

# Development of a New Nordic Diet score and its association with gestational weight gain and fetal growth – a study performed in the Norwegian Mother and Child Cohort Study (MoBa)

Elisabet R Hillesund<sup>1,\*</sup>, Elling Bere<sup>1</sup>, Margaretha Haugen<sup>2</sup> and Nina C Øverby<sup>1</sup>

<sup>1</sup>Department of Public Health, Sports and Nutrition, University of Agder, Serviceboks 422, 4604 Kristiansand, Norway; <sup>2</sup>Division of Environmental Medicine, Norwegian Institute of Public Health, Oslo, Norway

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## Abstract

**Objective:** To construct a diet score for assessing degree of adherence to a healthy and environmentally friendly New Nordic Diet (NND) and to investigate its association with adequacy of gestational weight gain and fetal growth in a large prospective birth cohort.

**Design:** Main exposure was NND adherence, categorized as low, medium or high adherence. Main outcomes were adequacy of gestational weight gain, described as inadequate, optimal or excessive according to the 2009 Institute of Medicine guidelines, and fetal growth, categorized as being small, appropriate or large for gestational age. Associations of NND adherence with gestational weight gain and fetal growth were estimated with multinomial logistic regression in crude and adjusted models.

**Setting:** Norway.

**Subjects:** Women (*n* 66 597) from the Norwegian Mother and Child Cohort Study (MoBa).

**Results:** Higher NND adherence implied higher energy and nutrient intakes, higher nutrient density and a healthier macronutrient distribution. Normal-weight women with high as compared with low NND adherence had lower adjusted odds of excessive gestational weight gain (OR=0.93; 95 % CI 0.87, 0.99; *P*=0.024). High as compared with low NND adherence was associated with reduced odds of the infant being born small for gestational age (OR=0.92; 95 % CI 0.86, 0.99; *P*=0.025) and with higher odds of the baby being born large for gestational age (OR=1.07; 95 % CI 1.00, 1.15; *P*=0.048).

**Conclusions:** The NND score captures diet quality. Adherence to a regional diet including a large representation of fruits and vegetables, whole grains, potatoes, fish, game, milk and drinking water during pregnancy may facilitate optimal gestational weight gain in normal-weight women and improve fetal growth in general.

## Keywords

Diet index

Dietary pattern

Birth weight

Gestational weight gain

For several decades there has been much focus and research on the so-called Mediterranean diet and its demonstrated protective association with a range of non-communicable diseases and mortality<sup>(1)</sup>. Recently there has also been growing interest in whether the same health benefits could be replicated with other regionally based diets; for example, a diet consisting largely of healthy foods native to a Nordic climate, like certain whole grains, wild fish and game, potatoes, root vegetables, cabbages, fruits and wild or cultivated berries<sup>(2,3)</sup>. The concept of a so-called New Nordic Diet (NND) additionally incorporates concern for environmental sustainability and planetary health<sup>(3,4)</sup>. Recent investigations into associations of healthy Nordic diets with measures of health indicate inverse relationships with several cardiovascular risk factors<sup>(5)</sup>,

abdominal obesity<sup>(6,7)</sup>, body fat<sup>(7)</sup>, inflammatory markers and serum lipids<sup>(8)</sup>, colorectal cancer risk<sup>(9)</sup> and total mortality<sup>(10)</sup>. Associations of a Nordic diet with health-related pregnancy outcomes have not, however, been investigated so far.

Maternal nutritional status and diet during pregnancy may have long-lasting influences on offspring health<sup>(11,12)</sup>. Excessive gestational weight gain (GWG) increases birth weight independently of genetic factors<sup>(13)</sup>. Animal studies indicate that *in utero* overnutrition has the potential of inducing permanent changes in key organs, disturbing appetite signalling and predisposing the infant to later overeating and obesity<sup>(14,15)</sup>. Macrosomia, or high infant birth weight, is associated with increased risk of complications for both mother and infant during delivery and

in the perinatal period<sup>(16)</sup> and with increased risk of later obesity, insulin resistance and metabolic syndrome in the child<sup>(17)</sup>. Fetal growth restriction, or being born small for gestational age (SGA), is similarly associated with future cardiovascular risk<sup>(11,12)</sup>. Achieving maternal and intra-uterine conditions that optimize fetal growth and development is therefore an important public health concern.

GWG within the ranges recommended in the Institute of Medicine guidelines is associated with favourable health outcomes for both mother and infant<sup>(18)</sup>. At present, however, a large proportion of women are gaining weight outside their recommended range<sup>(18,19)</sup>. Excessive GWG may contribute to excessive fetal growth, whereas inadequate GWG increases the risk of fetal growth restriction, both being associated with adverse short- and long-term health<sup>(18)</sup>. Documentation on successful ways of facilitating weight gain within optimal ranges is, however, scarce and research on this topic has been called for<sup>(19,20)</sup>.

In a meta-analysis of three large cohort studies in non-pregnant adults, Mozaffarian *et al.* found that long-term weight gain was inversely associated with an increase in intake of vegetables, whole grains, fruits, nuts and yoghurt<sup>(21)</sup>, most of which are also central constituents of the NND. In line with this and with the demonstrated effects of a healthy Nordic diet on various health parameters and satiety<sup>(5)</sup>, we hypothesize that adherence to the NND during pregnancy could facilitate optimal GWG and optimize fetal growth.

The purposes of the present study were to: (i) construct an NND score reflecting adherence to an environmentally sustainable and healthy Nordic diet; and (ii) investigate its association with adequacy of GWG and fetal growth in a large population-based pregnancy cohort.

## Experimental methods

The data for the present study were derived from the Norwegian Mother and Child Cohort Study (MoBa), which is a prospective, population-based, pregnancy cohort study conducted and maintained by the Norwegian Institute of Public Health<sup>(22)</sup>. The study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Norwegian Data Inspectorate and The Regional Committee for Ethics in Medical Research (reference S-97045 and S-95113). Written informed consent was obtained from all participants upon recruitment. Participants were recruited from all parts of Norway from 1999 to 2008, and 38.5% of invited women consented to participate. The cohort now includes 108 000 children, 90 700 mothers and 71 500 fathers. Follow-up is conducted by questionnaires at regular intervals and by linkage to national health registries. The current study is based on version 7 of the quality-assured data released for research in July 2012. For the present study, data from the Medical Birth Registry of Norway

(MBRN) and from three separate questionnaires were used: (i) a baseline questionnaire (Q1) that was completed around gestational week 17; (ii) an FFQ that was completed around gestational week 22 (Q2); and (iii) a follow-up questionnaire (Q4) completed 6 months postpartum.

### Preparation of the data set

Prerequisites for study eligibility were carrying a single fetus, having completed Q1, Q2 and Q4, and contributing data from the MBRN. A total of 85 160 women fulfilled these criteria. Exclusion criteria comprised delivery at <37 or >42 weeks of gestation ( $n$  4414), lack of information on length of gestation ( $n$  344), more than one pregnancy contributed by the same mother ( $n$  10 434), biologically implausible energy intakes ( $\leq 4500$  kJ or  $> 20\,000$  kJ;  $n$  1181), diabetes mellitus diagnosed prior to pregnancy ( $n$  362), maternal height <140 cm or  $\geq 193$  cm ( $n$  1), lack of information on maternal pre-pregnancy weight or height ( $n$  1791), lack of information on birth weight ( $n$  33) and birth weight <1000 g at  $\geq 37$  weeks of pregnancy ( $n$  3). The final study sample consisted of 66 597 mother–infant pairs.

### Construction of the New Nordic Diet score

The NND score was constructed to reflect and quantify participant adherence with the fundamental guidelines of the NND, basically being the inclusion in the diet of: (i) more calories from plant foods and fewer from meat; (ii) more calories from the sea and lakes; and (iii) more calories from the wild countryside as compared with current diet<sup>(4)</sup>. In addition, the score aimed to cover nutritional aspects of importance in attaining healthy balanced diets. The rationale, dietary composition and nutrient content of the NND have been carefully described by Mithril *et al.*<sup>(4)</sup>.

Ten dietary indicators (subscales) were chosen to constitute the score, based on a combination of their potential Nordic identity, the possibility of the foods being caught, grown, cultivated or picked locally without extensive use of fertilizers, their tradition or importance as a food source within the Nordic countries, and their favourable nutritional or health-enhancing potential relative to similar foods within the same food group<sup>(3,4)</sup>. A brief description of the ten subscales is included below.

1. Meal pattern: frequency of eating breakfast, lunch, dinner and evening meal.
2. Nordic fruits: frequency of eating apples, pears, plums and strawberries.
3. Root vegetables: frequency of eating carrots, rutabaga and various types of onions.
4. Cabbages: frequency of eating kale, cauliflower, broccoli and Brussels sprouts.
5. Potatoes: frequency of eating potatoes relative to rice and pasta.
6. Whole grain breads: consumption of whole grain breads relative to refined breads.
7. Oatmeal porridge: frequency of eating oatmeal porridge.

8. Foods from the wild countryside: frequency of eating game, fish, seafood and native berries.
9. Milk: consumption of unsweetened milk relative to fruit juice.
10. Water: consumption of water relative to sweetened beverages.

The NND as defined by Mithril *et al.* additionally comprises guidelines on the consumption of free-range livestock, rapeseed oil, legumes, nuts and seeds, fresh herbs, seaweeds, wild plants and mushrooms<sup>(4)</sup>. These foods were not addressed in the MoBa FFQ and could therefore not be included in the score. Meal frequency was, however, included in the score as an indicator of meal regularity, the fact that high-quality food is more often served in prepared meals and that complying with main meals may prevent frequent snacks and overeating<sup>(23)</sup>. Wild fish, seafood, game and native berries were combined in a common subscale since they share much quality due to their complete reliance on soil and local vegetation. Salmon and trout were excluded from this subscale since a large proportion of their consumption represents cultivated seafood not necessarily being in agreement with the perspectives of the NND<sup>(3)</sup>.

The dietary information was collected from a self-administered, semi-quantitative FFQ that has been validated for use in MoBa<sup>(24)</sup>. The FFQ covers the period from conception until mid-pregnancy and comprises 255 food items that have been converted into daily energy and nutrient intakes by FoodCalc and the Norwegian food composition table<sup>(24,25)</sup>. The FFQ can be downloaded from the MoBa website (<http://www.fhi.no/morogbarn/>). All subscales were constructed in a positive direction, so that increasing value indicated higher consumption of the relevant foods or more of the dietary behaviour in question. Each subscale was dichotomized using the median as cut-off and '0' was assigned for a sum score below the median and '1' for a sum score above the median. In brief, the approximate dietary behaviours associated with scoring in the respective subscales were: (i) eating at least 24 main meals/week; (ii) eating Nordic fruits at least 5 times/week; (iii) eating root vegetables at least 5 times/week; (iv) eating cabbage at least 2 times/week; (v) eating potatoes at least one-third of total occasions of eating potatoes, rice or pasta; (vi) choosing whole grain bread more often than refined bread; (vii) eating oatmeal at least monthly; (viii) eating fish/game/berries about 2 times/week; (ix) drinking milk more often than juice; and (x) drinking at least six times as much water as sugar-sweetened beverages. Similar methods have been extensively used in studies investigating associations of adherence to a Mediterranean diet with health parameters<sup>(26)</sup>. The NND score was computed by adding the ten dichotomized subscales, yielding a possible scoring range from 0 to 10. For description and analysis, the NND score was divided into 'low' (0–3 points), 'medium' (4–5 points) and 'high' (6–10 points) NND adherence, respectively.

### Outcome variables

The pregnancy outcomes investigated were adequacy of GWG and fetal growth. GWG was calculated as the difference between pre-pregnancy body weight and body weight at birth as reported in Q1 and Q4. Pre-pregnancy BMI was calculated as weight divided by height squared ( $\text{kg}/\text{m}^2$ ). Absolute GWG was categorized as inadequate, optimal or excessive according to maternal pre-pregnancy BMI in line with the BMI-specific Institute of Medicine guidelines for weight gain during pregnancy<sup>(18)</sup>. Optimal weight gain was 12.5–18.0 kg if the mother was underweight ( $\text{BMI} < 18.5 \text{ kg}/\text{m}^2$ ), 11.5–16.0 kg if normal weight ( $\text{BMI} = 18.5\text{--}24.9 \text{ kg}/\text{m}^2$ ), 7.0–11.5 kg if overweight ( $\text{BMI} = 25.0\text{--}29.9 \text{ kg}/\text{m}^2$ ) and 5.0–9.0 kg if the mother was obese pre-pregnancy ( $\text{BMI} \geq 30.0 \text{ kg}/\text{m}^2$ )<sup>(18)</sup>.

To operationalize fetal growth, newborn birth weight was obtained from the MBRN and categorized according to gender-specific cut-off values as SGA, appropriate for gestational age (AGA) or large for gestational age (LGA). The cut-off values for SGA and LGA corresponded to the 10th and 90th birth-weight percentile, respectively, as measured in 60 000 newborns with gestational age of 37–42 weeks born to nulliparous mothers in MoBa.

### Other variables

Information on maternal age (years), length of gestation (weeks), marital status and gestational diabetes was obtained from the MBRN. Data regarding smoking, maternal weight and height, gestational weight gain, exercise in pregnancy, educational attainment and parity were obtained from Q1. Since diet was the main exposure, maternal characteristics are presented according to NND adherence.

In building the regression models we investigated variables previously shown to be associated with both outcome and NND adherence, explored potential covariates in univariate models, and included those with significant associations in the multivariable models to reveal and assess potential confounding of the relationship between NND adherence and the outcomes<sup>(27)</sup>. Covariates assessed for inclusion in the GWG model included age, parity, pre-pregnancy BMI, length of gestation, marital status, exercise during pregnancy, educational attainment, smoking habits during pregnancy and sex of the infant. For inclusion in the fetal growth model we additionally assessed the contribution of maternal height and gestational diabetes. Neither marital status nor sex of the child contributed significantly to the models and since their removal changed the parameter estimates by < 10 %, they were not included in the final model. Offspring sex was not included in the fetal growth model since the measure of fetal growth was gender-specific.

### Statistical analyses

All statistical analyses were performed with the statistical software package IBM SPSS Statistics version 19.0. Most food and nutrient intake variables were skewed and are

therefore presented as median and interquartile range. Differences in energy and nutrient intakes across NND adherence categories were analysed with the Kruskal–Wallis test. The  $\chi^2$  test was used to assess differences in food frequency and categorical maternal and infant characteristics across NND adherence.

We used multinomial logistic regression to estimate crude and adjusted odds of attaining inadequate and excessive GWG (with optimal GWG as reference) with high NND as compared with low NND adherence. Likewise, we used multinomial logistic regression to estimate the odds of suboptimal fetal growth (SGA or LGA with AGA as reference), with high as compared with low NND adherence. Results are presented as crude and adjusted odds ratios with 95% confidence intervals. All models were checked for violation of assumptions.

The covariates retained in the GWG model comprised maternal age at delivery (years), length of gestation (37–42 weeks), parity (0, 1, 2,  $\geq 3$ ), educational attainment ( $\leq 12$  years, 13–16 years,  $\geq 17$  years), exercise in pregnancy (rarely, 1–2 times/week,  $\geq 3$  times/week), smoking during pregnancy (yes/no), pre-pregnancy BMI ( $< 25.0$  kg/m<sup>2</sup>, 25.0–29.9 kg/m<sup>2</sup>,  $\geq 30.0$  kg/m<sup>2</sup>), and energy intake (kJ). Additional covariates retained in the fetal growth model were maternal height (140–164 cm, 165–168 cm, 169–172 cm, 173–193 cm) and gestational diabetes (yes/no).

A two-sided *P*-value of  $< 0.05$  was considered statistically significant.

## Results

### ***Dietary implications of higher adherence to the New Nordic Diet***

The final study sample consisted of 66 597 pregnant women and their offspring, representing 78% of the eligible group before exclusion. Mean maternal age was 30.1 (SD 4.6) years. Participants were categorized according to NND score into low (*n* 17 802), medium (*n* 23 558) or high (*n* 25 237) adherence to the NND, the groups representing 27%, 35% and 38% of the sample, respectively. Table 1 describes the intakes of selected foods and drinks across NND adherence. Higher NND adherence implied higher intakes of fruits and vegetables, potatoes, whole grain bread, fish, game, milk and water. Women categorized with high NND adherence had a median daily intake of close to six portions of fruits and vegetables, almost twice as much as those with low NND adherence.

Higher NND adherence implied higher intakes of energy and nutrients (Table 2). There was a slightly lower proportion of energy (E%) from fat (30.8 *v.* 31.7 E%,  $P < 0.001$ ) and a higher proportion from protein (15.7 *v.* 14.9 E%,  $P < 0.001$ ) with high as compared with low NND adherence. Median proportion of energy from added sugar was lower (8.9 *v.* 11.2 E%,  $P < 0.001$ ) and fibre intake higher (35 *v.* 24 g/d,  $P < 0.001$ ) with high as compared with low NND adherence.

Each one-unit increment between 0 and 10 in NND score corresponded with increased energy and nutrient intakes, higher nutrient density and improved macronutrient distribution (data not shown). Micronutrients associated with fruits, berries, vegetables and grains were especially abundant in the diet of those with higher NND adherence, as documented by the intake of  $\beta$ -carotene per 10 MJ that was almost doubled with high as compared with low NND adherence. Median fibre intake per 10 MJ was 50% higher, and that of vitamin C, folic acid, Mg, K and Ca about 20% higher, with high as compared with low NND adherence.

### ***Maternal and infant characteristics***

Table 3 presents maternal and infant characteristics according to NND adherence. In short, women with high NND adherence were older, more educated and of higher parity than those with low NND adherence. They were also less likely to be smoking, less likely to be overweight or obese prior to pregnancy and more likely to exercise than women with low NND adherence.

### ***Gestational weight gain***

Mean total GWG in the sample was 15.0 (SD 5.9) kg, averaging 6.8 (SD 3.9) kg in the inadequate GWG group, 12.8 (SD 2.5) kg in the optimal GWG group and 19.3 (SD 4.7) kg in the excessive GWG group. A total of 41% of normal-weight women attained optimal GWG as compared with only 21% of overweight/obese women (Table 3). Since the definition of what constitutes inadequate, optimal and excessive GWG depends on pre-pregnancy BMI, we ran the model stratified by BMI even though there was no formal interaction ( $P = 0.133$  for excessive GWG and  $P = 0.497$  for inadequate GWG). Because of observed effect modification by BMI on the association between NND adherence and adequacy of GWG, analyses were carried out and presented stratified by BMI, the categories hereby denoted normal weight (BMI  $< 25.0$  kg/m<sup>2</sup>) and overweight/obese (BMI  $\geq 25.0$  kg/m<sup>2</sup>; Table 4). High as compared with low NND adherence implied lower adjusted odds of excessive GWG (OR = 0.93; 95% CI 0.87, 0.99;  $P = 0.024$ ) in normal-weight women. Degree of NND adherence was not significantly associated with GWG among overweight/obese women, but there was a trend towards higher odds of excessive GWG with high as compared with low NND adherence in this subset of participants (OR = 1.11; 95% CI 1.00, 1.23;  $P = 0.061$ ). Moving from low to medium NND adherence implied lower odds of inadequate GWG among overweight/obese women (OR = 0.86; 95% CI 0.74, 0.99;  $P = 0.038$ ). Otherwise there was no association between NND adherence and risk of inadequate GWG after adjustment for relevant confounding.

### ***Fetal growth***

Birth weight distribution and adequacy of fetal growth according to NND adherence are presented in Table 3. High as compared with low NND adherence was associated with

**Table 1** Comparison of weekly food and drink consumption according to degree of adherence to the New Nordic Diet (NND) in the Norwegian Mother and Child Cohort Study (MoBa), presented as frequency, portions or units per week (*n* 66 597)

	Degree of NND adherence						<i>P</i> value*
	Low ( <i>n</i> 17 802)		Medium ( <i>n</i> 23 558)		High ( <i>n</i> 25 237)		
	Median	P25, P75	Median	P25, P75	Median	P25, P75	
Oatmeal porridge (frequency/week) and breads (slices/week)							
Bread total	37	28, 49	41	30, 51	44	33, 56	<0.001
Bread (white and semi-white)	23	9, 35	18	4, 32	7	2, 28	<0.001
Whole grain bread	7	2, 21	16	5, 32	28	14, 42	<0.001
Oatmeal porridge	0	0, 0	0	0, 0.6	0.3	0, 0.6	<0.001
Vegetables (frequency/week)							
Vegetables total	9.9	6.7, 14.0	14.2	10.0, 19.8	20.2	14.9, 27.5	<0.001
Root vegetables	3.3	2.1, 4.7	4.8	3.1, 7.3	7.3	5.3, 10.3	<0.001
Kale vegetables	1.3	0.7, 1.8	1.8	1.2, 3.0	3.0	2.1, 4.7	<0.001
Fruits and berries (portions/week)†							
Fruits and berries total	10.0	6.1, 16.5	14.5	9.0, 22.0	19.9	13.6, 28.4	<0.001
Nordic fruits	3.0	1.5, 5.0	5.0	2.4, 7.9	7.7	4.8, 11.0	<0.001
Potatoes, rice and pasta (frequency/week)							
Potatoes	1.5	0.7, 3.5	1.5	1.5, 3.5	3.5	1.5, 3.5	<0.001
Rice and/or pasta	3.0	1.8, 3.0	3.0	1.8, 3.0	3.0	2.2, 3.0	0.089
French fries	0.7	0.3, 0.7	0.7	0.3, 0.7	0.3	0.3, 0.7	<0.001
Fish, seafood and meat (frequency/week)							
Fish and seafood	1.0	0.5, 1.5	1.3	0.8, 2.0	2.0	1.3, 2.8	<0.001
Pork and red meat	1.3	0.8, 1.8	1.3	0.8, 2.0	1.5	0.8, 2.3	<0.001
Game	0.0	0.0, 0.3	0.0	0.0, 0.3	0.3	0.0, 0.5	<0.001
Poultry	1.3	0.8, 2.0	1.3	0.8, 2.0	1.5	0.8, 2.0	<0.001
Milk and cheese (units/week)‡							
Unsweetened milk (all)	7.0	1.3, 17.5	7.3	2.1, 17.5	17.5	5.0, 19.0	<0.001
Low-fat milk (<0.7% fat)	0.0	0.0, 5.5	0.0	0.0, 7.0	1.5	0.0, 17.5	<0.001
Fermented milk and yoghurt	1.5	0.5, 4.3	2.1	0.6, 5.6	3.5	1.3, 7.0	<0.001
Cheese (frequency/week)	5.5	1.5, 14.0	6.3	2.5, 14.0	7.0	3.5, 14.0	<0.001
Other drinks (units/week)‡							
Water, fresh and carbonated	32	18, 46	34	19, 50	46	32, 57	<0.001
Fruit juice	7.0	2.1, 14.0	6.1	2.1, 10.5	6.1	2.1, 9.0	<0.001
Sugar-sweetened beverages	3.5	0.9, 8.3	2.1	0.6, 6.1	1.5	0.5, 3.8	<0.001
Artificially sweetened beverages	1.5	0.0, 7.0	0.8	0.0, 5.0	0.6	0.0, 3.0	<0.001
Coffee	0.5	0.0, 5.0	0.9	0.0, 7.0	1.5	0.0, 7.6	<0.001
Cakes and desserts (frequency/week)							
Cakes	2.0	1.2, 3.1	2.2	1.3, 3.5	2.5	1.4, 3.7	<0.001
Desserts	1.5	0.9, 2.4	1.8	1.0, 2.7	2.1	1.4, 3.2	<0.001
Sweets and snacks (frequency/week)							
Sweets	4.2	2.3, 6.8	3.9	2.2, 6.5	3.9	2.3, 6.2	<0.001
Salty snacks	2.0	1.2, 3.0	1.8	1.2, 2.8	1.8	1.0, 2.7	<0.001

P25, 25th percentile; P75, 75th percentile.

\*Kruskal–Wallis test across NND adherence categories.

†One portion of fruit is equivalent to one fruit or a similar amount (1/2 grapefruit, 8–10 grapes, etc.).

‡One unit of drink is equivalent to 250 ml.

reduced odds of the infant being born SGA (OR=0.92; 95% CI 0.86, 0.99; *P*=0.025) and increased odds of the baby being born LGA (OR=1.07; 95% CI 1.00, 1.15; *P*=0.048; Table 5). No formal interaction was observed between NND adherence and fetal growth (*P*=0.538 for SGA and *P*=0.578 for LGA). Since GWG could be in the causal pathway between NND adherence and fetal growth, GWG was not adjusted for in the multivariable model.

## Discussion

In the present study we found that adherence to a regionally based diet including a large representation of fruits and vegetables, whole grains, potatoes, fish, game, milk and drinking water during pregnancy may facilitate

optimal GWG in normal-weight women and improve fetal growth in general. Although the NND score may be seen as a fairly crude indicator of diet adherence, its dose-dependent association with nutrient density and a healthier macronutrient distribution confirms its ability to capture diet quality.

Normal-weight women with high as compared with low NND adherence had an estimated 7% lower odds of excessive GWG. Albeit small, this risk difference may be relevant in a public health perspective given the high prevalence of excessive GWG and its documented association with offspring macrosomia, perinatal morbidity, obstetric complications and later maternal and child health<sup>(19,28,29)</sup>. The fact that NND adherence was differently (although not significantly) associated with risk of excessive GWG in overweight/obese women is difficult to

**Table 2** Comparison of energy and nutrient intakes according to degree of adherence to the New Nordic Diet (NND) in the Norwegian Mother and Child Cohort Study (MoBa; *n* 66 597)

	Degree of NND adherence						<i>P</i> value*
	Low ( <i>n</i> 17 802)		Medium ( <i>n</i> 23 558)		High ( <i>n</i> 25 237)		
	Median	P25, P75	Median	P25, P75	Median	P25, P75	
Energy (MJ/d)	8.7	7.2, 10.4	9.2	7.8, 10.9	10.0	8.5, 11.8	<0.001
Energy (kcal/d)	2059	1723, 2462	2190	1859, 2601	2372	2069, 2796	<0.001
Protein (g/d)	76	65, 89	83	72, 97	92	80, 106	<0.001
Protein (E%)	14.9	13.6, 16.3	15.4	14.1, 16.8	15.7	14.5, 17.0	<0.001
Total fat (g/d)	71	59, 87	75	62, 92	80	66, 98	<0.001
Total fat (E%)	31.7	28.6, 34.8	31.3	28.3, 34.4	30.8	28.0, 33.9	<0.001
SFA (g/d)	28	23, 34	29	24, 36	31	25, 38	<0.001
SFA (E%)	12.3	10.9, 13.7	12.0	10.7, 13.4	11.7	10.5, 13.0	<0.001
<i>Trans</i> -fatty acids (g/d)	1.9	1.4, 2.6	2.1	1.5, 2.7	2.2	1.6, 2.9	<0.001
<i>Trans</i> -fatty acids (E%)	0.8	0.7, 1.0	0.8	0.7, 1.0	0.8	0.7, 1.0	<0.001
MUFA (g/d)	23	19, 28	24	20, 29	26	21, 32	<0.001
MUFA (E%)	10.1	9.0, 11.2	10.0	8.9, 11.1	9.9	8.7, 11.1	<0.001
PUFA (g/d)	13	10, 16	14	11, 17	15	12, 19	<0.001
PUFA (E%)	5.6	4.7, 6.8	5.6	4.8, 6.8	5.6	4.8, 6.7	0.014
Carbohydrates (g/d)	274	224, 336	291	241, 353	316	265, 378	<0.001
Carbohydrates (E%)	53.8	50.6, 57.1	53.7	50.6, 56.8	53.9	51.0, 56.8	<0.003
Added sugar (g/d)	56	38, 84	53	36, 77	51	36, 73	<0.001
Added sugar (E%)	11.2	8.2, 15.0	9.9	7.2, 13.0	8.9	6.7, 11.1	<0.001
Dietary fibre (g/d)	24	19, 29	29	24, 35	35	29, 42	<0.001
Dietary fibre (g/10 MJ)	28	24, 32	31	27, 35	35	30, 39	<0.001
Retinol (µg/10 MJ)	626	442, 1001	679	474, 1073	731	502, 1110	<0.001
β-Carotene (µg/10 MJ)	1659	1251, 2239	2079	1549, 3060	2877	2005, 4249	<0.001
Retinol equivalents (µg/10 MJ)	960	732, 1361	1119	848, 1546	1317	999, 1755	<0.001
Vitamin D (µg/10 MJ)	3.0	2.0, 4.0	3.3	2.3, 4.4	3.6	2.6, 4.8	<0.001
Vitamin E (mg/10 MJ)	9.3	7.9, 11.0	9.9	8.5, 11.7	10.6	9.1, 12.5	<0.001
Thiamin (mg/10 MJ)	1.52	1.37, 1.68	1.58	1.44, 1.73	1.63	1.50, 1.78	<0.001
Riboflavin (mg/10 MJ)	1.79	1.52, 2.11	1.95	1.66, 2.27	2.09	1.82, 2.39	<0.001
Niacin (mg/10 MJ)	19.4	17.1, 21.8	20.0	17.8, 22.3	20.4	18.5, 22.6	<0.001
Niacin equivalents (mg/10 MJ)	30.7	27.6, 34.0	31.9	28.9, 35.1	32.6	29.9, 35.8	<0.001
Vitamin B <sub>6</sub> (mg/10 MJ)	1.46	1.28, 1.66	1.58	1.40, 1.79	1.70	1.53, 1.91	<0.001
Folic acid (µg/10 MJ)	249	213, 293	273	237, 317	300	263, 346	<0.001
Vitamin B <sub>12</sub> (µg/10 MJ)	5.2	4.0, 6.7	5.8	4.5, 7.4	6.3	5.0, 7.9	<0.001
Vitamin C (mg/10 MJ)	143	99, 199	154	110, 209	169	127, 223	<0.001
Ca (mg/10 MJ)	963	786, 1169	1039	860, 1243	1104	933, 1296	<0.001
P (mg/10 MJ)	1629	1466, 1814	1738	1572, 1922	1835	1673, 2012	<0.001
Na (mg/10 MJ)	3145	2816, 3482	3176	2853, 3503	3175	2872, 3482	<0.001
K (mg/10 MJ)	3777	3381, 4197	4100	3711, 4529	4426	4033, 4870	<0.001
Na:K (mg/10 MJ)	0.83	0.72, 0.96	0.78	0.67, 0.89	0.72	0.62, 0.82	<0.001

P25, 25th percentile; P75, 75th percentile; E%, macronutrient energy contribution.  
\*Kruskal–Wallis test across NND adherence categories.

explain, but could simply reflect that improved diet quality *per se* may not be sufficient to limit GWG to the low weight range recommended for these groups (7.0–11.5 kg and 5.0–9.0 kg, respectively). Whether the NND can positively influence GWG gain in overweight/obese women who, unlike the present participants, are aware of their weight gain goals can only be answered in a properly conducted randomized intervention study.

Few studies have explored dietary patterns in relation to GWG. Uusitalo *et al.* reported a dose–response association of a ‘fast-food pattern’ with rate of GWG, whereas an inversely associated ‘healthy pattern’ was not statistically significant<sup>(30)</sup>. Stuebe *et al.* investigated associations of several dietary and nutritional aspects with risk for excessive GWG in 1388 pregnant women and found total energy intake, dairy and fried foods to be directly associated with risk of excessive GWG, whereas a vegetarian diet in the first

trimester was inversely associated with excessive GWG<sup>(31)</sup>. Olafsdottir *et al.* reported in a study in 495 pregnant women that eating more sweets in early pregnancy, drinking more milk and eating more food in general during late pregnancy increased the risk of excessive GWG<sup>(32)</sup>. Normal-weight women with high NND adherence in our study had lower risk of excessive GWG despite higher milk intake, higher reported intakes of cakes and desserts and higher total energy intake than those with lower NND adherence, possibly pointing to the importance of taking into account the complexity of the diet when investigating associations of diet with health outcomes.

The estimated 9% reduced odds of giving birth to an SGA infant with high as compared with low NND adherence may also be of public health relevance given the well-known risk of adverse fetal programming resulting from compromised nutrient supply that potentially can

**Table 3** Maternal and infant characteristics in the whole sample and according to degree of adherence to the New Nordic Diet (NND) in the Norwegian Mother and Child Cohort Study (MoBa)

	Degree of NND adherence								P value*
	Whole sample (n 66 597)		Low (n 17 802)		Medium (n 23 558)		High (n 25 237)		
	Mean or n	SD or %	Mean or n	SD or %	Mean or n	SD or %	Mean or n	SD or %	
Mean age (years)	30.1	4.6	29.1	4.6	30.0	4.5	30.8	4.5	<0.001
Age category									<0.001
≤19 years	599	0.9	291	1.6	181	0.8	127	0.5	
20–34 years	54 716	82.2	15 303	85.9	19 503	82.8	19 910	78.8	
≥35 years	11 282	16.9	2208	12.4	3874	16.5	5200	20.6	
Marital status									<0.001
Cohabiting	63 953	96.0	16 964	95.3	22 627	96.0	24 362	96.5	
Single	2644	4.0	838	4.7	931	4.0	875	3.5	
Parity									<0.001
0	34 747	52.2	10 191	57.2	12 610	53.5	11 946	47.3	
1	20 202	30.3	5236	29.4	7038	29.9	7928	31.4	
2	9131	13.7	1885	10.6	3088	13.1	4158	16.5	
≥3	2517	3.7	490	2.8	822	3.5	1205	4.7	
Educational attainment†									<0.001
≤12 years	20 315	31.2	6549	37.7	7281	31.6	6485	26.2	
13–16 years	27 830	42.7	7038	40.5	9785	42.5	11 007	44.4	
≥17 years	17 051	26.2	3776	21.7	5981	26.0	7294	29.4	
Mean BMI (kg/m <sup>2</sup> )‡	24.0	4.2	24.4	4.5	24.2	4.3	23.7	4.0	<0.001
BMI category									<0.001
<25 kg/m <sup>2</sup>	46 069	69.2	11 576	65.0	16 225	68.9	18 268	72.4	
25–29 kg/m <sup>2</sup>	14 357	21.6	4218	23.7	5057	21.5	5082	20.1	
≥30 kg/m <sup>2</sup>	6171	9.3	2008	11.3	2276	9.7	1887	7.5	
Smoking†									<0.001
No	60 956	92.2	15 827	89.6	21 514	92.0	23 615	94.2	
Yes	5169	7.8	1844	10.4	1880	8.0	1445	5.8	
Exercise†									<0.001
Rarely	22 155	36.2	7642	47.3	8042	37.3	6471	27.6	
1–2 times/week	19 776	36.2	4875	30.2	7049	32.7	7852	33.5	
≥3 times/week	19 265	31.5	3640	22.5	6494	30.1	9131	38.9	
GWG adequacy†,‡									<0.001
Inadequate	10 504	18.5	2800	18.7	3669	18.4	4035	18.6	
Optimal	19 634	34.7	4938	33.0	6911	34.6	7785	35.9	
Excessive	26 491	46.8	7243	48.3	9404	47.1	9844	45.4	
GWG (BMI <25.0 kg/m <sup>2</sup> )‡									0.008
Inadequate	8574	21.8	2141	21.8	3002	21.7	3431	21.8	
Optimal	15 947	40.5	3833	39.1	5560	40.2	6554	41.6	
Excessive	14 855	37.7	3833	39.1	5267	38.1	5755	36.6	
GWG (BMI ≥25.0 kg/m <sup>2</sup> )‡									0.076
Inadequate	1930	11.2	659	12.7	667	10.8	604	10.2	
Optimal	3687	21.4	1105	21.4	1351	21.9	1231	20.8	
Excessive	11 636	67.4	3410	65.9	4137	67.2	4089	69.0	
Mean birth weight (g)	3640	485	3622	482	3636	487	3655	484	<0.001
Birth weight category									<0.001
<2500 g	503	0.8	151	0.8	185	0.8	167	0.7	
2500–2999 g	5188	7.8	1489	8.4	1866	7.9	1833	7.3	
3000–3999 g	46 002	69.1	12 406	69.7	16 185	68.7	17 411	69.0	
4000–4999 g	11 980	18.0	3043	17.1	4283	18.2	4654	18.4	
≥4500 g	2924	4.4	713	4.0	1039	4.4	1172	4.7	
Fetal growth§									<0.001
SGA	6959	10.4	1997	11.2	2478	10.5	2484	9.8	
AGA	52 211	78.4	13 921	78.2	18 489	78.5	19 801	78.5	
LGA	7427	11.2	1884	10.6	2591	11.0	2952	11.7	

GWG, gestational weight gain; SGA, small for gestational age; AGA, appropriate for gestational age; LGA, large for gestational age.

Continuous variables are presented as mean and standard deviation, categorical variables as number and percentage.

\* $\chi^2$  test for trend (categorical variables) and one-way ANOVA test for trend (continuous variables) across NND adherence categories.

†Number of missing observations: education, *n* 1401 (2.1%); BMI, *n* 1687 (2.5%); smoking, *n* 472 (0.7%); exercise, *n* 5401 (8.1%); GWG, *n* 9968 (15.0%).

‡Adequacy of GWG was defined according to maternal pre-pregnancy BMI in line with the BMI-specific Institute of Medicine guidelines for weight gain during pregnancy, with optimal weight gain constituting 12.5–18.0 kg if the mother was underweight (BMI <18.5 kg/m<sup>2</sup>), 11.5–16.0 kg if normal weight (BMI = 18.5–24.9 kg/m<sup>2</sup>), 7.0–11.5 kg if overweight (BMI = 25.0–29.9 kg/m<sup>2</sup>) and 5.0–9.0 kg if the mother was obese pre-pregnancy (BMI ≥30.0 kg/m<sup>2</sup>)<sup>(18)</sup>.

§Gender-specific cut-off values for SGA and LGA correspond to the 10th and 90th birth-weight percentile, respectively, as measured in 60 000 newborns with gestational age 37–42 weeks born to nulliparous mothers in MoBa.

**Table 4** Associations of adherence to the New Nordic Diet (NND) with adequacy of gestational weight gain (GWG) in the Norwegian Mother and Child Cohort Study (MoBa; *n* 56 629)

NND adherence	<i>n</i>	Inadequate GWG*				Optimal GWG*,†		Excessive GWG*			
		Crude OR	95 % CI	Adjusted OR‡	95 % CI	Reference OR	Crude OR	95 % CI	Adjusted OR‡	95 % CI	
BMI < 25.0 kg/m <sup>2</sup>											
Low†	9807	1.00	–	1.00	–	1.00	1.00	–	1.00	–	
Medium	13 829	0.97	0.90, 1.04	0.99	0.92, 1.07	1.00	0.95	0.89, 1.00	0.99	0.93, 1.06	
High	15 740	0.94	0.88, 1.02	0.98	0.91, 1.06	1.00	0.88	0.83, 0.93	0.93	0.87, 0.99	
BMI ≥ 25.0 kg/m <sup>2</sup>											
Low†	5174	1.00	–	1.00	–	1.00	1.00	–	1.00	–	
Medium	6155	0.83	0.72, 0.95	0.86	0.74, 0.99	1.00	0.99	0.91, 1.09	1.01	0.92, 1.14	
High	5924	0.82	0.72, 0.94	0.90	0.77, 1.06	1.00	1.08	0.98, 1.18	1.11	1.00, 1.23	

\*Absolute GWG was categorized as inadequate, optimal or excessive according to maternal pre-pregnancy BMI in line with the BMI-specific Institute of Medicine guidelines for weight gain during pregnancy, with optimal weight gain constituting 12.5–18.0 kg if the mother was underweight (BMI < 18.5 kg/m<sup>2</sup>), 11.5–16.0 kg if normal weight (BMI = 18.5–24.9 kg/m<sup>2</sup>), 7.0–11.5 kg if overweight (BMI = 25.0–29.9 kg/m<sup>2</sup>) and 5.0–9.0 kg if the mother was obese pre-pregnancy (BMI ≥ 30.0 kg/m<sup>2</sup>)<sup>(18)</sup>.

†Low NND adherence is the reference category for diet and optimal GWG is the reference category for GWG in the multinomial model.

‡Adjusted for parity, pre-pregnancy BMI, educational attainment, energy intake, smoking, exercise during pregnancy, length of gestation, maternal age at delivery and maternal age squared.

**Table 5** Associations of adherence to the New Nordic Diet (NND) in pregnancy with adequacy of fetal growth in the Norwegian Mother and Child Cohort Study (MoBa; *n* 66 597)

NND adherence	<i>n</i>	SGA*				AGA*,†		LGA*			
		Crude OR	95 % CI	Adjusted OR‡	95 % CI	Reference OR	Crude OR	95 % CI	Adjusted OR‡	95 % CI	
Low†	17 802	1.00	–	1.00	–	1.00	1.00	–	1.00	–	
Medium	23 558	0.93	0.88, 1.00	0.95	0.89, 1.02	1.00	1.04	0.97, 1.10	1.04	0.97, 1.12	
High	25 237	0.87	0.82, 0.93	0.92	0.86, 0.99	1.00	1.10	1.04, 1.17	1.07	1.00, 1.15	

SGA, small for gestational age; AGA, appropriate for gestational age; LGA, large for gestational age.

\*Gender-specific cut-off values for SGA and LGA correspond to the 10th and 90th birth-weight percentile, respectively, as measured in 60 000 newborns with gestational age 37–42 weeks born to nulliparous mothers in MoBa.

†Low NND adherence is the reference category for diet and AGA is the reference category for fetal growth in the multinomial model.

‡Adjusted for maternal age at delivery, parity, pre-pregnancy BMI, maternal height, educational attainment, smoking, gestational diabetes, exercise during pregnancy and energy intake.

lead to increased cardiovascular risk later in life<sup>(33,34)</sup>. The fact that high as compared with low NND adherence also implied an estimated 7 % higher adjusted odds of the infant being born LGA indicates that factors associated with better diet quality may improve fetal substrate availability and enhance fetal growth in general. Boney *et al.* demonstrated that the risk of developing metabolic syndrome in childhood was associated with the intra-uterine environment conferred by maternal obesity and diabetes in addition to the risk conferred by being born LGA<sup>(17)</sup>. Whether being born LGA as a result of a healthy and nutritious maternal diet is differently associated with future health than being born LGA due to maternal obesity or diabetes has not been investigated to our knowledge.

Mechanisms relating diet quality to fetal growth comprise direct effects through fetal nutrient availability as well as indirect effects related to modulation of placental gene expression affecting placental function<sup>(35)</sup>. Several studies have reported a healthier and more nutritious maternal diet to be inversely associated with the risk of fetal growth restriction. Knudsen *et al.* found that women with a 'health conscious' dietary pattern characterized by higher intake

of fruits and vegetables, fish and poultry had 24 % reduced odds of delivering an SGA infant compared with women with a 'Western' dietary pattern characterized by a higher intakes of red and processed meat, high-fat dairy and energy<sup>(36)</sup>. Olsen *et al.* demonstrated reduced odds of SGA with increasing maternal milk consumption as compared with no milk intake, as well as higher odds of LGA with milk intakes exceeding 2–3 glasses/d<sup>(37)</sup>. Brantsæter *et al.* found reduced risk of SGA but no impact on risk of LGA with higher fish and seafood intake<sup>(38)</sup>. Chatzi *et al.* found that high *v.* low adherence to a Mediterranean diet modified the detrimental effect of smoking on birth size<sup>(39)</sup>. Higher milk and fish consumptions were also among the characteristics of higher NND adherence in the present study.

Strengths to our study are its prospective design, the large size of the cohort, detailed and validated information on dietary intake from conception to mid-pregnancy and detailed information on a range of covariates. The use of a comprehensive diet assessment tool rather than investigating single foods as exposure in relation to health outcomes has the advantage of capturing a larger part of



whole diet complexity with potential inherent interactive or synergistic effects of foods eaten in combination<sup>(40,41)</sup>.

Some limitations should, however, be addressed. Generalizability can be questioned since young and single mothers, smokers and mothers with more than two children are under-represented in the MoBa compared with the Norwegian background population<sup>(42)</sup>. This implies a more homogeneous sample regarding health-related characteristics and may have influenced the estimates of the associations between NND adherence and the outcomes. Some misclassification of NND adherence and BMI category is likely because these data were self-reported. Gross under- and over-reporting of dietary intake was eliminated by the exclusion of participants with biologically implausible energy intakes<sup>(25)</sup>. However, bias introduced by selective over-reporting of healthy dietary behaviours or under-reporting of perceived unhealthy dietary behaviours cannot be excluded<sup>(25)</sup>. This could influence cut-off levels in the subscales that constitute the NND score and lead to misclassification of NND adherence. If randomly distributed, misreporting of diet would only tend to blur associations, but not change the direction of the findings. If misreporting should be correlated with specific participant traits or characteristics, however, the resulting misclassification of NND adherence could potentially diminish, conceal or even change the apparent direction of the estimated associations of NND adherence with the outcomes in participants with these traits. In the present study this kind of misclassification would tend to attenuate associations, thus potentially resulting in underestimation of the true associations between NND adherence and the outcomes.

Increasing NND score was reflected in higher absolute energy intake. This seems to be a common feature of healthy dietary indices<sup>(37,39,41,43)</sup> and may bias associations of dietary patterns with health outcomes closely related to energy intake. To account for this we adjusted for energy intake in the multivariable regression models even though energy intake could be in the causal pathway between NND adherence and the outcomes.

Importantly, the NND score was not constructed to capture the healthiest or most efficient weight-controlling diet possible, but rather to be an indicator of a generally healthy, realistic and sustainable regional diet. The fact that by this fairly crude classification of diet we were able to detect associations with adequacy of GWG and fetal growth confirms the ability of the NND score to capture aspects of diet quality.

## Conclusion

The implication of the present study is that adherence to a regionally based diet including a large representation of fruits and vegetables, whole grain bread, potatoes, fish, game, milk, and drinking water during pregnancy may facilitate attainment of optimal GWG in normal-weight women and improve fetal growth in general. The NND

score captures diet quality and will be used to investigate associations of NND adherence with other pregnancy outcomes in further studies.

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