

The Development of a Diet Quality Score for Preschool Children and Its Validation and Determinants in the Generation R Study^{1–3}

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Abstract

Background: Although many studies have examined health effects of infant feeding, studies on diet quality shortly after the weaning and lactation period are scarce.

Objectives: Our aims were to develop and evaluate a diet score that measures overall diet quality in preschool children and to examine the sociodemographic and lifestyle determinants of this score.

Methods: On the basis of national and international dietary guidelines for young children, we developed a diet score containing 10 components: intake of vegetables; fruit; bread and cereals; rice, pasta, potatoes, and legumes; dairy; meat and eggs; fish; oils and fats; candy and snacks; and sugar-sweetened beverages. The total score ranged from 0 to 10 on a continuous scale and was standardized to an energy intake of 1200 kcal/d with the residual method. The score was evaluated in 3629 children participating in the Generation R Study, a population-based prospective cohort study. Food consumption was assessed with a food-frequency questionnaire (FFQ) at a median age of 13 mo.

Results: The mean \pm SD diet score was 4.1 ± 1.3 . The food-based diet score was positively associated with intakes of many nutrients, including $n-3$ ($\omega-3$) fatty acids [FAs; 0.25 SD increase (95% CI: 0.22, 0.27) per 1 point increase in the diet score], dietary fiber [0.32 (95% CI: 0.30, 0.34)], and calcium [0.13 (95% CI: 0.11, 0.16)], and was inversely associated with intakes of sugars [−0.28 (95% CI: −0.31, −0.26)] and saturated fat [−0.03 (95% CI: −0.05, −0.01)]. A higher diet score was associated with several health-conscious behaviors, such as maternal folic acid supplement use during pregnancy, no smoking during pregnancy, and children watching less television.

Conclusion: We developed a novel food-based diet score for preschool children that could be applied in future studies to compare diet quality in early childhood and to investigate associations between diet in early childhood and growth, health, and development. *J Nutr* 2015;145:306–14.

Keywords: diet index, dietary pattern, healthy diet, toddlers, preschoolers, infants, validation, predictors, sociodemographic determinants, birth cohort

Introduction

Dietary behaviors and food preferences develop early in life (1), and there is evidence that they remain stable during childhood

(2) and from childhood to adulthood (3). Furthermore, an inadequate diet in childhood affects child health (4) and may also affect health later in life (5). Therefore, it is important to study diet in early childhood. Although many studies have examined infant feeding, studies on diet quality shortly after the weaning and lactation period are scarce.

One way to examine diet is to focus on intakes of individual foods or nutrients. A complementary approach is to use holistic measures of overall diet, such as dietary patterns or diet scores

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³ Supplemental Figures 1–4, Supplemental Tables 1–7, and Supplemental Methods are available from the “Online Supporting Material” link in the online posting of the article and from the same link in the online table of contents at <http://jn.nutrition.org>.

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(6, 7). Diet scores or patterns can either be data driven, on the basis of dietary intakes in the population, or they can be predefined, e.g., on the basis of dietary guidelines (7, 8). An advantage of the data-driven approach is that it reflects actual dietary patterns in the population. A disadvantage, however, is that a pattern that is considered to be healthier does not necessarily reflect a diet that is actually healthy (7, 9). Dietary guidelines, on the other hand, are developed on the basis of known relations between diet and health. Hence, guideline-driven approaches may better reflect a desirable dietary pattern. Another advantage of a guideline-driven approach is that different populations can be more easily compared. However, disadvantages of a predefined dietary pattern or index are that the variation between subjects might be small and that there is often scientific debate on what constitutes the healthiest diet (7, 9).

There are a few previously published diet indices for children (4, 10), but these were not developed for preschool children (11–13), they focused on dietary variety or behaviors rather than quality (14, 15), they were developed for specific health outcomes (16), or they included intake of specific micronutrients for which data are not commonly available in observational studies (17). Therefore, first, we aimed to develop a new food-based diet quality index for evaluating overall diet quality in preschool children. Second, we aimed to evaluate the construct validity of this score in preschool children participating in the Generation R Study, a population-based cohort study in The Netherlands. Our third aim was to study the associations of various sociodemographic and lifestyle factors with the diet score in participants from the Generation R Study.

Methods

Subjects. This study was embedded in the Generation R Study, a multiethnic population-based prospective cohort study from fetal life onward in Rotterdam, The Netherlands (18). The study was approved by the local Medical Ethics Committee and written consent was given by parents. Pregnant women were enrolled between 2001 and 2005, and 7893 live born children were available for postnatal follow-up. An FFQ to assess diet of the children around the age of 1 y was sent to 5088 mothers who provided consent for follow-up and had sufficient mastery of the Dutch language. In total, 3650 (72%) of these mothers returned the questionnaire (19). After exclusion of subjects with invalid dietary data ($n = 18$) and withdrawn consent ($n = 3$), information on diet was available from 3629 children (Supplemental Figure 1). Mothers of a subgroup of the cohort, consisting of Dutch children only, received an additional FFQ around their child's age of 2 y (18). This FFQ was completed for 844 children (94%; Supplemental Figure 2).

Dietary assessment. Dietary intake was assessed when the children's median age was 13 mo (95% range: 12–19 mo), with a validated semiquantitative FFQ (19) (Supplemental Methods). This FFQ included foods that, according to a Dutch national food consumption survey in 2002, are frequently consumed by children aged 9–18 mo (20). The final FFQ consisted of 211 food items. Information on frequencies and serving sizes was converted into grams per day with the use of standardized portion sizes. Nutrient intakes were calculated with the use of the Dutch Food Composition Table 2006 (21). Information on vitamin and mineral supplement use (yes/no) was obtained from the FFQ but was not included in nutrient calculations because the exact dosage of vitamin and mineral supplementation was not available.

The FFQ was evaluated against three 24-h recalls performed by trained nutritionists in a representative sample of 32 Dutch children with a median age of 14 mo (95% range: 6–20 mo) living in Rotterdam (19). Interclass correlation coefficients for nutrient intakes ranged from 0.36 to 0.74. Further details on the FFQ and the evaluation study are provided in Supplemental Methods.

An almost identical FFQ was completed for a subgroup of 844 Dutch children at a median age of 25 mo (95% range: 24–28 mo). This FFQ

consisted of 230 food items and, compared with the FFQ at the age of 13 mo, included more items on specific dairy products, nuts and seeds, and toddler foods and fewer items on specific types of infant formula. For 777 children, dietary data were available at both 13 mo and 25 mo of age, with a median time difference between the 2 measurements of 12 mo (95% range: 5–14 mo).

Construction of the diet score. We used national and international dietary guidelines as a basis for the development of the diet score. These guidelines were the few available food-based guidelines for preschool children with quantitative recommendations: from The Netherlands (1–3 y) (22), Germany (1 y) (23), Switzerland (1 y) (24), Flanders (1.5–3 y) (25), and Northern Ireland (1–5 y) (26). We also considered US food-based recommendations for the general population from the age of 2 y (27) and other scientific literature on foods that were not consistently included in these dietary guidelines (e.g., sugar-sweetened beverages, fish, and whole milk) (28–30). Summaries of these guidelines are available on request from the corresponding author.

Based on the guidelines and literatures we decided to include the following 10 food groups and cutoffs in the diet score: vegetables (≥ 100 g/d); fruit (≥ 150 g/d); bread and cereals (≥ 70 g/d); rice, pasta, potatoes, and legumes (≥ 70 g/d); dairy (≥ 350 g/d); meat, poultry, eggs, and meat substitutes (≥ 35 g/d); fish (≥ 15 g/d); oils and fats (≥ 25 g/d); candy and snacks (≤ 20 g/d); and sugar-sweetened beverages (≤ 100 g/d; Supplemental Table 1). To better distinguish between more and less healthy diets and in line with several of the guidelines (22–24, 27), we took account of the healthier and less healthy options within the food groups; except for the snacks and the sugar-sweetened beverages components, we only included recommended food items from the food groups (e.g., whole-wheat bread, but not white bread for the bread and cereal component). Details on the components, cutoffs, and included food items are provided in Supplemental Table 1.

Cutoff values for the intakes of foods were derived from recommendations in existing guidelines (22–27). For each food group, we calculated the ratio of the reported intake and the recommended intake, an approach that has previously been used for other diet indices (13, 31). For instance, a child with a fruit intake of 120 g/d is assigned a score of 0.8 (120 divided by 150 g/d) for the fruit component. For each component the score was truncated at 1, meaning that if a child exceeds the recommended intake for a food group the score for this food group is 1. For the candy and snacks and the sugar-sweetened beverages components, children were assigned a score of 0 for intakes at or above the maximum cutoff (Supplemental Table 1) and were assigned a score proportional between 0 and 1 if they consumed less than this cutoff, with a higher score for lower intakes. The scores for the single components were added together, resulting in an overall score that ranged from 0 to 10 on a continuous scale, with a higher score representing a healthier diet.

The score was adjusted for energy intake to control for overconsumption or underconsumption and to reduce the potential measurement error in the dietary assessment (32). The diet score was standardized to an energy intake of 1200 kcal/d, which is the recommended energy intake for 1- to 4-y-old children in The Netherlands (33) and in line with energy recommendations in other guidelines (23, 25).

Parental sociodemographic and lifestyle factors. Information on maternal ethnicity, educational level, disease history, marital status, parity, and folic acid supplement use in early pregnancy; on household income; and on paternal age, educational level, and smoking were obtained with the use of questionnaires at enrollment (18). Parental education was dichotomized into higher and primary/secondary education (34). Net household income was categorized into $<€2200$ and $\geq €2200$ per month (35). Ethnicity of the mother was defined as follows: if both parents were born in The Netherlands, the ethnicity was defined as Dutch; if one of the parents was born in a country other than The Netherlands, that country determined ethnicity; if both parents were born in countries other than The Netherlands, the mother's country applied (36). Diet of the mother during pregnancy was assessed at enrollment (median: 13.5 wk of gestation) with a validated semiquantitative FFQ, and total energy and fiber intake were calculated (37). Maternal smoking and alcohol consumption during pregnancy were

TABLE 1 Associations between the diet score and intakes of nutrients in children aged 13 and 25 mo¹

	β (95% CI)		
	13 mo, ² <i>n</i> = 3629	13 mo, ³ <i>n</i> = 3629	25 mo, ² <i>n</i> = 844
Macronutrients			
Protein	0.43 (0.41, 0.45)*	0.40 (0.38, 0.42)*	0.45 (0.40, 0.50)*
Vegetable protein	0.34 (0.31, 0.36)*	0.20 (0.18, 0.22)*	0.32 (0.26, 0.38)*
Animal protein	0.23 (0.21, 0.26)*	0.28 (0.25, 0.30)*	0.25 (0.20, 0.30)*
Fat	−0.02 (−0.05, 0.01)	0.07 (0.05, 0.09)*	0.08 (0.02, 0.14)*
Saturated fat	−0.04 (−0.06, −0.02)*	−0.03 (−0.05, −0.01)*	−0.06 (−0.10, −0.01)
Monounsaturated fat	−0.06 (−0.09, −0.04)*	0.06 (0.04, 0.08)*	0.11 (0.05, 0.17)*
Polyunsaturated fat	0.13 (0.11, 0.16)*	0.14 (0.12, 0.17)*	0.22 (0.16, 0.27)*
n-3 FAs	0.33 (0.31, 0.36)*	0.25 (0.22, 0.27)*	0.30 (0.24, 0.35)*
n-6 FAs	0.25 (0.22, 0.27)*	0.14 (0.12, 0.16)*	0.21 (0.15, 0.27)*
Carbohydrates	−0.13 (−0.16, −0.11)*	−0.21 (−0.23, −0.18)*	−0.20 (−0.26, −0.14)*
Monosaccharides and disaccharides	−0.26 (−0.28, −0.24)*	−0.28 (−0.31, −0.26)*	−0.32 (−0.37, −0.27)*
Polysaccharides	0.19 (0.17, 0.22)*	0.13 (0.10, 0.15)*	0.23 (0.17, 0.29)*
Dietary fiber	0.34 (0.31, 0.36)*	0.32 (0.30, 0.34)*	0.42 (0.37, 0.47)*
Micronutrients			
β -Carotene	0.36 (0.34, 0.38)*	0.35 (0.33, 0.38)*	0.40 (0.34, 0.45)*
Vitamin B-6	0.31 (0.29, 0.33)*	0.26 (0.24, 0.28)*	0.44 (0.38, 0.49)*
Vitamin B-12	0.22 (0.19, 0.47)*	0.22 (0.20, 0.25)*	0.31 (0.25, 0.36)*
Vitamin C	−0.07 (−0.10, −0.05)*	0.05 (0.02, 0.07)*	0.04 (−0.02, 0.10)
Vitamin D	−0.21 (−0.23, −0.19)*	0.05 (0.04, 0.05)*	0.05 (−0.01, 0.11)
Vitamin E	−0.14 (−0.16, −0.11)*	0.08 (0.07, 0.10)*	0.19 (0.13, 0.25)*
Calcium	−0.02 (−0.05, 0.01)	0.13 (0.11, 0.16)*	0.21 (0.15, 0.27)*
Food folate (naturally present)	0.47 (0.45, 0.49)*	0.36 (0.34, 0.38)*	0.46 (0.41, 0.51)*
Total folate (including added folic acid)	0.01 (−0.02, 0.03)	0.03 (0.00, 0.05)	0.09 (0.03, 0.15)*
Iron	−0.25 (−0.27, −0.22)*	−0.02 (−0.03, −0.01)	0.13 (0.07, 0.18)*
Magnesium	0.38 (0.36, 0.40)*	0.32 (0.29, 0.34)*	0.41 (0.36, 0.47)*
Phosphorus	0.34 (0.31, 0.37)*	0.34 (0.32, 0.36)*	0.52 (0.46, 0.59)*
Potassium	0.34 (0.31, 0.36)*	0.32 (0.30, 0.34)*	0.46 (0.40, 0.53)*
Selenium	0.42 (0.39, 0.44)*	0.30 (0.28, 0.32)*	0.37 (0.32, 0.43)*
Sodium	0.24 (0.21, 0.26)*	0.10 (0.08, 0.13)*	0.28 (0.23, 0.34)*
Zinc	−0.10 (−0.13, −0.08)*	0.12 (0.11, 0.14)*	0.20 (0.14, 0.25)*

¹ Values are regression coefficients from linear regression models with the diet score as independent variable and energy-adjusted standardized nutrient intakes as dependent variables. Regression coefficients can be interpreted as the difference in nutrient intake (SD) with 1 point increase in the diet score while keeping energy intake constant. **P* < 0.0017 (0.05/29 because of Bonferroni correction).

² Models are adjusted for child's age and sex.

³ Additionally adjusted for current intake of infant formula (energy adjusted) and current breastfeeding (yes/no).

assessed with questionnaires in each trimester (38). At enrollment, maternal and paternal anthropometrics were measured without shoes or heavy clothing at the research center and BMI was calculated (18).

Child sociodemographic and lifestyle factors. Information on child's sex, birth weight, and gestational age at birth was available from medical records and hospital registries (18). Information on vitamin and mineral supplement use (yes/no) at the age of 13 mo was obtained from the previously mentioned FFQ. Ethnicity of the child was defined in the same way as for the mothers (36). Child's height and weight were measured at the Community Child Health Centers at a median age of 14 mo (95% range: 13–16 mo) and weight-for-age and height-for-age z scores were calculated with the use of Dutch reference curves (39). Information about breastfeeding was obtained from delivery reports and postnatal questionnaires at 2, 6, and 12 mo after delivery. Breastfeeding was categorized into never, partial in the first 4 mo, or exclusive for at least 4 mo (19). Timing of introduction of solids in the first year of life was obtained from the FFQ at 13 mo in 3 categories: <3 mo, 3–6 mo, or ≥6 mo (40). Information on doctor-diagnosed food allergies and hospital admission was obtained through questionnaires at the child's ages of 6 and 12 mo (18). Day care attendance in the first year of life was assessed in a questionnaire at the age of 12 mo and was categorized into ≤24 or >24 h/wk (41). Child's picky eating behavior was assessed with a questionnaire at the age of 1.5 y and dichotomized into picky or

nonpicky eating (42). Information about sleep duration and television watching was collected with questionnaires at the age of 2 y. Nighttime sleep duration was dichotomized into <11.5 or ≥11.5 h/night (43). Average duration of television watching was categorized into <1 or ≥1 h/d (44).

Statistical analysis. The nutrient residual method was used to standardize the diet score and the component scores to a total energy intake of 1200 kcal/d (45). Briefly, we used linear regression analysis to calculate energy-adjusted diet score residuals for each subject, with energy intake as independent variable and the diet score as dependent variable. Subsequently, the predicted score for a daily energy intake of 1200 kcal was added as a constant. We compared the diet score with previously defined data-driven dietary patterns for the 13-mo-old children with Pearson correlations (19). We also compared the diet score at the age of 13 mo with the score at the age of 25 mo with the use of Pearson correlations.

The construct validity of the diet score was assessed by evaluating the associations of the food-based diet score with intakes of nutrients considered to be healthy (e.g., vitamins, dietary fiber, and n-3 FAs) or unhealthy (e.g., saturated fat, sodium, and sugars). For this we used linear regression models with energy-adjusted nutrient intake as dependent variable and the diet score as independent variable, adjusted for child's age and sex, and in separate models additionally adjusted for current breastfeeding and intake of infant formula (energy adjusted). To

adjust for multiple testing, a Bonferroni correction was applied and a value of $P = 0.0017$ (0.05/29 tests) was used as threshold of statistical significance. In addition to these models with nutrient intakes as continuous variables, we assessed the association between the diet score and adequate nutrient intakes as specified by European guidelines for young children (46).

Linear regression models were used to analyze the associations of various sociodemographic and lifestyle factors with the diet score. Variables with $P < 0.10$ in univariable models were included in 1 multivariable model. To retain only the strongest determinants, we performed a stepwise backward elimination procedure on the full multivariable model (with $P < 0.10$ as endpoint).

To diminish potential bias associated with attrition, missing values of sociodemographic and lifestyle variables were multiple imputed by generating 10 independent data sets with the use of the fully conditional specification method (predictive mean matching), assuming no monotone missing pattern. The multiple imputation procedure was based on the correlation between each variable with missing values and other subject characteristics (47, 48). Because we found similar effect estimates, we present the pooled regression coefficients after the multiple imputation procedure.

We performed several sensitivity analyses. First, because the FFQ was developed and validated for Dutch children but different ethnicities are included in our cohort, analyses were repeated in Dutch children only. Second, we performed sensitivity analyses in which children who still consumed breast milk ($n = 319$) or a substantial amount of infant formula (i.e., >500 kcal/d, $n = 477$) were excluded. Finally, we repeated our analyses after excluding 1 random child per twin pair to account for clustering. All statistical analyses were performed with SPSS version 21.0 (SPSS, Inc.).

Results

Subject and diet score characteristics. Most of the mothers were highly educated (66%), were nulliparous at enrollment (59%), and did not smoke during pregnancy (78%). Most of the children had a Dutch ethnicity (68%) (Supplemental Table 2). After standardization to an energy intake of 1200 kcal/d, the diet score ranged from 0.6 to 8.8 with a mean \pm SD of 4.1 ± 1.3 in the 13-mo-old children in our study population (Supplemental Figure 3). Most children had relatively high component scores for the intakes of fruit (median standardized score of 0.80) and bread and cereal (0.81) but relatively low scores for the intakes of meat, eggs, and meat substitutes (0.23); fish (0.15); and candy and snacks (0.18; Supplemental Table 3). Among Dutch children ($n = 2413$) for whom we previously derived data-driven dietary patterns with principal component analysis (19), the diet score had a strong positive correlation with adherence to the “health-conscious” dietary pattern ($r = 0.47$, $P < 0.001$) and a slight inverse correlation with adherence to the “Western” dietary pattern ($r = -0.12$, $P < 0.01$).

The standardized diet score in the 844 Dutch children at the age of 25 mo ranged from 0.7 to 8.4, with a mean of 4.6 ± 1.1 (Supplemental Figure 4). For 777 children, dietary data were available at both 13 and 25 mo of age. In this subgroup, mean diet score was 4.2 ± 1.4 at the age of 13 mo, increasing to 4.8 ± 1.2 at the age of 25 mo ($P < 0.001$). This increase was driven by an increase in all individual component scores, except for the candy and snacks component (Supplemental Table 3). The correlation between the diet score at the 2 different ages was 0.39 ($P < 0.001$).

Associations between the diet score and intakes of nutrients. We evaluated the construct validity of the diet score by assessing the associations between the diet score and intakes of nutrients (Table 1). With regard to macronutrients, a 1 point

increase in the diet score was associated with a 0.40 SD increase in protein intake (95% CI: 0.38, 0.42), with a 0.07 SD increase in fat intake (95% CI: 0.05, 0.09), and with a 0.21 SD decrease in carbohydrate intake (95% CI: -0.23 , -0.18). More specifically, the diet score was positively related to intakes of polysaccharides and dietary fiber [0.32 (95% CI: 0.30, 0.34)] but inversely to the intake of monosaccharides and disaccharides [-0.28 (95% CI: -0.31 , -0.26)]. Also, the diet score was inversely related to the intake of SFAs [-0.03 (95% CI: -0.05 , -0.01)] and positively associated with the intake of PUFAs, mainly $n-3$ FAs [0.25 (95% CI: 0.22, 0.27)].

The diet score was positively associated with intakes of several vitamins and minerals (Table 1). However, in models adjusted for age and sex only, the diet score was inversely associated with vitamins C, D, and E; iron; and zinc. After further adjustment for intake of infant formula and current breastfeeding, these associations became significantly positive, except for iron intake. The diet score was also positively associated with sodium intake. In the subgroup of 25-mo-old children, intake of formula and breast milk was very low, and associations between the diet score and nutrient intakes were all in the expected direction, except for the positive association between the diet score and sodium intake (Table 1).

Similar results were obtained in sensitivity analyses in which 1 child per twin pair (results not shown) or in which non-Dutch children were excluded (Supplemental Table 4). In analyses in which children who still consumed breast milk or a substantial amount of infant formula were excluded, results were similar to those of the whole group after adjustment for intake of formula and breastfeeding (results not shown). In line with results from the models with nutrient intakes as a continuous variable, the diet score was also associated with achieving recommended micronutrient intakes (Supplemental Table 5).

Sociodemographic and lifestyle determinants of the diet score. Associations between the diet score and various parental and child sociodemographic and lifestyle factors are presented in Table 2. In the multivariable model that included all variables kept after the backward selection procedure, the diet score was higher in children of mothers with health-conscious behaviors during pregnancy, such as a higher fiber intake, folic acid supplement use, no smoking, and having quit alcohol use. Furthermore, children with 2 or more older siblings had a 0.24 lower diet score than children who were their mother's firstborns (95% CI: -0.33 , -0.15). The diet score was not associated with maternal age, education, ethnicity, BMI, or marital status; household income; or paternal age, education, BMI, or smoking.

The diet score was slightly higher in boys [0.11 (95% CI: 0.19, 0.04)] and in children with a higher weight-for-age. Turkish children had a 0.28 lower diet score (95% CI: -0.47 , -0.09) and Surinamese/Antillean children had a 0.26 lower score (95% CI: -0.42 , -0.17) than children of Western ethnicity. A lower diet score was associated with current intake of breast milk or infant formula and with picky eating. Children who were breastfed in the first 4 mo of life, who were introduced to complementary foods after 6 mo of age, who currently receive food supplements, and who watch less television (<1 h/d) had a higher diet score. The child's day care attendance, sleep duration, and having a food allergy were not significantly associated with the diet score.

The full multivariable model without backward selection showed similar results (Table 2). In this model, older children had a slightly lower diet score, while in univariable models, higher age was associated with a higher diet score (Supplemental Table 6).

TABLE 2 Associations between parental and child sociodemographic and lifestyle factors and the diet score at the age of 13 mo ($n = 3629$)

	Multivariable model ¹		Multivariable model after stepwise backward selection ²	
	β (95% CI)	<i>P</i>	β (95% CI)	<i>P</i>
Parental characteristics ³				
Maternal age, y	0.01 (−0.01, 0.02)	0.16	—	
Maternal ethnicity				
Western	Reference			
Moroccan	0.34 (−0.09, 0.77)	0.12	—	
Turkish	−0.15 (−0.54, 0.24)	0.44	—	
Surinamese and Antillean	−0.02 (−0.21, 0.17)	0.92	—	
Other non-Western	−0.07 (−0.22, 0.08)	0.93	—	
Parity at enrollment				
0	Reference		Reference	
1	−0.01 (−0.10, 0.08)	0.84	0.01 (−0.09, 0.09)	0.98
≥2	−0.26 (−0.40, −0.11)	<0.01	−0.24 (−0.33, −0.15)	<0.01
Maternal BMI at enrollment, kg/m ²	−0.01 (−0.02, 0.00)	0.23	—	
Maternal education				
No higher education	Reference			
Higher	0.08 (−0.07, 0.23)	0.10	—	
Paternal education				
No higher education	Reference			
Higher	−0.02 (−0.16, 0.12)	0.74	—	
Marital stage				
Married or living together	Reference			
No partner	0.05 (−0.09, 0.20)	0.47	—	
Net household income, € per mo				
<2200	Reference			
≥2200	0.09 (−0.07, 0.11)	0.87	—	
Maternal energy intake during pregnancy, 100 kcal	0.00 (−0.01, 0.01)	0.99	—	
Maternal fiber intake during pregnancy, 10 g (energy adjusted)	0.43 (0.34, 0.52)	<0.01	0.44 (0.35, 0.53)	<0.01
Maternal smoking during pregnancy				
Never	Reference		Reference	
Until pregnancy was known	0.01 (−0.12, 0.14)	0.89	−0.01 (−0.16, 0.13)	0.86
Continued during pregnancy	−0.13 (−0.25, −0.01)	0.03	−0.17 (−0.29, −0.04)	0.01
Maternal alcohol use during pregnancy				
Never	Reference		Reference	
Until pregnancy was known	0.12 (0.00, 0.24)	0.06	0.15 (0.02, 0.27)	0.02
Continued during pregnancy	0.00 (−0.09, 0.10)	0.96	0.02 (−0.09, 0.12)	0.75
Maternal folic acid supplement use in early pregnancy				
Never	Reference		Reference	
Started in the first 10 wk	0.29 (0.13, 0.44)	<0.01	0.29 (0.14, 0.44)	<0.01
Started periconceptionally	0.23 (0.06, 0.40)	<0.01	0.23 (0.08, 0.38)	<0.01
Child characteristics ³				
Sex				
Male	Reference		Reference	
Female	−0.11 (−0.19, −0.04)	<0.01	−0.10 (−0.18, −0.02)	<0.01
Birth weight, per 100 g	0.00 (−0.01, 0.01)	0.50	—	
Age, mo	−0.03 (−0.05, 0.00)	0.02	−0.03 (−0.05, 0.00)	0.08
Ethnicity				
Western	Reference		Reference	
Moroccan	0.10 (−0.30, 0.50)	0.62	0.17 (−0.03, 0.38)	0.10
Turkish	−0.04 (−0.35, 0.27)	0.83	−0.28 (−0.47, −0.09)	<0.01
Surinamese and Antillean	−0.24 (−0.45, −0.03)	0.03	−0.26 (−0.42, −0.17)	<0.01
Other non-Western	0.16 (−0.03, 0.36)	0.10	0.17 (−0.11, 0.28)	0.64
Breastfeeding				
Full in first 4 mo	Reference		Reference	
Partially in first 4 mo	−0.19 (−0.29, −0.09)	<0.01	−0.20 (−0.30, −0.10)	<0.01
Never	−0.14 (−0.29, 0.00)	0.05	−0.16 (−0.32, −0.01)	0.05

(Continued)

TABLE 2 *Continued*

	Multivariable model ¹		Multivariable model after stepwise backward selection ²	
	β (95% CI)	P	β (95% CI)	P
Currently receiving breast milk				
No	Reference		Reference	
Yes	-0.62 (-0.77, -0.47)	<0.01	-0.60 (-0.75, -0.46)	<0.01
Intake of infant formula at 13 mo (energy adjusted), per 100 mL	-0.14 (-0.16, -0.13)	<0.01	-0.14 (-0.16, -0.13)	<0.01
Timing of introduction of solids				
≥6 mo	Reference		Reference	
3 to <6 mo	-0.09 (-0.17, 0.00)	0.04	-0.09 (-0.17, -0.01)	0.03
<3 mo	-0.19 (-0.37, -0.01)	0.03	-0.19 (-0.36, -0.02)	0.03
Currently receiving food supplements ⁴				
No	Reference		Reference	
Yes	0.22 (0.14, 0.31)	<0.001	0.22 (0.14, 0.31)	<0.01
Picky eating at age 1.5 y				
No	Reference		Reference	
Yes	-0.24 (-0.33, -0.14)	<0.01	-0.24 (-0.37, -0.11)	<0.01
History of any food allergy at age 1 y				
No	Reference		Reference	
Yes	-0.13 (-0.34, 0.09)	0.24	—	
Television watching at age 2 y, h/d				
<1	Reference		Reference	
≥1	-0.11 (-0.20, -0.03)	<0.01	-0.13 (-0.21, -0.05)	<0.01
Sleep duration at age 2 y, h/night				
<11.5	Reference		Reference	
≥11.5	0.07 (-0.02, 0.16)	0.14	—	
Weight-for-age at 14 mo, z score	0.09 (0.02, 0.16)	0.02	0.06 (0.01, 0.10)	0.02
Height-for-age at 14 mo, z score	-0.05 (-0.09, 0.01)	0.11	—	

¹ Values are regression coefficients with 95% CIs from a linear regression analysis that included all variables mentioned in the table.

² Values are regression coefficients with 95% CIs from a linear regression analysis with stepwise backward selection with $P = 0.10$ as endpoint.

³ Variables with $P > 0.10$ in univariable analyses were not included in the multivariable model (Supplemental Table 6).

⁴ Primarily, vitamin D supplements (Supplemental Table 2), which are recommended for preschool children.

For the multivariable model presented in Table 2, similar results were obtained after excluding 1 child per twin pair or children who still consumed breast milk or a substantial amount of infant formula (results not shown). In analyses in Dutch children only, maternal smoking and alcohol use during pregnancy were no longer associated with the diet score; the effect estimates for the other determinants were similar to those in the whole group (Supplemental Table 7).

Discussion

We developed a novel food-based diet score that can be used to evaluate overall diet quality of preschool children. The diet score was applied in a large cohort of children aged 12–19 mo and showed adequate construct validity because it was positively associated with intake of nutrients considered healthy and inversely with intake of unhealthy nutrients. Furthermore, the score was associated achieving recommended nutrient intakes. The diet score was also associated with other lifestyle factors of mothers and children but not with those of the fathers.

Development and construct validity of the diet score. The components and cutoff values of the diet score were defined on the basis of several food-based dietary guidelines for preschool children. Besides the decisions on what food groups to include, no additional weights were applied. It is not plausible that all food groups have the same health impact; however, there is also not enough evidence to assign relative contributions for the different food groups to overall health (8). To control for

different levels of food intakes, we adjusted the score for energy intake. This removes part of the variation caused by differences in age and body size, partly controls for underconsumption and overconsumption, and might remove part of the measurement error in the dietary assessment (32).

As a first step in validating the diet score, we assessed its construct validity, i.e., whether the score actually measures the construct being investigated: a healthy diet. Because our diet score was based on food groups, we used nutrient intakes and achieving recommended micronutrient intakes as alternative measures of healthy diet to assess construct validity. The diet score was positively associated with the intake of healthy nutrients, such as dietary fiber, PUFAs, and vitamins. Exceptions were iron and total folate, which were not significantly associated with the diet score at the age of 13 mo. This might be explained by the fact that many products for young children (e.g., biscuits and infant cereals) are fortified with folic acid and iron. Most of these products are not included in the diet score because of their high sugar content and/or because they are low in dietary fiber. Indeed, the diet score was positively associated with naturally present folate but inversely with added folic acid (Table 1). The lack of an association between the score and iron intake might also be caused by the contribution of fat meat products to iron intake in the children's diets. In the diets of the 13-mo-old children, the diet score was also inversely related to intakes of nutrients that are generally available in high amounts in infant formula or breast milk, such as vitamins D and E and zinc. After adjusting for intake of formula or after excluding children who still consumed breast milk or large amounts of

formula, associations between the diet score and these nutrients became positive, both for continuous nutrient intakes and for achieving recommended intakes. This indicates that our diet score is a good indicator of a healthy overall diet when one does not consider intake of breast milk or infant formula, which is no longer specifically recommended after the age of 1 y.

As expected, the score was inversely associated with the intake of monosaccharides and disaccharides and with saturated fat. However, the diet score was positively associated with sodium intake. A potential explanation could be that many healthy food items are still rich in sodium (e.g., whole bread, canned vegetables, or fish). Also, FFQs are limited in estimating sodium intake and our FFQ did not include items on added salt (i.e., during cooking or during consumption of a meal). Therefore, our estimates of sodium intake should be interpreted with caution. Overall, of the 29 examined foods and nutrients, 26 showed associations in the expected direction, indicating that the diet score showed adequate construct validity. We aim to evaluate the predictive validity of the score for later health, growth, and development in future studies.

Sociodemographic and lifestyle determinants. The mean diet score in our study population at the age of 13 mo was 4.1 ± 1.3 , on a theoretical scale from 0 to 10, indicating that diet quality could be improved. We investigated the associations with several sociodemographic and lifestyle factors to identify potential determinants of diet quality. In our sample, boys had a slightly higher diet score than girls, whereas previous studies observed better diet quality in girls [reviewed by Smithers et al. (49)]. Turkish and Surinamese/Antillean, but not Moroccan children, had a lower diet score than children with a Western ethnicity. However, our FFQ was constructed and validated for Dutch children, which means that dietary intakes might be less accurately assessed in non-Dutch ethnicities.

Previous studies have shown that as children get older, diet quality tends to decrease (13, 17, 50, 51), which might be explained by parents' lower levels of control over the diets of their school-going children (17). In our group of young children, age was not strongly associated with the diet score; and within the subgroup of children of whom dietary data were available at 2 time points, the diet score increased between the age of 13 and 25 mo. This increase in diet quality can be explained by the increase in consumption of normal table foods and decrease in formula and toddler foods: in a subgroup of children who had dietary data available at both 13 and 25 mo of age and who did not receive infant formula or breast milk at either time point ($n = 259$), mean diet score was the same at both time points (4.8 ± 1.3).

As expected, a higher diet score was associated with health-conscious behaviors, including no maternal smoking during pregnancy, folic acid supplement use in early pregnancy, maternal fiber intake, exclusive breastfeeding, food supplement use, and children spending less time watching television. These associations were significant after adjustment for sociodemographic variables. As expected, children who were picky eaters had a lower diet quality score than children who were not. Interestingly, children with 2 or more older siblings had a lower diet score than children who were their mother's firstborns. This is in line with results from previous studies in young children in which a poorer diet quality was observed in children with more siblings (52, 53). Parents who have more children might be less strict with controlling the diets of their children. Also, children with older siblings might be exposed to more unhealthy food products through their older brothers or sisters.

Strengths and limitations. Because individuals do not consume single nutrients or foods but combinations of food items, intakes of nutrients are correlated and their function and metabolism may interact (6, 7). An advantage of using a diet score is that it takes these interrelations into account (54). Also, studying this diet score in relation to health outcomes could facilitate future development of food-based dietary guidelines for this age group. Moreover, the score provides an overall measure of a healthy diet, which can be useful as a potential covariate in epidemiologic studies on other nutrition and lifestyle factors (6). A limitation of using diet scores is that there is no general consensus on what constitutes a healthy diet; therefore, there are differences in the components and cutoffs among diet scores (7). We based our score on current guidelines and scientific literature, but we were limited by the scarcity of quantitative food-based dietary guidelines for young children, a problem that has been acknowledged before (4).

We evaluated the diet score in a large multiethnic group of children from The Netherlands with an age range between 12 and 19 mo and in a smaller subgroup of Dutch children between 24 and 28 mo of age. In this population, the score had good construct validity for intake of nutrients, especially for children who no longer receive large amounts of infant formula or breast milk. Because breastfeeding and infant formula intake are no longer recommended in the guidelines and therefore not included in the diet score, the score will be lower in children who consume a substantial amount of breast milk or formula. This should be taken into account when applying the diet score in subsequent studies. Future studies should examine whether our diet score can also be used for slightly older preschool children and in other populations and countries.

Of all mothers who received the FFQ, 72% returned the questionnaire. Mothers who returned the questionnaire were generally higher educated and had a more healthy lifestyle. This selection toward a more healthy population may have underestimated true associations of sociodemographic and unhealthy lifestyle factors with the diet score. The FFQ was sent to Dutch-speaking mothers only, but with different ethnic backgrounds. A limitation is that this FFQ was only validated for Dutch children (19). However, sensitivity analyses restricted to Dutch children revealed similar results, indicating that in our analyses no large bias because of ethnicity was present. Another limitation of FFQs, in general, is that they rely on memory, and reported food intakes are subject to substantial measurement error (32). By adjusting for total energy intake, we aimed to reduce the measurement error (32, 55). Validation of our FFQ against three 24-h recalls showed intraclass correlation coefficients for nutrient intakes from 0.36 to 0.74. These are not optimal but are in line with coefficients obtained in other validation studies of dietary measurements (56). Unfortunately, we were not able to validate our FFQ against energy or protein intake assessed with doubly labeled water or 24-h urine nitrogen (32).

An advantage of using predefined diet scores is that they better reflect an actual healthy diet and may better predict health outcomes than data-driven dietary patterns. In our population, the diet score was positively associated with adherence to a previously identified health-conscious data-driven dietary pattern and inversely with a Western dietary pattern (19). Future studies are needed to explore whether the predefined diet score can better predict growth, health, and disease outcomes in children than the a posteriori defined dietary patterns.

Conclusion. Our diet score for preschool children is positively associated with intakes of healthy nutrients and inversely

associated with intakes of unhealthy nutrients in a population of 12–19-mo-old children and in a subgroup of 24–28-mo-old children. The diet score was also associated with several other maternal and child lifestyle factors. The diet score can be a useful instrument for evaluating overall diet quality in preschool children. Furthermore, this diet score can be used in future studies that investigate the associations between childhood diet and health outcomes.

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