention, $n = 125$) or the conventional group (CG, control, $n = 125$), and the study started. Thus, baseline in the present study represents a period from 4 to 6 mo of age rather than a fixed age. Parents, the research nurses, and the dietitians could not be completely blinded to the group allocation due to the specific food items in each group. Other staff, including the laboratory team and the researchers responsible for the analyses, were blinded to the participants' group allocation. Baby food products offered in the study were manufactured by Semper AB, Sweden and provided free of charge (Supplemental Table 1).

New Nordic food and diet

Participants in the NG were provided with specially prepared, protein-reduced, age-adjusted milk cereal drinks (MCDs), baby cereals, baby milk, and commercially available baby foods in glass jars (BIGs) (Supplemental Table 1). Detailed descriptions of the modified, protein-reduced (in total 30% lower intake) diet for the OTIS trial have

been published elsewhere [31,32]. For the intervention diet to remain isocaloric, it was supplemented with mainly plant-based foods. In the MCDs, baby cereals, and baby milks, the lower energy content from the reduction of protein was substituted with lactose and wheat starch. The food for the NG contained 100% Nordic ingredients, and the selection of food items was based on the concept New Nordic Food Manifesto from the Nordic Council of Ministers [33], which promotes seasonal Nordic foods rich in plant foods, fish, and rapeseed oil and recommends reduction of added sugar, saturated fat, meat, and meat products. The nutrient composition in the ND complied with NNR (Nordic Nutrition Recommendations) [12,24]. For the main course meals, parents were suggested to use either homemade baby food recipes or BIGs. In the latter case, parents were asked to replace half of a BIG with vegetables from either commercial vegetable purées or 1 of 14 different homemade Nordic vegetable purées made by the parents. These purées contained a lot of complex carbohydrates and were not supplemented with other simple sugars.

Nordic portfolio in the NG

To enhance intake of the ND during CF, several successive interventions were offered; 1) 24-d taste portion schedule with repeated exposures of Nordic fruit, berries, and vegetables from 4 to 6 mo; 2) homemade protein-reduced baby food recipes with Nordic ingredients using fruit, berries, and vegetable purées and for the main course meal from 6 to 18 mo; 3) Nordic, protein-reduced baby food products from Semper AB, Sweden (Supplemental Table 1), and 4) invitation to a closed Facebook group for the parents.

Taste portion schedule in the NG

When infants in NG were between 4 and 6 mo, they were introduced to Nordic foods by repeated exposures from a taste portion schedule [32,34]. Parents were provided with 9 recipes of Nordic homemade purées from apple, green peas, raspberry, cauliflower, lingonberry, buckthorn, turnip, cranberry, and white radish. Composition, preparation, and sensory profiling of the recipes/purées have been described in detail elsewhere [32,34]. The advice was 3 exposures per day (5–15 mL purée per exposure) during 3 consecutive days per each

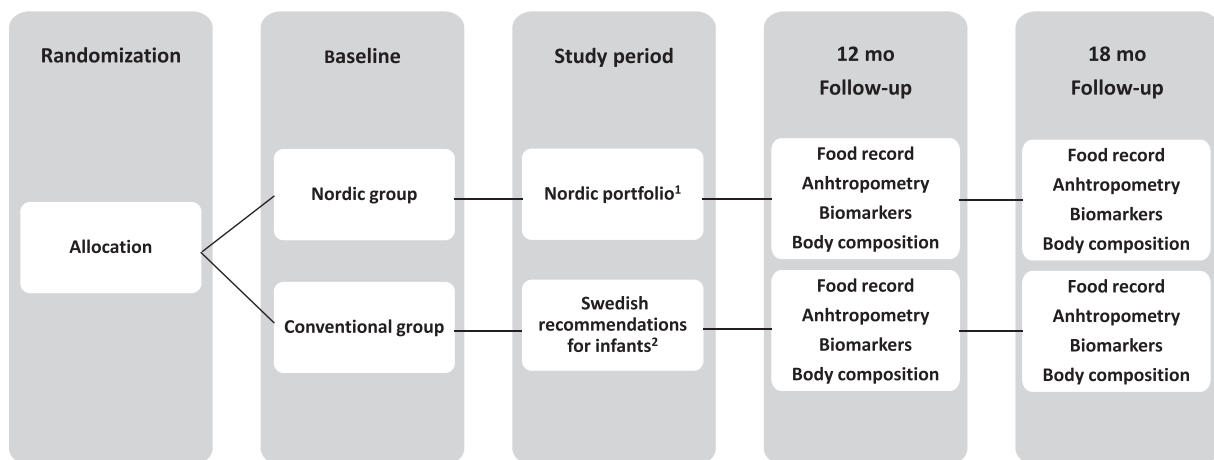


FIGURE 2. Study procedures in OTIS, a randomized controlled trial on the effects of a protein-reduced, Nordic complementary diet compared to the current, Swedish recommendations for infants ≤ 18 mo. Baseline was set at the age when parents started complementary feeding to their child. ¹The multicomponent intervention consisted of a taste portion schedule with repeated exposures of Nordic fruit, berries, and vegetables from baseline, homemade protein-reduced baby food recipes with Nordic ingredients from 6 to 18 mo, Nordic, protein-reduced baby food products from Semper AB, and invitation to a closed Facebook group for the parents. ²The conventional group parents received written information from the Swedish Food Agency with the current recommendations for infants. OTIS, optimized complementary feeding study.

fruit/berry or vegetable purée, totaling 72 exposures for 24 d alongside breastfeeding or formula feeding.

Taste portion introduction and guidelines in the CG

Parents of CG infants received a brochure from the Swedish National Food Agency [35] with recommendations for CF introduction, which suggest 6 mo of exclusive breastfeeding or formula if the child is not breastfed. From the age of 4 mo at the earliest, if the child became interested in other foods, parents could offer tiny taste portions alongside breastfeeding or formula feeding [35]. For CG, no instructions were given from the research team, besides full access to online information to the recommendations from the Swedish Food Agency website and support free of charge from the local child health care centers.

Body composition with total body water

Body composition at 12 and 18 mo, measured by deuterium dilution was the main outcome, and a difference in body fat content at 12 mo was the basis of the sample size calculation. In collaboration with the MRC Elsie Widdowson Laboratory (formally MRC Human Nutrition Research), Cambridge, United Kingdom, total body water (TBW) determination using deuterium dilution was used to estimate body composition (2-compartment model including fat and FFM) according to the procedure advised by the International Atomic Energy Agency [36,37]. On the same day as the anthropometrical measurements, a predose urine sample was collected by placing an absorbent pad (Bastos Viegas) in the diaper of the infant. Each participant was then given an oral weighed dose of deuterium oxide (100 mg/kg 99.8 atom % D₂O, Cambridge Isotope Laboratories Inc). Postdose urine samples were collected using absorbent pads as described above, at home once daily for 5 consecutive days, omitting the first urine portion of the day, with dates and times recorded for all samples. Each collected pad was stored at −18°C. The pads were then taken to the Pediatric Research Facility at Umeå University Hospital, thawed, and the urine content extracted using a press, collecting the urine in glass bottles. The glass bottles were stored at −20°C until transported to the MRC Elsie Widdowson Laboratory for analysis.

TBW analysis and calculations

All samples, including a sample of dose, were analyzed in singlicate for ²H enrichment. In brief, 0.4 mL of sample was flush-filled with H₂ gas and equilibrated over 6 h in the presence of a platinum catalyst. Headspace of the samples was then analyzed using a continuous flow Isotope Ratio Mass Spectrometer (Sercon ABCA-Hydra 20-22, Sercon Ltd). All samples were measured alongside secondary reference standards previously calibrated against the primary international standards VSMOW and Vienna-Standard Light Antarctic Precipitate (International Atomic Energy Agency). Sample enrichments were expressed relative to VSMOW. Analytical precision (SD) was ± 1.4 ppm for ²H. TBW was calculated using the 0-time intercept of ²H turnover and corrected for nonaqueous exchange within the body using the equation:

$$TBW (kg) = \frac{WA}{a} \times \frac{(E_a - E_w)}{(E_s - E_p)} \times \frac{1}{1.04} \times \frac{1}{1000}$$

where: W, amount of water used to dilute sample of dose (g); A, amount of dose taken by participant (g); a, amount of dose in diluted dose (g); E_a, enrichment of diluted dose; E_w, enrichment of water used to dilute the sample of dose; E_s, enrichment of postdose sample; E_p, enrichment of predose sample. Fomon hydration factors [38] were used to derive FFM, and FM was calculated as the difference between body weight and FFM.

Anthropometry, blood samples, and laboratory analyses

Anthropometrical measurements were part of assessing body composition, but they also reflect supporting methods of assessing body composition, that is, weight-for-height and BMI, and they are important outcomes on their own. Infants were measured at the Pediatric Research Facility at Umeå University Hospital at baseline and within 2 wk of the infant's 12- and 18-mo birthdays. Anthropometric data were collected and calculated according to standardized procedures [39] and detailed descriptions are published elsewhere [32]. Weight-for-age, length-for-age, BMI-for-age, and head circumference-for-age z-scores were calculated according to the WHO Child Growth Standards [40].

Two-hour fasted venous blood samples were collected by research nurses, at baseline, 12 mo, and 18 mo. Biomarkers of metabolic function were part of the main outcomes of the study: plasma glucose, insulin, TGs, total cholesterol, HDL cholesterol, apolipoprotein A1, and apolipoprotein B were analyzed at the Department of Clinical Chemistry, Umeå University, Sweden using a Roche Cobas 8000 (Roche Diagnostics). LDL-cholesterol was calculated according to Friedewald's formula [41]. IGF-1 was analyzed at the Pediatric Research Laboratory, Department of Clinical Sciences, Pediatrics, Umeå University, Sweden using a Milliplex MAP ELISA-kit (EMD Millipore). As biomarkers of adherence hemoglobin, mean corpuscular

TABLE 1

Baseline characteristics of study participants in OTIS, a randomized controlled trial on the effects of a protein-reduced, Nordic complementary diet¹

Characteristic	Nordic group (n = 125)	Conventional group (n = 125)
Age at baseline (mo)	4.5 ± 0.5	4.5 ± 0.5
Birth weight (kg)	3.6 ± 0.4	3.6 ± 0.5
Birth length (cm)	50.7 ± 1.9	50.6 ± 2.1
Gestational age at birth (wk)	39.5 ± 1.3	39.8 ± 1.3
Sex (male)	73 (58)	69 (55)
Baseline anthropometry and feeding		
Weight (kg)	7.3 ± 0.8	7.3 ± 0.8
Weight-for-age z score	0.31 ± 0.87	0.35 ± 0.89
Weight-for-length z score	0.07 ± 0.98	0.12 ± 0.96
Length (cm)	65.2 ± 3.0	65.1 ± 2.4
Length-for-age z score	0.47 ± 0.85	0.50 ± 0.94
BMI (kg/m ²)	17.2 ± 1.5	17.2 ± 1.4
BMI-for-age z score	0.05 ± 0.96	0.09 ± 0.95
Breastfed at baseline	95 (76)	94 (75)
Never breastfed	2 (1.6)	2 (1.6)
Duration of exclusive breastfeeding (mo)	4.1 ± 1.5	4.2 ± 1.4
Family characteristics		
Mother's age	31 ± 4.6	31 ± 4.9
Parent's age	34 ± 5.0	32 ± 5.4
Families with siblings	62 (50)	56 (45)
Mother's BMI (kg/m ²)	25.5 ± 4.8	24.9 ± 4.0
Partner's BMI (kg/m ²)	25.7 ± 4.2	25.9 ± 4.2
Mother's educational level		
≤12 y	36 (29)	40 (32)
>12 y	86 (69)	84 (67)
Partner's educational level		
≤12 y	54 (43)	57 (46)
>12 y	68 (54)	67 (54)
Parents born in Sweden		
Mother	120 (96)	118 (94)
Partner	110 (88)	104 (83)

OTIS, optimized complementary feeding study.

¹ Data presented are mean ± SD or n (%).

volume (MCV), plasma transferrin, transferrin saturation, plasma iron, ferritin, urea, and folate were analyzed at the Department of Clinical Chemistry, Umeå University, Sweden as described elsewhere [32]. If the child was ill or had recently been immunized, sampling was postponed by 2 wk to avoid the influence of an acute-phase response on blood indices. Definition of mild iron deficiency was ferritin <12 µg/L; moderate iron deficiency, 2 of 3 criteria of ferritin <12 µg/L and/or MCV <71 fL and/or transferrin saturation <10%; and serious iron deficiency, 2 criteria of moderate deficiency and hemoglobin <110 g/L. Blood pressure was part of the main outcomes and was measured with the child sitting in the parent’s lap using a Carescape Dinamap V100 monitor (GE Healthcare AB) and age-appropriate blood pressure cuffs.

Food records and dietary assessment

As part of adherence to the study diet, but also as a secondary outcome to investigate the intervention effect on dietary intake, 5-d food records (FRs) were collected within 2 wk of the infant’s 12- and 18-mo birthdays. Two pediatric dieticians calculated mean daily EI, macronutrient subclasses, and mean fruit and vegetable content from the FRs [32].

TABLE 2

Body composition and anthropometrical measurements in the 2 study groups in OTIS, a randomized controlled trial on the effects of a protein-reduced, Nordic complementary diet at 12 and 18 mo¹

A	Nordic group	Conventional group	Between-group difference (95% CI)	P ²
12 mo				
Body composition				
	<i>n</i> = 74	<i>n</i> = 88		
Total body FM (kg)	2.8 ± 0.8	2.6 ± 0.8	0.14 (−0.11, 0.39)	0.26
Total body FM (%)	27.4 ± 6.7	26.1 ± 6.5	1.3 (−0.74, 3.37)	0.21
Total lean mass (kg)	7.4 ± 0.8	7.5 ± 0.9	−0.17 (−0.43, 0.09)	0.21
FMI (kg/m ²) ³	4.9 ± 1.4	4.6 ± 1.3	0.25 (−0.17, 0.67)	0.24
FFMI (kg/m ²) ⁴	12.8 ± 1.2	13.0 ± 1.1	−0.21 (−0.57, 0.15)	0.26
Anthropometry				
	<i>n</i> = 106	<i>n</i> = 119		
Age at follow-up (mo)	11.7 ± 1.2	11.8 ± 0.3	−0.14 (−0.37, 0.08)	0.23
Body weight (kg)	10.2 ± 1.1	10.1 ± 1.0	0.04 (−0.24, 0.32)	0.80
Weight-for-age z score	0.66 ± 0.88	0.55 ± 0.87	0.03 (−0.20, 0.25)	0.36
Weight-for-length z score	0.71 ± 0.9	0.63 ± 0.9	0.08 (−0.16, 0.31)	0.53
Body length (cm)	75.9 ± 2.2	76.1 ± 2.6	−0.18 (−0.83, 0.47)	0.58
Length-for-age z score	0.45 ± 0.84	0.56 ± 0.99	−0.12 (−0.36, 0.13)	0.34
Head circumference (cm)	46.9 ± 1.7	46.8 ± 1.4	0.08 (−0.27, 0.43)	0.66
Head circumference-for-age z score	1.02 ± 0.81	1.01 ± 0.93	0.004 (−0.23, 0.24)	0.97
BMI (kg/m ²)	17.6 ± 1.4	17.5 ± 1.3	0.14 (−0.22, 0.49)	0.45
BMI-for-age z score	0.66 ± 0.88	0.55 ± 0.87	0.11 (−0.12, 0.34)	0.36
18 mo				
Body composition				
	<i>n</i> = 42	<i>n</i> = 60		
Total body FM (kg)	3.0 ± 0.7	2.9 ± 0.8	0.05 (−0.26, 0.36)	0.76
Total body FM (%)	25.1 ± 4.6	24.9 ± 5.7	0.22 (−1.90, 2.34)	0.84
Total lean mass (kg)	8.8 ± 0.9	8.7 ± 0.8	0.14 (−0.21, 0.49)	0.43
FMI (kg/m ²) ³	4.4 ± 1.0	4.3 ± 1.2	0.05 (−0.39, 0.50)	0.81
FFMI (kg/m ²) ⁴	12.9 ± 0.9	12.8 ± 0.8	0.12 (−0.22, 0.47)	0.48
Anthropometry				
	<i>n</i> = 93	<i>n</i> = 111		
Age at follow-up (mo)	17.8 ± 0.4	17.9 ± 0.3	−0.07 (−0.17, 0.03)	0.18
Body weight (kg)	11.7 ± 1.1	11.7 ± 1.2	−0.01 (−0.34, 0.32)	0.95
Weight-for-age z score	0.75 ± 0.79	0.76 ± 0.87	−0.01 (−0.25, 0.22)	0.92
Weight-for-length z score	0.74 ± 0.83	0.75 ± 0.86	−0.007 (−0.24, 0.23)	0.95
Body length (cm)	82.5 ± 2.4	82.7 ± 2.9	−0.20 (−0.94, 0.55)	0.60
Length-for-age z score	0.38 ± 0.82	0.46 ± 0.96	0.09 (−0.34, 0.17)	0.50
Head circumference (cm)	48.4 ± 1.1	48.4 ± 1.4	−0.03 (−0.40, 0.34)	0.88
Head circumference-for-age z score	1.1 ± 0.79	1.2 ± 0.92	−0.06 (−0.31, 0.19)	0.66
BMI (kg/m ²)	17.0 ± 1.2	17.0 ± 1.3	0.02 (−0.32, 0.36)	0.91
BMI-for-age z score	0.71 ± 0.85	0.70 ± 0.87	0.01 (−0.23, 0.26)	0.91

FFMI, FFM index; FMI, FM index; OTIS, optimized complementary feeding study.

¹ Data presented are mean ± SD.

² Independent samples t-test.

³ FMI

⁴ FFMI are calculated by dividing respective mass by body length².

Demographic variables

Demographic information has been published elsewhere [31,32], but a summary is reported in Table 1.

Sample size calculation

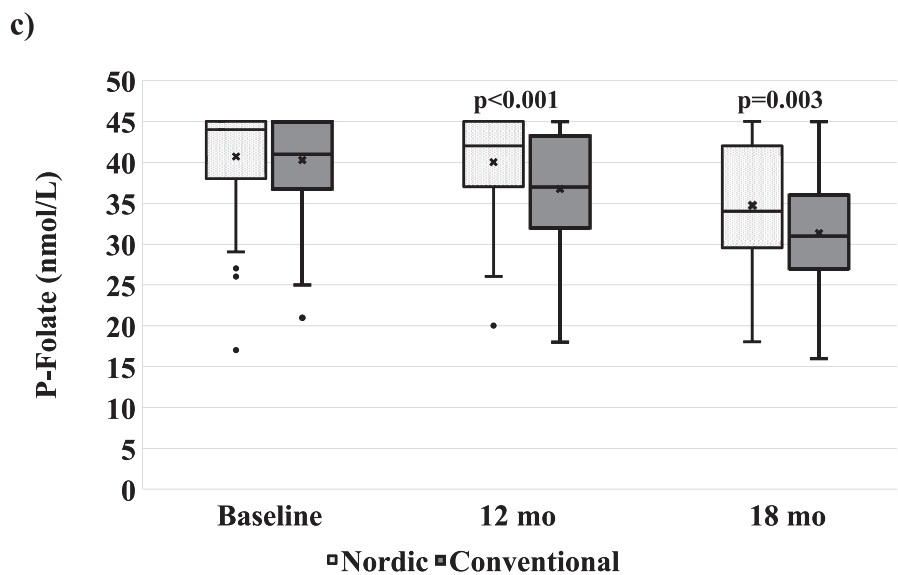
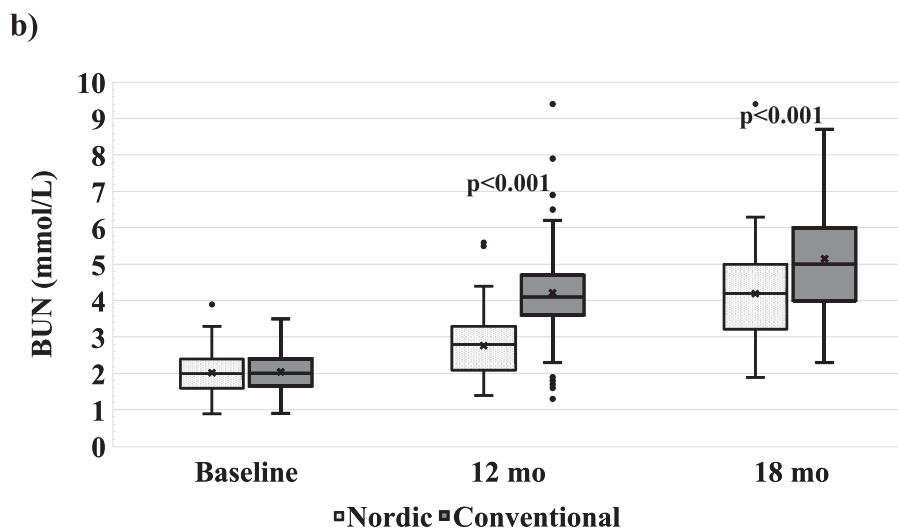
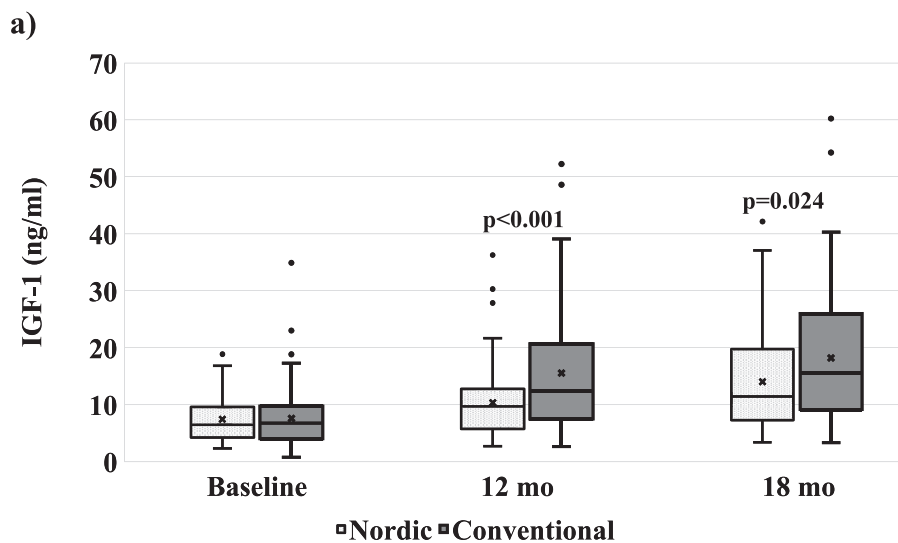
Sample size calculation for the study was based on the detection of a difference in body FM of 0.4 SD between NG and CG at 12 mo with a power of 80% and α set to 0.05. Allowing for an attrition rate of 20%, we recruited 125 participants per study group [31].

Ethical considerations

The study was approved by the Regional Ethical Review Board at Umeå University (2014-363-31M), Umeå, Sweden. Written informed consent was obtained from both caregivers.

Statistical analyses

Statistical analyses were performed using SPSS 28.0 (SPSS). Results are presented as means (± SD) or, if non-parametric data, as median [min, max or interquartile range]. Categorical data are pre-



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sented as numbers and percentages. Energy and macronutrient intake are presented as total intake of kilojoules (kJ) and grams (g) per day, respectively, and as intake per kg body weight per day. The significance level was set at $P < 0.05$. For comparisons between the groups, independent t-test was used on normally distributed data and the Mann–Whitney test was used for non-normally distributed data. The χ^2 test was used for comparisons between categorical variables. Regression models were used to assess the effects of possible confounders, for example, breastfeeding status. Effect size for parametric data was calculated with Glass's delta [42] (Δ), where $\Delta = \frac{(\text{Mean}_1 - \text{Mean}_2)}{\text{s.d. control}}$. Glass's delta calculation was used as it was more representative of the variation of the unaffected CG population. The Glass's delta interpretation of a large effect size ($r = 1$) means that the 84th percentile of the distribution in one group is the mean value of the other. Finally, we used 2-factor repeated measures ANOVA to test changes in anthropometrical measurements over time and the effect of study group.

Results

Study participants

Of the 250 recruited infants, 206 (82%) completed the study (Figure 1). There were no differences at baseline in background data such as neonatal or family characteristics, breastfeeding duration, anthropometry, or biochemical data between the groups (Table 1) [32]. Attrition was significantly higher ($\chi^2 P = 0.012$) in NG ($n = 30$, 24%) compared with CG ($n = 14$, 12%). From the dropout analyses, there were no differences in anthropometric, dietary, biomarkers, or demographic data, except a difference in father/partner age between the groups ($P = 0.026$). The fathers/partners were younger among CG infants who left the study compared with NG infants and to the participants who remained in the study.

Body composition, anthropometry, biochemical data, and blood pressure

Body composition measured with TBW showed no differences between the groups at 12 and 18 mo (Table 2). Attrition for the body composition measurements were high at both time points (35% and 59%, respectively) and significantly higher in NG at 18 mo ($\chi^2 P = 0.021$). Further, for the anthropometrical measurements, either used alone or as composites, that is, weight-for-height or BMI, there were no group differences at 12 or 18 mo (Table 2). The 2-factor repeated measures ANOVA did not reveal any group \times time effects, and adjusting the analyses for potential confounders such as breastfeeding status did not affect the outcomes (data not shown). For the metabolic biomarkers, plasma IGF-1 was significantly lower in the NG compared to the CG at both 12 and 18 mo (Figure 3A), and a slightly higher plasma glucose concentration was observed in NG compared with CG at 12 mo, with a small effect size (Glass's 0.25) (Table 3). For the biomarkers of adherence, BUN was lower and plasma folate higher in NG compared to CG at 12 and 18 mo (Figure 3B and C). At 18 mo, NG had a lower mean hemoglobin concentration compared with CG (Table 3). However, none of the iron parameters (MCV, transferrin, transferrin saturation, ferritin, or iron) nor frequency of iron deficiency showed any group differences (Table 3). There were no group differences in blood pressure at any time point

(Table 3). Again, the analyses for potential confounders such as breastfeeding status did not affect the outcomes (data not shown).

Energy and macronutrients intake

At 12 and 18 mo, there were no significant differences in mean total daily energy, fat, or carbohydrate intake between the groups. However, the E% provided by carbohydrate was significantly higher in NG at 12 mo but not at 18 mo (Table 4). There was not a significant difference in the daily EI between the groups at either 12 mo (367 ± 53 kJ/kg compared with 381 ± 60 kJ/kg), NG compared with CG, respectively or 18 mo (346 ± 54 kJ/kg compared with 353 ± 61 kJ/kg), NG compared with CG, respectively.

Mean daily protein intake was lower in NG compared to CG at both ages, calculated either as intake in g/d or as E% (Table 4). Specifically, the total daily protein intake (g) was 29% lower at 12 mo and 17% lower at 18 mo among NG infants. The effect size was large at 12 mo (Glass's 1.79) and moderate at 18 mo (Glass's 0.73). Mean energy distribution (E%) from protein at 12 mo in the NG was marginally below (9.2 E%) the recommended range 10% to 15 E% (Table 4). At 18 mo, the mean E% protein was in accordance with NNR for both groups (Table 4). NG had a lower protein intake (g/kg body weight) (Figure 4) compared with CG at both ages, and the effect size was large at 12 mo (Glass's 1.60) and moderate at 18 mo (Glass's 0.71).

Fruit and vegetable intake

Infants in NG consumed 42% more fruits and vegetables per day at 12 mo and 45% more at 18 mo compared to CG (Figure 5A). The effect size was large at 12 mo (Glass's 0.80) and moderate at 18 mo (Glass's 0.67). Both groups decreased daily fruit and vegetable intake by ~14% to 16% from 12 to 18 mo (Figure 5B and C). CG reduced vegetable intake by 36% between 12 and 18 mo, whereas fruit intake was consistent (Figure 5B and C). At 18 mo, NG consumed 85% more vegetables per day compared with CG (Figure 5C). NG consumed more berries and root vegetables per day at 12 and 18 mo compared with CG ($P < 0.001$) (Table 5, Figure 5D). CG ate more imported, exotic fruits at both ages, whereas NG consumed very small amounts (Table 5).

The dietary assessment showed that in general, family food contained low amounts of vegetables in comparison to commercial baby food and homemade baby food dishes. The infants in CG ate more of the family food compared to NG at both ages ($P < 0.001$). The infants in NG consumed more of homemade baby food dishes containing a high content of vegetables compared with CG at 12 mo ($P < 0.001$) and 18 mo ($P = 0.001$).

Discussion

To our knowledge, this is the first longitudinal, multicomponent, randomized trial to evaluate a protein-reduced complementary diet based on Nordic foods. Although our admittedly high attrition rate (almost 60% of participants not providing a useful sample at 18 mo) may have contributed to the null finding on body composition, the anthropometrical measurements of body composition, that is, weight-for-length and BMI z-scores, showed no statistical differences, supporting the interpretation that the intervention had little to no effect.

FIGURE 3. (A) Plasma IGF-1 (Insulin-like growth factor 1) (ng/mL), (B) plasma BUN (mmol/L), and (C) plasma folate (nmol/L) in the 2 study groups in OTIS, a randomized controlled trial on the effects of a protein-reduced, Nordic complementary diet at baseline, 12, and 18 mo. The laboratory reported plasma folate values above 45 nmol/L as “>45 nmol/L.” In the analyses, these were set to 45 nmol/L. BUN, blood urea nitrogen; IGF; OTIS, optimized complementary feeding study; P, plasma.

TABLE 3Biochemical data and blood pressure in the 2 study groups in OTIS, a randomized controlled trial on the effects of a protein-reduced, Nordic complementary diet at 12 and 18 mo¹

	Nordic group	Conventional group	Between-group difference (95% CI)	P ^{2,3,5}
12 mo	<i>n</i> = 94	<i>n</i> = 107		
Hemoglobin (g/L)	114.4 ± 8.2	116.6 ± 7.8	−2.2 (−4.4, 0.02)	0.053 ²
MCV (fL)	75.7 ± 2.6	75.1 ± 6.1	0.62 (−0.72, 1.2)	0.34 ²
P-transferrin (g/L)	2.6 ± 0.3	2.6 ± 0.3	−0.03 (−0.12, 0.06)	0.50 ²
P-transferrin saturation (%)	15.7 ± 7.6	15.0 ± 6.3	0.73 (−1.21, 2.66)	0.47 ²
P-ferritin (ug/L) ³	35.7 ± 1.7	38.1 ± 1.9	−1.1 (−1.25, 0.91)	0.43 ²
P-iron (umol/L)	10.1 ± 4.6	9.9 ± 4.2	0.22 (−1.01, 1.45)	0.73 ²
P-glucose (mmol/L)	5.0 ± 0.4	4.9 ± 0.4	0.15 (0.03, 0.27)	0.017 ²
P-insulin (mIU/L)	6.0 ± 5.0	6.0 ± 4.5	−0.02 (−1.35, 1.32)	0.98 ²
P-TGs (mmol/L)	1.7 ± 0.8	1.6 ± 0.8	0.03 (−0.19, 0.26)	0.77 ²
P-cholesterol (mmol/L)	3.6 ± 0.8	3.5 ± 0.7	0.13 (−0.07, 0.34)	0.21 ²
P-HDL-C (mmol/L)	1.0 ± 0.2	1.0 ± 0.3	0.03 (−0.03, 0.09)	0.36 ²
P-LDL-C (mmol/L)	1.9 ± 0.8	1.8 ± 0.7	0.13, (−0.07, 0.33)	0.20 ²
P-apo-A1 (g/L)	1.19 ± 0.14	1.15 ± 0.17	0.04 (−0.01, 0.08)	0.19 ²
P-apo-B (g/L)	0.80 ± 0.20	0.76 ± 0.18	0.04 (−0.01, 0.09)	0.13 ²
P-apo-B/A1 ratio	0.69 ± 0.21	0.68 ± 0.19	0.01 (−0.04, 0.07)	0.72 ²
HOMA-IR ⁶	1.39 ± 1.3	1.33 ± 1.1	0.06 (−0.28, 0.40)	0.71 ²
Systolic blood pressure (mm Hg)	101 ± 10	101 ± 11	0.02 (−2.9, 2.9)	0.99 ²
Diastolic blood pressure (mm Hg)	66 ± 8	65 ± 10	0.7 (−1.8, 3.3)	0.57 ²
Number of days between food recording and follow-up visit	6.7 ± 5.6	7.1 ± 3.9	—	0.53 ²
Mild iron deficiency, <i>n</i> (%)	4 (2.8)	0 (0)	—	0.25 ⁵
Moderate iron deficiency, <i>n</i> (%)	1 (0.9)	0 (0)	—	1.00 ⁵
Severe iron deficiency, <i>n</i> (%)	0 (0)	0 (0)	—	NA
18 mo	<i>n</i> = 85	<i>n</i> = 95		
Hemoglobin (g/L)	117.2 ± 8.5	120.7 ± 9.1	−3.5 (−6.1, −0.9)	0.008 ²
MCV (fL)	76.3 ± 2.5	76.3 ± 2.6	−0.01 (−0.77, 0.75)	0.98 ²
P-transferrin (g/L)	2.7 ± 0.3	2.7 ± 0.3	0.02 (−0.07, 0.12)	0.66 ²
P-transferrin saturation (%)	15.5 ± 8.5	17.0 ± 7.4	−1.47 (−3.83, 0.88)	0.22 ²
P-ferritin (ug/L)	33.6 ± 1.9 ³	36.0 ± 1.6 ³	−1.1 (−1.27, 0.90) ³	0.42 ²
P-iron (umol/L)	10.7 ± 5.4	11.4 ± 5.0	−0.76 (−2.30, 0.79)	0.34 ²
P-glucose (mmol/L)	4.8 ± 0.4	4.8 ± 0.4	0.02 (−0.10, 0.13)	0.80 ²
P-insulin (mIU/L)	5.5 ± 3.4	6.3 ± 5.1	−0.78 (−2.19, 0.63)	0.28 ²
P-TGs (mmol/L)	1.4 ± 0.7	1.4 ± 0.6	0.09 (−0.12, 0.30)	0.40 ²
P-cholesterol (mmol/L)	3.7 ± 0.7	3.5 ± 0.7	0.15 (−0.06, 0.37)	0.16 ²
P-HDL-C (mmol/L)	1.0 ± 0.3	1.0 ± 0.3	0.02 (−0.10, 0.06)	0.60 ²
P-LDL-C (mmol/L)	2.0 ± 0.7	1.9 ± 0.5	0.12 (−0.07, 0.31)	0.21 ²
P-apo-A1 (g/L)	1.14 ± 0.18	1.18 ± 0.18	−0.03 (−0.09, 0.02)	0.23 ²
P-apo-B (g/L)	0.81 ± 0.21	0.77 ± 0.18	0.05 (−0.01, 0.11)	0.13 ²
P-apo-B/A1 ratio	0.73 ± 0.27	0.71 ± 0.50	0.02 (−0.11, 0.15)	0.78 ²
HOMA-IR ⁶	1.21 ± 0.9	1.39 ± 1.2	−0.18 (−0.52, 0.15)	0.28 ²
Systolic blood pressure (mm Hg)	103 ± 11	103 ± 11	0.54 (−3.0, 4.0)	0.76 ²
Diastolic blood pressure (mm Hg)	66 ± 9	65 ± 7	1.3 (−1.3, 3.9)	0.32 ²
Number of days between food recording and follow-up visit	9.6 ± 8.2	8.6 ± 6.0	—	0.37 ²
Mild iron deficiency, <i>n</i> (%)	0 (0)	2 (2.4)	—	0.21 ⁵
Moderate iron deficiency, <i>n</i> (%)	1 (1.1)	0 (0)	—	1.00 ⁵
Severe iron deficiency, <i>n</i> (%)	0 (0)	0 (0)	—	NA

APO, apolipoprotein; HOMA-IR, homeostatic model assessment for insulin resistance; MCV, mean corpuscular volume; NA, not available; OTIS, optimized complementary feeding study; P, plasma.

⁴Geometric mean.

¹ Data presented are mean ± SD or otherwise indicated.

² Independent samples t-test.

³ Mann-Whitney test.

⁵ Fisher's test for iron deficiency.

⁶ HOMA-IR: insulin × glucose/22.5.

Another explanation to us seeing no effects on body composition or anthropometry may be that the protein intake in CG, which was 12.5 E% at 12 mo and 14.6 E% at 18 mo was already so low that it did not contribute to altered growth [18]. A third explanation may be that insufficient time had passed to properly evaluate the effects of the protein reduction during infancy on later body composition and growth, despite the effects on IGF-1.

Thorsdottir et al. [22] demonstrated that high animal protein intake at 12 mo was associated with increased growth in infancy and higher

BMI in girls at 6 y. Total animal and dairy protein intakes at 12 mo were associated with increased IGF-1. In this Icelandic study, the anthropometry data and EI were similar to our data at 12 mo in CG, but total protein intake was higher, that is, at 14.5 E% in the Iceland study compared with 12.5 E% in our CG [22]. Günther et al. [43] reported that high protein intake, especially animal protein intake during CF at 12 and 18 to 24 mo, was associated with higher BMI and percentage body fat at 7 y. Similarly, we previously found an association between higher protein intake from 6 to 18 mo and higher BMI at 4 y of age

TABLE 4Daily mean intake of energy and macronutrients in the 2 study groups in OTIS, a randomized controlled trial on the effects of a protein-reduced, Nordic complementary diet at 12 and 18 mo¹

	Nordic group	Conventional group	Between-group difference (95% CI)	P ²
12 mo	<i>n</i> = 100	<i>n</i> = 114		
Age at follow-up (mo)	11.6 ± 0.3	11.6 ± 0.3	−0.02 (−0.11, 0.07)	0.65
Energy (kJ)	3721 ± 558	3839 ± 571	−118 (−270, 34.8)	0.13
Protein (g)	20.0 ± 4.7	28.4 ± 5.8	−8.4 (−9.8, −6.9)	<0.001
Protein (E%)	9.2 ± 1.8	12.5 ± 1.5	−3.4 (−3.8, −2.9)	<0.001
Fat (g)	33.8 ± 6.9	35.2 ± 7.3	−1.4 (−3.3, 0.53)	0.15
Fat (E%)	33.6 ± 4.6	33.9 ± 4.7	−0.3 (−1.6, 0.9)	0.62
CHO (g)	121.2 ± 23.1	117.0 ± 19.5	4.3 (−1.5, 10.0)	0.15
CHO (E%)	55.3 ± 5.7	51.8 ± 4.8	3.5 (2.1, 4.9)	<0.001
18 mo	<i>n</i> = 86	<i>n</i> = 98		
Age at follow-up (mo)	17.5 ± 0.4	17.6 ± 0.4	−0.07 (−0.18, 0.04)	0.21
Energy (kJ)	4012 ± 583	4082 ± 681	−69.9 (−255, 116)	0.45
Protein (g)	29.2 ± 8.1	35.1 ± 7.2	−6.0 (8.2, −3.7)	<0.001
Protein (E%)	12.4 ± 2.8	14.6 ± 1.6	−2.3 (−2.9, −1.6)	<0.001
Fat (g)	36.6 ± 7.9	36.5 ± 9.4	0.09 (−2.5, 2.6)	0.94
Fat (E%)	33.7 ± 4.7	33.0 ± 5.1	0.71 (−0.72, 2.1)	0.33
CHO (g)	121.3 ± 21.4	120.0 ± 21.6	1.3 (−4.9, 7.5)	0.69
CHO (E%)	51.5 ± 5.6	50.1 ± 5.4	1.4 (−0.24, 3.0)	0.10

OTIS, optimized complementary feeding study.

¹ Data presented are mean ± SD.² Independent samples t-test.

[44]. In the present study, total EI per kg body weight, as recorded through FRs in both groups, was higher than the energy requirements for children at 12 mo based on those measured using doubly labeled water [12]. EI in both groups at 12 and 18 mo was similar to our previous study in the same age groups measured with FRs [44]. FRs tend to overestimate EI among infants compared with energy expenditure measured with doubly labeled water [45].

The differences in biochemical markers reflect in part the differences in dietary intake between the groups with lower BUN confirming the lower protein intake in NG compared to CG and higher plasma folate concentrations indicating higher intakes of fruits and vegetables in NG compared with CG. At 18 mo, hemoglobin was significantly lower in NG, but other markers of iron status were not, and risk of iron deficiency was not higher or different in NG compared with CG. In a Danish randomized study of 8 to 11 y old schoolchildren, the signature foods of the ND increased and resulted in higher folate compared with the control group but with no between-group differences in hemoglobin or serum ferritin when consuming a ND [28,46,47]. Health effects of the ND have been found in several age groups [26–29], but the present study could not show such outcomes during infancy. The long-term health benefits of introducing the ND during a highly dynamic period of early childhood are thus yet to be assessed. However, follow-up of the infants as they approach school age should give indications of any lasting health benefits.

A secondary objective was to investigate the effects of the intervention on the overall complementary diet. Macronutrient composition expressed as a percentage of total EI was within recommended NNR levels in both groups, except for protein at 12 mo in NG, which at 9 E% was slightly below the recommended daily intake of protein intake 10 to 15 E% [12]. At 18 mo, this had increased to 13 E%, which is slightly lower than the 13 to 16 E% range observed in other Nordic studies investigating protein intake during infancy [18]. Similar to previous studies [18], however, protein intake per kg body weight was 2 to 3 times higher in both groups compared to WHO recommendation (1.0 g/kg body weight) [12]. In order to make the diets isocaloric, the reduced protein in NG was replaced by plant-based carbohydrates,

which resulted in a higher E% from carbohydrates at 12 but not 18 mo, and with no difference in amount of carbohydrates consumed per day. In terms of pattern of dietary intake, we found a higher consumption of Nordic fruits, berries, roots, and vegetables lasting until 18 mo among NG infants compared with CG infants, without negative effects on growth, iron status, or other biomarkers. In contrast to a study from the Netherlands [48], where vegetable intake increased during the intervention and decreased between 12 to 23 mo, our intervention resulted in a higher intake of fruits and vegetables at both 12 mo (89 g/d) and 18 mo (82 g/d) among NG but not among CG infants. A previous systematic review in children aged 5 y and under demonstrated that multicomponent interventions would probably increase fruit and vegetable intake in children by ~75 to 100 g/d, but it was uncertain how parental support and education interventions affected these intakes [49]. A randomized trial from the United Kingdom that examined whether parental social support had an effect on the intake of fruit and vegetables showed significant differences in specific fruit and vegetable intake at 12 mo but no difference at 18 mo [50]. We cannot state whether it was the parental support or early repeated exposure in NG that increased the daily intake of fruit and vegetables per se, but both efforts probably affected vegetable intake over time.

The ND conforms to the healthy reference diet reported from the EAT-Lancet Committee on the reduction of greenhouse gases and increased intake of plant-based foods [23], and meeting the United Nations sustainable development goals [51]. Thus, despite the higher attrition, the present intervention demonstrates that the ND is feasible to implement during CF and contributes to a higher intake of plant-based foods from the Nordic region, which are healthy, climate friendly, and environmentally sustainable [25,52].

A strength of the study was the randomized design, where differences in outcomes can be attributed to the intervention per se and not due to unmeasured random effects. We could also validate dietary intakes with biomarkers. Further, the adherence to the study protocol was high in both groups. However, there was a significantly higher attrition rate in NG compared with CG, affecting the power to draw firm conclusions. In planning for the study, we were aware that the ND would

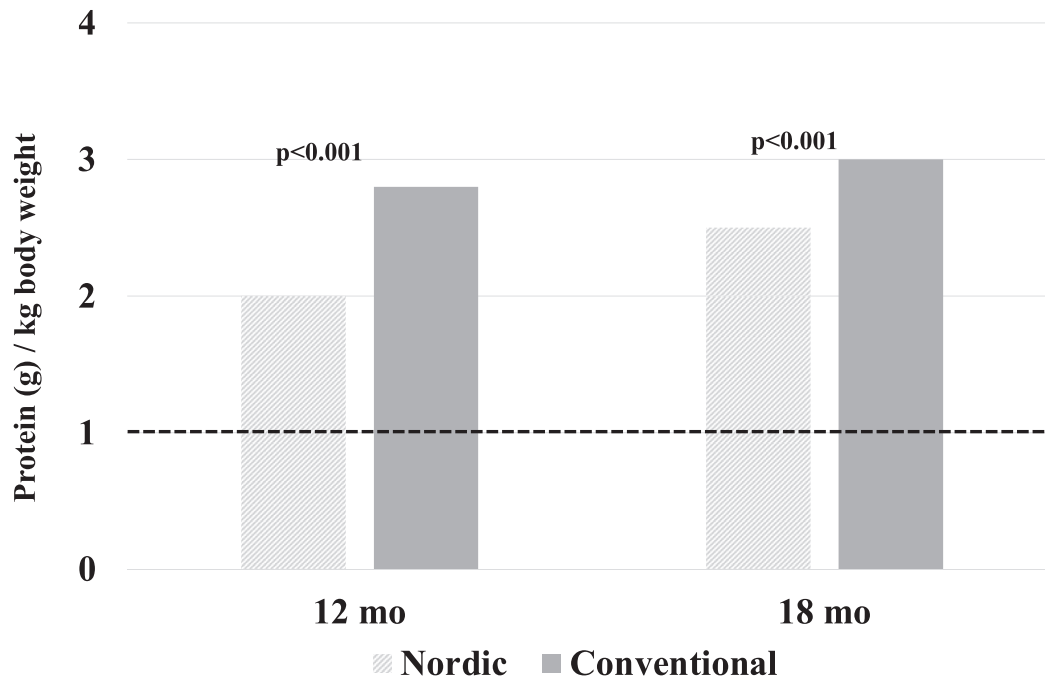


FIGURE 4. Protein intake (g) per kg body weight in the 2 study groups in OTIS, a randomized controlled trial on the effects of a protein-reduced, Nordic complementary diet at 12 and 18 mo. The dashed line denotes the safe level suggested by WHO at 1.0 g/kg body weight. *P* values indicate between-group differences. OTIS, optimized complementary feeding study.

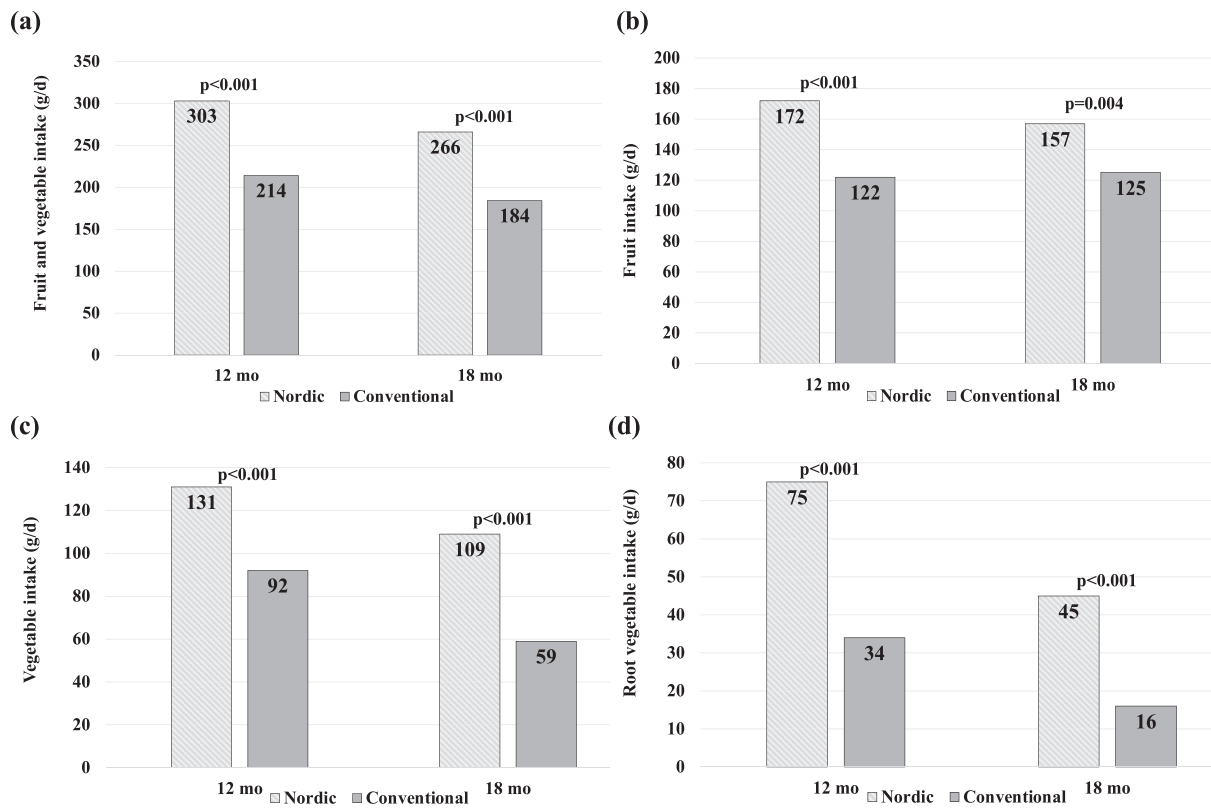


FIGURE 5. (A) Mean daily fruit and vegetable intake (g/d), (B) mean daily fruit intake (g/d), (C) mean daily vegetable intake (g/d), and (D) mean daily root vegetable intake (g/d) in the 2 study groups in OTIS, a randomized controlled trial on the effects of a protein-reduced, Nordic complementary diet at 12 and 18 mo. Fruit juices, vegetable juices, potatoes, chili, garlic, ginger, and herbs were not included in the calculations. *P* values indicate between-group differences. OTIS, Optimized complementary feeding study.

TABLE 5

Daily intake of berries and exotic fruits in the 2 study groups in OTIS, a randomized controlled trial on the effects of a protein-reduced, Nordic complementary diet at 12 and 18 mo¹

	Nordic group		Conventional group		<i>P</i> ²
Berries (g/d) ³					
12 mo	<i>n</i> = 100	11 (17)	<i>n</i> = 114	1 (4)	<0.001
18 mo	<i>n</i> = 86	8 (14)	<i>n</i> = 98	3 (9)	<0.001
Exotic fruits (g/d)					
12 mo	<i>n</i> = 100	0 (0)	<i>n</i> = 114	81 (75)	<0.001
18 mo	<i>n</i> = 86	0 (0)	<i>n</i> = 98	82 (63)	<0.001

OTIS, optimized complementary feeding study.

¹ Data presented are medians and interquartile range.

² Mann-Whitney test for differences between study groups.

³ Strawberries were not included in the category.

introduce a lot of new, unfamiliar, and possibly burdensome elements into the lives of the participants and their families. Despite measures to ameliorate these challenges, 36% of the dropouts in NG choosing to leave the study did so due to nonadherence to the ND. This demonstrates the existing gap between what highly educated and affluent parents were expecting to provide as CF to their infants and what is preferable both in terms of health and sustainability. Bridging this gap further is essential both in future studies to optimize dietary intake in early childhood and when trying to implement the ND as CF on a wider scale. Further weaknesses include a study population of parents that was mostly born in Sweden, not reflecting the current ethnic composition of the country and that multicomponent interventions complicate the assessment of which interference had the most effect on the outcomes.

In conclusion, CF with reduced protein had no effect on body composition at either 12 or 18 mo. However, a ND with more plant-based foods, introduced to infants naïve to this model of eating, increased the intake of fruits and vegetables, establishing a preferable eating pattern lasting over a 12-mo period, with no negative effects on iron status or growth. Nordic foods are therefore possible to use when exposing infants to a variety of flavors and may contribute to establishing healthy, sustainable, climate friendly food preferences and dietary patterns early in life. Long-term effects on dietary intakes, body composition, metabolic processes or other health benefits remains to be studied.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ajcnut.2023.03.020>.

Data Availability

Data described in the manuscript, code book, and analytic code will not be made available because this was not stated in the ethics application.

References

- [1] J.M. Saavedra, D. Deming, A. Dattilo, K. Reidy, Lessons from the Feeding Infants and Toddlers Study in North America: what children eat, and implications for obesity prevention, *Ann. Nutr. Metab.* 62 (Suppl 3) (2013) 27–36, <https://doi.org/10.1159/000351538>.
- [2] P.D. Gluckman, M.A. Hanson, Developmental and epigenetic pathways to obesity: an evolutionary-developmental perspective, *Int. J. Obes. (Lond)*. 32 (Suppl 7) (2008) S62–S71, <https://doi.org/10.1038/ijo.2008.240>.
- [3] J.C. Trabulsi, J.A. Mennella, Diet, sensitive periods in flavour learning, and growth, *Int. Rev. Psychiatr.* 24 (3) (2012) 219–230, <https://doi.org/10.3109/09540261.2012.675573>.
- [4] G. Harris, Development of taste and food preferences in children, *Curr. Opin. Clin. Nutr. Metab. Care.* 11 (3) (2008) 315–319, <https://doi.org/10.1097/MCO.0b013e3282f9e228>.
- [5] E.I. Knudsen, Sensitive periods in the development of the brain and behavior, *J. Cogn. Neurosci.* 16 (8) (2004) 1412–1425, <https://doi.org/10.1162/0898929042304796>.
- [6] M. Fewtrell, J. Bronsky, C. Campoy, M. Domellöf, N. Embleton, N. Fidler Mis, et al., Complementary feeding: a position paper by the European Society for Paediatric Gastroenterology, Hepatology, and Nutrition (ESPGHAN) Committee on Nutrition, *J. Pediatr. Gastroenterol. Nutr.* 64 (1) (2017) 119–132, <https://doi.org/10.1097/MPG.0000000000001454>.
- [7] [Internet], Global status report on noncommunicable diseases 2010, World Health Organization, Geneva, Switzerland, 2011 [cited 1 December, 2022]. Available from: <https://apps.who.int/iris/handle/10665/44579>.
- [8] K. Lock, J. Pomerleau, L. Casuer, D.R. Altmann, M. McKee, The global burden of disease attributable to low consumption of fruit and vegetables: implications for the global strategy on diet, *Bull. World Health Organ.* 83 (2) (2005) 100–108.
- [9] [Internet], WHO and FAO announce global initiative to promote consumption of fruit and vegetables, World Health Organization, Geneva, Switzerland, 2003 [cited 1 December, 2022]. Available from: <https://www.who.int/news/item/>

- 11-11-2003-who-and-fao-announce-global-initiative-to-promote-consumption-of-fruit-and-vegetables.
- [10] E. Amcoff, A. Edberg, H. Enghardt Barbieri, A.K. Lindroos, C. Nälsén, M. Pearson, et al., Riksmaten - vuxna 2010-11. Livsmedels- och näringsintag bland vuxna i Sverige, Swedish National Food Agency, Uppsala, Sweden, 2012.
- [11] H. Barbieri Enghardt, M. Pearson, W. Becker, Riksmaten - barn 2003. Livsmedels- och näringsintag bland barn i Sverige, Swedish National Food Agency, Uppsala, Sweden, 2003.
- [12] Nordic Nutrition Recommendations 2012, 5th Edition. Vol. 2013, Nordic Council of Ministers, Copenhagen, Denmark, 2013.
- [13] L. Moreaus, A.K. Lindroos, E. Warensjö Lemming, I. Mattisson, Diet diversity score and healthy eating index in relation to diet quality and socio-demographic factors: results from a cross-sectional national dietary survey of Swedish adolescents, *Public Health Nutr* 23 (10) (2020) 1754–1765, <https://doi.org/10.1017/S1368980019004671>.
- [14] J.A. Mennella, J.C. Trabulsi, Complementary foods and flavor experiences: setting the foundation, *Ann. Nutr. Metab.* 60 (Suppl 2) (2012) 40–50, <https://doi.org/10.1159/000335337>.
- [15] L.L. Birch, Development of food acceptance patterns in the first years of life, *Proc. Nutr. Soc.* 57 (4) (1998) 617–624, <https://doi.org/10.1079/pns19980090>.
- [16] K. Dewey, Guiding principles for complementary feeding of the breastfed child [Internet], WHO, Pan American Health Organization, Washington, DC, 2003 [cited 1 December 1, 2022]. Available from: <https://iris.paho.org/handle/10665.2/752>.
- [17] G.K. Beauchamp, J.A. Mennella, Early flavor learning and its impact on later feeding behavior, *J. Pediatr. Gastroenterol. Nutr.* 48 (Suppl 1) (2009), <https://doi.org/10.1097/MPG.0b013e31819774a5>. S25–S30.
- [18] A. Hörnell, H. Lagström, B. Lande, I. Thorsdottir, Protein intake from 0 to 18 years of age and its relation to health: a systematic literature review for the 5th Nordic Nutrition Recommendations, *Food Nutr. Res.* 57 (2013), 21083, <https://doi.org/10.3402/fnr.v57i0.21083>.
- [19] M.F. Rolland-Cachera, M. Deheeger, M. Akrouf, F. Bellisle, Influence of macronutrients on adiposity development: a follow up study of nutrition and growth from 10 mo to 8 y of age, *Int. J. Obes.* 19 (1995) 573–578.
- [20] B. Koletzko, R. von Kries, R. Closa, J. Escribano, S. Scaglioni, M. Giovannini, et al., Lower protein in infant formula is associated with lower weight up to age 2 y: a randomized clinical trial, *Am. J. Clin. Nutr.* 89 (6) (2009) 1836–1845, <https://doi.org/10.3945/ajcn.2008.27091>.
- [21] E.K. Arnesen, B. Thorisdottir, C. Lamberg-Allardt, L. Bärebring, B. Nwaru, J. Dierkes, et al., Protein intake in children and growth and risk of overweight or obesity: a systematic review and meta-analysis, *Food Nutr. Res.* 66 (2022), <https://doi.org/10.29219/fnr.v66.8242>.
- [22] B. Thorisdottir, I. Gunnarsdottir, G.I. Palsson, T.I. Halldorsson, I. Thorsdottir, Animal protein intake at 12 months is associated with growth factors at the age of six, *Acta Paediatr* 103 (5) (2014) 512–517, <https://doi.org/10.1111/apa.12576>.
- [23] W. Willett, J. Rockström, B. Loken, M. Springmann, T. Lang, S. Vermeulen, et al., Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems, *Lancet* 393 (10170) (2019) 447–492, [https://doi.org/10.1016/S0140-6736\(18\)31788-4](https://doi.org/10.1016/S0140-6736(18)31788-4).
- [24] C. Mithril, L.O. Dragsted, C. Meyer, I. Tetens, A. Biloft-Jensen, A. Astrup, Dietary composition and nutrient content of the New Nordic Diet, *Public Health Nutr* 16 (5) (2013) 777–785, <https://doi.org/10.1017/S1368980012004521>.
- [25] H.M. Meltzer, A.L. Brantsæter, E. Trolle, H. Eneroth, M. Fogelholm, T.A. Ydersbond, et al., Environmental sustainability perspectives of the Nordic Diet, *Nutrients* 11 (9) (2019) 2248, <https://doi.org/10.3390/nu11092248>.
- [26] V. Adamsson, A. Reumark, I.B. Fredriksson, E. Hammarström, B. Vessby, G. Johansson, et al., Effects of a healthy Nordic diet on cardiovascular risk factors in hypercholesterolaemic subjects: a randomized controlled trial (NORDIET), *J. Intern. Med.* 269 (2) (2011) 150–159, <https://doi.org/10.1111/j.1365-2796.2010.02290.x>.
- [27] M. Uusitupa, K. Hermansen, M.J. Savolainen, U. Schwab, M. Kolehmainen, L. Brader, et al., Effects of an isocaloric healthy Nordic diet on insulin sensitivity, lipid profile and inflammation markers in metabolic syndrome—a randomized study (SYSDIET), *J. Intern. Med.* 274 (1) (2013) 52–66, <https://doi.org/10.1111/joim.12044>.
- [28] R. Andersen, A. Biloft-Jensen, E.W. Andersen, M. Ege, T. Christensen, K.H. Ygil, et al., Effects of school meals based on the New Nordic Diet on intake of signature foods: a randomised controlled trial. The OPUS School Meal Study, *Br. J. Nutr.* 114 (5) (2015) 772–779, <https://doi.org/10.1017/S0007114515002299>.
- [29] K. Vejrup, N. Agnihotri, E. Bere, S. Schjølberg, M. LeBlanc, E.R. Hillesund, et al., Adherence to a healthy and potentially sustainable Nordic diet is associated with child development in The Norwegian Mother, Father and Child Cohort Study (MoBa), *Nutr. J.* 21 (1) (2022) 46, <https://doi.org/10.1186/s12937-022-00799-5>.
- [30] J. Renzella, N. Townsend, J. Jewell, J. Breda, N. Roberts, M. Rayner, et al., What national and subnational interventions and policies based on Mediterranean and Nordic diets are recommended or implemented in the WHO European region, and is there evidence of effectiveness in reducing noncommunicable diseases, WHO Regional Office for Europe, Copenhagen, Denmark, 2018.
- [31] T. Lind, U. Johansson, I. Öhlund, L. Lindberg, B. Lönnerdal, C. Tennefors, et al., Study protocol: optimized complementary feeding study (OTIS): a randomized controlled trial of the impact of a protein-reduced complementary diet based on Nordic foods, *BMC Public Health* 19 (1) (2019) 134, <https://doi.org/10.1186/s12889-019-6466-1>.
- [32] U. Johansson, I. Öhlund, O. Hernell, B. Lönnerdal, L. Lindberg, T. Lind, Protein-reduced complementary foods based on Nordic ingredients combined with systematic introduction of taste portions increase intake of fruits and vegetables in 9 month old infants: a randomised controlled trial, *Nutrients* 11 (6) (2019) 1255, <https://doi.org/10.3390/nu11061255>.
- [33] [Internet], The emergence of a New Nordic food culture: final report from the program New Nordic Food II, 2010–2014, The Nordic Council of Ministers, Copenhagen, Denmark, 2015 [cited 1 December, 2022]. Available from: <https://www.norden.org/en/news/emergence-new-nordic-food-culture>.
- [34] U. Johansson, L. Lindberg, I. Öhlund, O. Hernell, B. Lönnerdal, S. Lundén, et al., Acceptance of a Nordic, protein-reduced diet for young children during complementary feeding—a randomized controlled trial, *Foods* 10 (2) (2021) 275, <https://doi.org/10.3390/foods10020275>.
- [35] [Internet], Good food for infants under one year, Sweden Food Agency, Uppsala, Sweden, 2011 [cited 1 December, 2022]. Available from: <https://www.livsmedelsverket.se/>.
- [36] Introduction to body composition assessment using the deuterium dilution technique with analysis of urine samples by isotope ratio mass spectrometry, human health series no. 13, IAEA, International Atomic Energy Agency, Vienna, Austria, 2011.
- [37] Body composition assessment from birth to two years of age, human health series no. 22, IAEA, International Atomic Energy Agency, Vienna, Austria, 2014.
- [38] S.J. Fomon, F. Haschke, E.E. Ziegler, S.E. Nelson, Body composition of reference children from birth to age 10 years, *Am. J. Clin. Nutr.* 35 (5) (1982) 1169–1175, <https://doi.org/10.1093/ajcn/35.5.1169>, suppl.
- [39] T.G. Lohman, A.F. Roche, R. Martorell, Anthropometric standardization reference manual, Human Kinetics Publications, Champaign, IL, USA, 1988.
- [40] WHO child growth standards: length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: methods and development, World Health Organization, Geneva, 2006.
- [41] W.T. Friedewald, R.I. Levy, D.S. Fredrickson, Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge, *Clin. Chem.* 18 (6) (1972) 499–502.
- [42] L.V. Hedges, Distribution theory for Glass’s estimator of effect size and related estimators, *J. Educ. Stat.* 6 (2) (1981) 107–128, <https://doi.org/10.3102/10769986006002107>.
- [43] A.L.B. Günther, A.E. Buyken, A. Kroke, Protein intake during the period of complementary feeding and early childhood and the association with body mass index and percentage body fat at 7 y of age, *Am. J. Clin. Nutr.* 85 (6) (2007) 1626–1633, <https://doi.org/10.1093/ajcn/85.6.1626>.
- [44] I. Öhlund, O. Hernell, A. Hörnell, H. Stenlund, T. Lind, BMI at 4 years of age is associated with previous and current protein intake and with paternal BMI, *Eur. J. Clin. Nutr.* 64 (2) (2010) 138–145, <https://doi.org/10.1038/ejcn.2009.132>.
- [45] T.L. Burrows, R.J. Martin, C.E. Collins, A systematic review of the validity of dietary assessment methods in children when compared with the method of doubly labeled water, *J. Am. Diet. Assoc.* 110 (10) (2010) 1501–1510, <https://doi.org/10.1016/j.jada.2010.07.008>.
- [46] R. Andersen, A. Biloft-Jensen, T. Christensen, E.W. Andersen, M. Ege, A.V. Thorsen, et al., Dietary effects of introducing school meals based on the New Nordic Diet - a randomised controlled trial in Danish children. The OPUS School Meal Study, *Br. J. Nutr.* 111 (11) (2014) 1967–1976, <https://doi.org/10.1017/S0007114514000634>.
- [47] L.B. Sørensen, C.T. Damsgaard, S.M. Dalskov, R.A. Petersen, N. Egelund, C.B. Dysseggaard, et al., Diet-induced changes in iron and n-3 fatty acid status and associations with cognitive performance in 8–11-year-old Danish children: secondary analyses of the optimal well-being, development and health for Danish children through a Healthy New Nordic Diet School Meal Study, *Br. J. Nutr.* 114 (10) (2015) 1623–1637, <https://doi.org/10.1017/S0007114515003323>.
- [48] C. Barends, J.H.M. de Vries, J. Mojet, C. de Graaf, Effects of starting weaning exclusively with vegetables on vegetable intake at the age of 12 and 23 months, *Appetite* 81 (2014) 193–199, <https://doi.org/10.1016/j.appet.2014.06.023>.
- [49] R.K. Hodder, K.M. O’Brien, F.G. Stacey, R.J. Wyse, T. Clinton-McHarg, F. Tzelpis, et al., Interventions for increasing fruit and vegetable consumption

- in children aged five years and under, *Cochrane Database Syst. Rev.* 5 (5) (2018) CD008552, <https://doi.org/10.1002/14651858.CD008552.pub5>.
- [50] R.G. Watt, K.I. Tull, R. Hardy, M. Wiggins, Y. Kelly, B. Molloy, et al., Effectiveness of a social support intervention on infant feeding practices: randomised controlled trial, *J. Epidemiol. Community Health.* 63 (2) (2009) 156–162, <https://doi.org/10.1136/jech.2008.077115>.
- [51] [Internet], The 17 goals, United Nations, New York, 2015 [cited 1 December, 2022]. Available from: <https://sdgs.un.org/goals>.
- [52] T. Hjorth, E. Huseinovic, E. Hallström, A. Strid, I. Johansson, B. Lindahl, et al., Changes in dietary carbon footprint over ten years relative to individual characteristics and food intake in the Västerbotten Intervention Programme, *Sci. Rep.* 10 (1) (2020) 20, <https://doi.org/10.1038/s41598-019-56924-8>.