Public Health Nutrition: 21(12), 2320–2328 doi:10.1017/S1368980018000769

Breast-feeding duration and child eating characteristics in relation to later vegetable intake in 2–6-year-old children in ten studies throughout Europe

Victoire WT de Wild[1,*], Gerry Jager[1], Annemarie Olsen[2], Vassiliki Costarelli[3], Eric Boer[4,5] and Gertrude G Zeinstra[6]

[1]Division of Human Nutrition, Wageningen University & Research, PO Box 17, 6700 AA Wageningen, The Netherlands: [2]Department of Food Science, University of Copenhagen, Copenhagen, Denmark: [3]Department of Home Economics and Ecology, Harokopio University of Athens, Athens, Greece: [4]Biometris, Wageningen University & Research, Wageningen, The Netherlands: [5]Food Informatics, Wageningen Food & Biobased Research, Wageningen, The Netherlands: [6]Consumer Science & Health, Wageningen Food & Biobased Research, Wageningen, The Netherlands

Submitted 24 October 2017: Final revision received 11 January 2018: Accepted 2 March 2018: First published online 10 April 2018

Abstract

Objective: Breast-feeding is thought to facilitate young children's acceptance of new foods, including vegetables, but the evidence for this relationship appears inconsistent across studies. Increasing children's vegetable intake remains challenging; therefore the present study aimed to investigate whether breast-feeding duration predicts vegetable intake in 2–6-year-old children.

Design: Actual vegetable intake was measured in studies across three European countries. General linear model analyses with breast-feeding duration, sex and age of the child and maternal education as variables were used to predict children's vegetable intake per country. Additionally, the relationships between child eating behaviour characteristics (asked through the Child Eating Behaviour Questionnaire) and vegetable intake were investigated via Pearson correlations.

Setting: Daycare centres, schools and home settings in Denmark, Greece and the Netherlands.

Subjects: Children aged 2–6 years (n 750).

Results: Breast-feeding duration was positively associated with children's vegetable intake at 2–6 years old in Denmark ($P<0·01$) and the Netherlands ($P<0·05$), but not in Greece ($P=0·17$). Age of the child, maternal education and sex of the child did not predict vegetable intake in our sample. All countries showed an inverse relationship between food neophobia and children's vegetable intake and a positive relationship between vegetable liking and intake.

Conclusions: The present study found that breast-feeding duration is a predictor of later vegetable intake, but that current child eating behaviour characteristics, such as vegetable liking, food neophobia and enjoyment of food, also influence vegetable intake. Besides encouragement of breast-feeding duration, strategies that support vegetable liking and food enjoyment and decrease food neophobia are needed to support young children's vegetable intake.

Keywords
Breast-feeding duration
Actual vegetable consumption
Child (eating) characteristics
EU programme HabEat
Real-life data

According to the WHO guidelines, breast-feeding offers optimal nutrition for an infant and exclusive breast-feeding is recommended for the first 6 months of life[1]. Research has shown that breast-feeding may have additional advantages; breast-fed children are more likely than formula-fed children to accept novel tastes, including vegetables, later in life[2–8]. However, not all studies show evidence for this relationship[9–11]. The relationship between breast-feeding history and vegetable consumption later in life is particularly relevant because a high vegetable intake is associated with a reduced risk of multiple diseases such as diabetes, CVD and some types of cancer[11–15]. Nevertheless, children's vegetable intake is far below that recommended in many countries[16–19] and previous studies have shown that increasing children's vegetable intake is a challenging task[19–22]. Therefore, it is

*Corresponding author: Email Victoire.dewild@wur.nl

important to investigate whether breast-feeding indeed has the potential to influence children's vegetable intake at a later age.

The majority of studies investigating the relationship between breast-feeding history and later vegetable consumption are cohort studies involving retrospective research, meaning that children's vegetable consumption measures are based on FFQ completed by parents/carers about a previous period. These self-reported data can cause an information bias, leading to over- or under-reporting of the child's actual vegetable consumption. Using actual intake data is more reliable. Such data have been collected in the EU research programme HabEat, which examined how food habits are formed in infants and young children with a focus on fruits and vegetables. Within this project, ten intervention studies were performed in three European countries[23–25]. All these studies aimed to increase vegetable intake in 2–6-year-old children and investigated the effectiveness of different strategies, such as imitation of a child idol or a teacher, choice-offering, involving the children in vegetable preparation and repeated exposure in combination with sensory variation, taking individual child and parental characteristics into account.

In the present study, data for 750 children aged between 2 and 6 years from Denmark, Greece and the Netherlands were collated and analysed. The main objective was to investigate whether breast-feeding duration, with maternal education and age and sex of the child as covariates, predicts vegetable intake during an eating session in 2–6-year-old children. As the secondary objective, we investigated whether child eating behaviour characteristics such as vegetable liking, food neophobia, enjoyment of food, food fussiness, satiety responsiveness and food responsiveness correlate with children's vegetable consumption.

Materials and methods

Participants

The analyses were based on data from ten experimental studies involving 2–6-year-old children, performed between 2011 and 2014 at four institutions in three countries: Denmark (two studies), Greece (three studies) and the Netherlands (five studies). The studies were performed in naturalistic settings such as daycare centres, primary schools, the home environment and a restaurant. Target vegetables used in the studies were carrots, Chinese radishes, sugar snaps, corn, cucumbers, tomatoes, peas, green beans, broccoli, cauliflower and string beans. Vegetables were served as a snack, or at lunch or dinner time. All studies were conducted according to the guidelines laid down in the Declaration of Helsinki and written parental informed consent was provided by the parents for all participating children in the three countries.

Vegetable intake

Vegetable intake was measured before and after the intervention and during the intervention sessions. An overview of the design of each study is shown in Table 1. Intake during the first session of the target vegetable was used as main outcome measure for the present analyses. This initial vegetable intake was used as the dependent variable in the current data analyses. Hereafter, we refer to baseline or first exposure intake as 'initial vegetable intake'. Intake in grams was calculated by pre- and post-weighing the servings and subtracting leftovers from the offered portion. In all experiments, children were offered a portion of 100 g of vegetables, except for two Dutch studies which offered 130 g and 150 g, respectively. Therefore, initial vegetable intake was converted to a ratio measure (100 %) to compare the data from all ten studies.

Demographic variables

Before the start of each study, parents completed questionnaires at home on demographics and child eating behaviour characteristics. Parents reported their child's date of birth, sex, weight and height, and maternal educational level. Child BMI (BMI *Z*-scores) were calculated using the WHO anthropometric calculator[26]. For comparison and consistency reasons and to ensure similar categories, maternal education level was rescaled from a six- or seven-category scale to a three-category scale: low, middle and high ('low' is primary and/or secondary school; 'middle' is vocational education; 'high' is higher vocational education and/or university degree).

Child eating behaviour characteristics

Breast-feeding history was assessed via two questions: 'breast-fed yes/no' and 'duration of breast-feeding'. Breast-feeding duration was ascertained in weeks, except in the Greek sample, where seven categories were used (i.e. '0 = no bf, '1 = < 1 week bf', '2 = 1–4 weeks bf', '3 = 1–3 months bf', '4 = 3–6 months bf', '5 = 6–9 months bf', '6 = 9–12 months bf' and '7 = > 12 months bf'), which were rescaled to weeks, taking the midpoint of the range as acutal duration. In addition, parents were asked to report their child's vegetable liking on a 5-point scale ranging from '1 = totally dislikes' to '5 = totally likes'. In Greece, vegetable liking was scored on a 7-point scale and consequently rescaled to a 5-point scale for comparison reasons. To assess the child's eating behaviour, parents completed the seven dimensions of the validated Child Eating Behaviour Questionnaire (CEBQ)[27] and the six-item version of the Food Neophobia Scale for Children (CFNS)[28,29]. For the current data analyses, we used four dimensions of the CEBQ: food fussiness (FF; six items), satiety responsiveness (SR; five items), food responsiveness (FR; five items) and enjoyment of food (EF; four items). Items were scored on a 5-point scale ranging from '1 = never' to '5 = always' and averaged across the items.

https://doi.org/10.1017/S1368980018000769 Published online by Cambridge University Press

Table 1 Overview of the designs of the ten studies performed in three countries (Denmark (DK), Greece (GR) and the Netherlands (NL)) within the European HabEat project, with vegetable intake as main outcome, 2011–2014

Experiment strategy	Country (no. of studies)	Age (years)	Setting	Timing	Design (no. of children)	Product	No. of exposures (portion)
Repeated exposure + sensory variation	DK (1)	3–5	Kindergarten	Afternoon snack, 14.00 hours	Between-subject (111)	Raw: Chinese radish sticks or triangles or grated	7× (100 g)
	NL (1)	4–6	Primary school	Morning snack, 10.00–10.30 hours	Between-subject (54)	Raw: carrot sticks and slices	10× (100 g)
Imitation teacher + idol	GR (2)	3–5	Nursery	Before lunchtime, 11.00 hours	Between-subject (167)	Raw: carrot sticks	8× (100 g)
	NL (2)	4–6	Primary school	Morning snack, 10.00–10.30 hours	Between-subject (177)	Raw: carrots	8× (100 g)
Choice	DK (1)	3–5	Kindergarten	Afternoon snack, 14.00 hours	Within-subject (33)	Raw: sugar snaps, carrots, baby corn	6× (100 g)
	GR (1)	3–5	Nursery	Before lunchtime, 11.00 hours	Within-subject (46)	Raw: cucumber, tomato, carrot	6× (100 g)
	NL (1)	2–6	At home	Main meal 'dinner', 18.00 hours	Between-subject (67)	Cooked: peas, carrots, broccoli, green beans, cauliflower, string beans	12× (100–150 g)
Self-prepare	NL (1)	4–6	Restaurant	Main meal 'dinner', 18.00 hours	Between-subject (95)	Cooked: carrots, green beans	4× (130 g)

Higher scores correspond with a stronger expression of the characteristic. The six statements of the CFNS were scored on a 5-point scale from '1 = strongly disagree' to '5 = strongly agree' and averaged across the items. Higher scores indicate stronger food neophobia. In total, data for 1107 children were initially included in the data set. Excluding children with missing data for breast-feeding history (*n* 273) and/or initial vegetable intake (*n* 161) resulted in data of 750 children included for statistical analyses.

Statistics

Data analysis

The statistical software package IBM SPSS Statistics version 22 was used to analyse the data. The α level for significance was set at $P < 0.05$. The assumption of normal distribution of the data was met for some variables, but not for all. Therefore, we did run logistic regression and non-parametric tests (Kruskal–Wallis, Mann–Whitney tests and Spearman) besides the parametric tests. Because these yielded similar results as the parametric tests, the parametric results (ANOVA and Pearson's correlation) are reported. Means per country were calculated to investigate potential differences between the countries in initial vegetable intake, demographics and eating behaviour characteristics. Differences between the countries regarding age, BMI *Z*-score, vegetable liking and the children's eating characteristics were examined using ANOVA with the Tukey *post hoc* test. Differences between the countries in sex distribution, percentages of children who were breast-fed (yes/no) and maternal education were analysed by using χ^2 tests.

Modelling intake by breast-feeding duration

The child's initial vegetable intake was modelled per country by using breast-feeding duration, age of the child, sex of the child and maternal education as predictor variables. Apart from breast-feeding duration, maternal education, age of the child and sex of the child were included in the model as separate factors (covariates), on the assumption that age and sex are related to children's vegetable intake (e.g. older children eat more, as do boys) but are causally unrelated to breast-feeding duration[17–19,30]. Maternal education is a possible confounding factor and therefore included in our model[31,32]. We used general linear model analyses to predict vegetable intake.

Vegetable liking is also known to be related to vegetable intake[10]. Apart from a direct effect on intake, vegetable liking may be connected to vegetable intake indirectly, via breast-feeding duration, i.e. that breast-fed children are more likely to accept novel tastes. For this reason, it is difficult to disentangle the effects of breast-feeding duration and vegetable liking on vegetable intake. Therefore, vegetable liking was not included in the main model, but was taken into account together with other

factors that are thought to be associated with vegetable intake, such as child eating behaviour characteristics. Pearson correlation coefficients were calculated to examine the relationships between these factors.

Results

Demographic variables

Table 2 describes the characteristics of the study sample overall and per country.

No significant differences between the three countries were found for sex of the child ($P > 0{\cdot}3$) and maternal education ($P > 0{\cdot}1$). The distribution of maternal education showed a high percentage of the highest level of education overall and per country (see Table 2). Significant differences between countries were found for age ($P < 0{\cdot}001$) and BMI *Z*-score ($P < 0{\cdot}001$). Dutch children were on average 4·5–6·5 months older than Danish children and Greek children. BMI *Z*-score was lower in the Netherlands compared with children in Greece ($P < 0{\cdot}001$). BMI *Z*-score did not differ significantly between Denmark and the other two countries (see Table 2).

Child eating behaviour characteristics

A significant difference between the three countries was found for the percentage of children being breast-fed ($P < 0{\cdot}001$). In the Danish population, the percentage of mothers who initiated breast-feeding was higher (94·4 %) than in Greece (83·0 %) and the Netherlands (77·6 %). Also, breast-feeding duration differed significantly between the three countries ($P < 0{\cdot}001$). Danish children were breast-fed significantly longer than Dutch and Greek children, respectively 41·1 (SD 20·8) weeks, 20·7 (SD 21·2) weeks and 15·2 (SD 15·4) weeks (all $P < 0{\cdot}001$). Greek children scored higher on vegetable liking than Dutch and Danish children ($P < 0{\cdot}001$) with a mean score of 3·9 (SD 1·0) *v.* 3·4 (SD 1·3; $P < 0{\cdot}001$) and 3·2 (SD 1·7; $P = 0{\cdot}01$), respectively. Danish children were less neophobic (2·7 (SD 0·8)) than Dutch and Greek children (both 3·1; $P < 0{\cdot}001$; see Table 2).

Differences between the countries were also observed for food enjoyment ($P < 0{\cdot}001$), satiety responsiveness ($P = 0{\cdot}01$) and food fussiness ($P < 0{\cdot}001$), see Table 2 for scores. No significant differences ($P > 0{\cdot}1$) were found for food responsiveness. Overall, we noticed significant differences between the countries for most variables, indicating heterogeneous sample populations in the different countries. Consequently, the model to predict vegetable intake was run per country.

Modelling vegetable intake at age 2–6 years old by breast-feeding duration

Table 3 shows the significant predictors of initial vegetable intake per country. Breast-feeding duration was a significant predictor in Denmark ($B_{BF} = 0{\cdot}35$; $P = 0{\cdot}005$) and the Netherlands ($B_{BF} = 0{\cdot}18$; $P = 0{\cdot}047$), where a longer

Table 2 Characteristics of the study participants, overall and per country, from the ten studies performed in three countries within the European HabEat project, 2011–2014

	All		Denmark		Greece		The Netherlands		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P* value
Age (months)	54·9	9·9	53·1[a]	9·7	51·2[a]	5·8	57·6[b]	10·9	$F_{(2,744)} = 34{\cdot}9$; $P < 0{\cdot}001$
n	747		143		213		391		
BMI *Z*-score	−0·006	1·4	0·02[a,b]	1·1	0·30[b]	1·6	−0·20[a]	1·3	$F_{(2,670)} = 8{\cdot}7$; $P < 0{\cdot}001$
n	673		121		208		344		
Girls (%)	47·8		47·9		43·7		50·0		$P > 0{\cdot}3$
n	750		144		213		393		
Maternal education (%)									
1 = low	9		14		8		7		$P > 0{\cdot}1$
2 = middle	29		32		29		28		
3 = high	62		54		63		65		
n	730		140		204		386		
Breast-feeding (% yes)	82·4		94·4		83·0		77·6		$\chi^2_{(2)} = 20{\cdot}7$; $P < 0{\cdot}001$
n	750		144		213		393		
Breast-feeding duration (weeks)	23·1	21·6	41·1[c]	20·8	15·2[a]	15·4	20·7[b]	21·2	$F_{(2,747)} = 80{\cdot}1$; $P < 0{\cdot}001$
n	750		144		213		393		
Child food neophobia (5-point scale)	3·0	1·0	2·7[a]	0·8	3·1[b]	0·8	3·1[b]	1·1	$F_{(2,703)} = 9{\cdot}3$; $P < 0{\cdot}001$
n	706		111		202		393		
Vegetable liking (5-point scale)	3·5	1·3	3·2[a]	1·7	3·9[b]	1·0	3·4[a]	1·3	$F_{(2,613)} = 13{\cdot}9$; $P < 0{\cdot}001$
n	616		113		199		304		
Food fussiness (5-point scale)	3·0	0·9	2·7[a]	0·8	3·0[b]	0·9	3·1[b]	0·8	$F_{(2,737)} = 9{\cdot}5$; $P < 0{\cdot}001$
n	736		144		300		392		
Enjoyment of food (5-point scale)	3·5	0·7	3·7[b]	0·7	3·7[b]	0·8	3·4[a]	0·7	$F_{(2,743)} = 14{\cdot}4$; $P < 0{\cdot}001$
n	746		144		210		392		
Satiety responsiveness (5-point scale)	3·1	0·7	3·1[a,b]	0·7	3·2[b]	0·7	3·0[a]	0·7	$F_{(2,741)} = 3{\cdot}1$; $P = 0{\cdot}01$
n	744		144		208		392		
Food responsiveness (5-point scale)	2·2	0·7	2·2	0·8	2·3	0·7	2·2	0·7	$P > 0{\cdot}1$
n	742		144		206		392		

[a,b,c]Mean values within a row with unlike superscript letters were significantly different ($P < 0{\cdot}05$).

https://doi.org/10.1017/S1368980018000769 Published online by Cambridge University Press

Table 3 Regression coefficients (*B*) and their standard errors for breast-feeding (weeks), age of the child (months), maternal education and sex of the child, per country, in predicting later vegetable intake (grams) among 2–6-year-old children in the ten studies performed in three countries within the European HabEat project, 2011–2014

	Denmark (*n* 139)	Greece (*n* 204)	The Netherlands (*n* 384)
Breast-feeding			
B	0·35	0·21	0·18
SE	0·12	0·15	0·09
P	0·005	0·17	0·047
Age			
B	−0·05	−0·16	−0·01
SE	0·26	0·40	0·17
P	0·84	0·69	0·98
Maternal education*			
B_{low}	−1·85	1·80	−9·71
SE	7·74	8·83	7·31
P	0·81	0·84	0·19
B_{middle}	−1·30	−6·48	−4·70
SE	5·77	5·25	4·21
P	0·82	0·22	0·26
Sex†			
B_{boys}	8·92	6·15	5·08
SE	5·15	4·70	3·67
P	0·09	0·19	0·17

*Reference is high education.
†Reference is girls.

Table 4 Pearson's correlations (*r*) between child (eating behaviour) characteristics and initial vegetable intake, per country, among 2–6-year-old children in the ten studies performed in three countries within the European HabEat project, 2011–2014

	Denmark	Greece	The Netherlands
Age (months)	0·008	−0·004	−0·001
P	0·93	0·95	0·98
n	143	213	391
BMI *Z*-score	0·13	0·03	0·06
P	0·15	0·70	0·24
n	121	208	344
Child food neophobia	−0·31	−0·19	−0·27
P	0·001	0·006	<0·001
n	111	202	393
Vegetable liking	0·30	0·43	0·33
P	0·001	<0·001	<0·001
n	113	204	393
Food fussiness	−0·09	−0·09	0·23
P	0·27	0·22	<0·001
n	144	204	392
Enjoyment of food	0·11	0·09	0·20
P	0·2	0·18	<0·001
n	144	210	392
Satiety responsiveness	0·04	−0·01	−0·07
P	0·64	0·91	0·18
n	144	208	392
Food responsiveness	0·12	−0·05	0·08
P	0·14	0·49	0·1
n	144	206	392

breast-feeding duration predicted a higher initial vegetable intake, but not in Greece ($P=0·17$). Age of the child and maternal education were not significant predictors of initial vegetable intake in any of the three countries. Sex of the child was a marginal predictor ($B_{boys}=8·92$; $P=0·09$) for children's initial vegetable intake in Denmark only.

The outcome of the Danish model implies that each additional week of breast-feeding duration resulted in an increase in vegetable consumption of 0·35 g (see beta coefficients in Table 3). Hence, a child who had been breast-fed for 1 year (52 weeks) ate on average 18 g more vegetables than a child who had not been breast-fed. For the Netherlands, the model showed an increase of 0·18 g of vegetable intake for each additional week of breast-feeding, indicating that Dutch children who had been breast-fed for 1 year ate 9 g more vegetables than Dutch children who had not been breast-fed.

Correlations

Table 4 shows the Pearson correlations representing the relationship between initial vegetable intake and child (eating behaviour) characteristics per country. There was no significant relationship between intake and age, or between intake and BMI *Z*-score, for any country (see Table 4). Neither were satiety responsiveness and food responsiveness correlated with vegetable intake in any of the three countries. All countries showed an inverse relationship between food neophobia and children's vegetable intake (respectively in Denmark, Greece and the Netherlands with a Pearson correlation of −0·31, −0·19 and −0·27; all $P<0·01$) and a moderately strong correlation between vegetable liking and intake (respectively, 0·30, 0·43 and 0·33; $P<0·01$). Food fussiness was positively correlated with children's vegetable intake only in the Netherlands ($P<0·001$) and enjoyment of food was positively correlated with children's vegetable intake also only in the Netherlands ($P<0·001$).

These results indicate that children with a higher vegetable liking ate more vegetables, and more neophobic children had a lower initial vegetable intake, as did children with higher scores on food fussiness (the Netherlands). Furthermore, Dutch children who enjoyed food more had a higher initial vegetable intake.

Discussion

The aim of the current study was to investigate whether breast-feeding duration has the potential to influence vegetable intake at age 2–6 years. Breast-feeding duration was positively associated with later vegetable intake during an eating session at a later age in Denmark and the Netherlands, but not in Greece. Children who were breast-fed for a longer period consumed more vegetables. We noticed differences in the outcome of this relationship across and between the countries. Overall, this indicates that the relationship between breast-feeding duration and later vegetable intake exists but is not straightforward. Age of the child, maternal education and sex of the child did not predict vegetable intake in our sample.

https://doi.org/10.1017/S1368980018000769 Published online by Cambridge University Press

The mixed findings across European countries found in the current study are in line with other HabEat research that reported mixed findings on the relationship between breast-feeding and vegetable intake across four European cohorts[33]. For vegetables, a positive relationship was found for children breast-fed for 3–6 months (*v.* never breast-fed) in France and the UK, but the association was not significant in Greece and Portugal. One possible explanation for these country differences is the way vegetable intake was measured. Each country used its own FFQ to assess the children's diet, which differed in the number of questions asked to assess vegetable consumption. They used as the main outcome whether a child did or did not reach a certain eating frequency of vegetables per day. In our study, vegetable intake was measured in the same way across the studies and reflected actual vegetable intake in grams. Consequently, this could not have biased our outcome, and therefore it is less likely that this has affected the differences that we found across the countries. However, it is important to note that vegetable intake in our study reflects intake of a particular vegetable during an eating session at a given day, which is indicative of a child's vegetable eating habits (usual intake) but not fully representative. Still, recent research showed that children – who were good vegetable eaters according to their parents – also had a higher intake of three different vegetables at the pre-test of an experiment[34].

In contrast to our study, Cooke *et al.* did not find a significant relationship between breast-feeding and vegetable consumption among 2–6-year-olds in the UK; breast-feeding ('breast-fed only' or 'breast- and bottle-fed') was a significant predictor of children's fruit intake compared with bottle-fed children, but this was not the case for vegetable intake[10]. In Cooke's study, other factors such as sex, enjoyment of food, food neophobia and parental intake played a role in children's vegetable intake. A very similar study to ours within the HabEat programme was that by Caton *et al.*, where vegetable intake was also actually measured during experiments performed in Denmark, France, the Netherlands and the UK. They reported that child eating behaviour characteristics were significant predictors of initial vegetable intake: younger children who enjoyed food more and scored lower on satiety responsiveness consumed more vegetables[9]. Additionally, their results showed that younger children were less fussy, enjoyed food more and had lower satiety responsiveness, characteristics which contributed to increased acceptance of a novel food (i.e. artichoke purée). Contrary to our results, breast-feeding duration did not influence initial vegetable intake in their study. Differences in the definition of breast-feeding duration between the studies could have mediated or confounded the effect. Caton *et al.* defined breast-feeding duration as the period of exclusive breast-feeding (i.e. until formula or food was introduced), whereas in our study breast-feeding duration was defined as the total period of any breast-feeding. Our study showed that child eating behaviour characteristics such as food neophobia, food fussiness, enjoyment of food and vegetable liking were also associated with vegetable intake. Children who were more neophobic and food fussy had a lower initial vegetable intake, whereas children who enjoyed food more and liked vegetables more had a higher vegetable intake, which is in line with previous studies reporting this[10,29,35]. All these studies point to the fact that, besides breast-feeding, other factors such as child eating behaviour characteristics seem to play a role in predicting later vegetable intake and these need to be taken into account.

There are several explanations for the observed differences in the effect of breast-feeding duration on children's vegetable intake across the three European countries. First, the observed differences between the countries are likely mediated by breast-feeding practices; average breast-feeding duration was longest in Denmark, followed by the Netherlands and then Greece. Differences and variations in breast-feeding duration between the countries can be in part explained by cultural and social aspects. To illustrate this: women in Denmark typically take 9–12 months' maternity leave, whereas Greek and Dutch policies prescribe shorter maternity leave, for a period of 17 and 16 weeks respectively. Once mothers are back to work, it may be more difficult for them to continue breast-feeding.

Second, the relationship between breast-feeding and vegetable consumption is complex. Research has shown that flavours like carrot, garlic, vanilla, ethanol and nicotine transfer via breast milk to the infant[4,36–41]. However, whether other flavours are also transferred via breast milk is less clear. The positive effect of breast-feeding may also be related to the continuous variation in mothers' milk concerning flavour diversity and intensity, because of mothers' dietary variety. Therefore, it is likely that the maternal diet facilitates the offspring's reaction to flavours via experience through breast-feeding[6]. Correspondingly, variety in a child's diet early in life seems to improve acceptance of new foods. Maier *et al.* emphasized that the combination of breast-feeding and a high variety was most effective in increasing intake of new foods, including vegetables, directly after weaning, 2 months later and at 6 years[3,42]. Although Lange *et al.* did not find an effect of exclusive breast-feeding on higher acceptance of new foods in general, the effect was significant for acceptance of vegetables[43]. Both studies stress the importance of offering variety early in life in combination with breast-feeding as powerful mechanisms for later vegetable acceptance.

A third possible explanation is that, as children get older, other aspects become more important for vegetable intake and start to overrule an early effect of breast-feeding duration on later vegetable intake. An example of such a factor could be food neophobia that develops around the age of 2 years and commonly peaks between 2 and 6 years of age[44,45]. Although the present study did

not show that age of the child was a predictor of children's vegetable intake, we know that during the period of 2–6 years, eating behaviour can be influenced by many different emerging factors such as peer pressure and more foods/meals provided out of the home. Enjoyment of food, availability and parental vegetable intake are also considered important factors regarding children's vegetable intake that may overrule the effect of breast-feeding[10,46,47]. Finally, cultural differences in timing and type of complementary feeding practices may have contributed to the differences found between countries in the present study.

Strengths of the current study are that the data used in the analyses were based on actual vegetable intake, that data were collected in a similar way across studies and that all experiments were conducted in a naturalistic setting. To our knowledge, Caton *et al.*'s recent study is the only other example where actual vegetable intake in relation to breast-feeding was investigated based on different experiments[9]. Most studies are based on self-reported and/or retrospective data on vegetable consumption in which FFQ or recalls are used, often only asking for frequency or servings per day, but these are not the most precise instruments to assess vegetable consumption[2,7,10,33,48].

Limitations of the present study include the self-reported information about breast-feeding history in a retrospective way, which may not be as accurate as prospective report. However, maternal recall of breast-feeding is generally considered to be reliable when breast-feeding is recalled after a short period of ≤3 years[49]. The recall period in the current study ranged from 2 to 6 years depending on the age of the child and the duration of breast-feeding. Breast-feeding duration as reported herein was not limited to exclusive breast-feeding but referred to any breast-feeding (including breast-feeding combined with bottle-feeding or complementary feeding); therefore, the intensity and the exact quantity of the breast-feeding stays unknown. Another limitation is that in the Greek sample, breast-feeding duration was reported by using a scale representing ranges instead of using absolute numbers, which could have explained the non-association between breast-feeding duration and vegetable intake among Greek children. Another limitation is the differences in experimental setting, i.e. type of meal (snack, lunch, dinner time) and type of setting (daycare centre, primary school, home environment, restaurant), which could have affected the outcome. Due to cultural habits, childeren may be more used to consume vegetables at a certain moment of the day or in a certain environment. Furthermore, the maternal education in our sample was relatively high. It remains unclear whether the positive relationship between breast-feeding duration and vegetable intake in our study can be extrapolated to less educated populations. Future research among more diverse samples regarding education level is recommended. Additionally, 32 % of the initial sample was excluded from the analyses due to non-completed questionnaires. It is possible that non-completion occurred more frequently among lower educated participants, which could have affected our outcome. Finally, no information was collected on other maternal characteristics such as motivation to breast-feed, motivation to serve a varied diet to their infant or desire for the child's well-being in terms of a healthy diet. These characteristics may have confounded the observed association between breast-feeding duration and initial vegetable intake.

Conclusion

To conclude, breast-feeding duration was related to children's vegetable intake during an eating session at age 2–6-years in Denmark and the Netherlands, but not in Greece. Our results further show that that a complex mix of factors such as vegetable liking and certain child eating behaviour characteristics (like food neophobia and enjoyment of food) also influence 2–6-year-old children's vegetable intake. Besides the promotion of breast-feeding, public health efforts should focus on the promotion of additional strategies such as repeated exposure and offering variety early in life as ways to stimulate children's vegetable intake, especially in countries where mothers tend to breast-feed for shorter periods. Further research should continue in this area to develop effective interventions with the aim to encourage children to eat sufficient vegetables which starts at a young age.

Acknowledgements

Acknowledgements: The authors thank all the families who participated in the studies throughout Europe. Special thanks are extended to Dr Sylvie Issanchou of the Institut National de la Recherche Agronomique (INRA), France for her advice, Dr Hendriek Boshuizen for her statistical advice and Catherine O'Dea for her contribution to the manuscript. *Financial support:* The present study was part of the HabEat programme aimed at understanding the development and key learning mechanism of food habits in young children. This research was supported by the European Community's Seventh Framework Programme (FP7/2007-2013, grant number 245012-HabEat). The European Community had no role in the design, analysis or writing of this article. *Conflict of interest:* None. *Authorship:* G.G.Z., G.J. and V.W.T.d.W. formulated the research questions; A.O., V.C., G.G.Z. and V.W.T.d.W. collected the data; E.B., G.G.Z., G.J. and V.W.T.d.W. analysed and interpreted the data; G.G.Z., G.J. and V.W.T.d.W. drafted the manuscript; all authors revised and approved the final manuscript. *Ethics of human subject participation:* This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by

the Institutional Review Boards of the local universities (Wageningen University, Wageningen, the Netherlands and the Harokopio University, Athens, Greece). The Danish experiments, which were performed by the University of Copenhagen, Denmark, did not require formal approval. Written parental informed consent was obtained from all participating children in the three countries.

References

1. World Health Organization & UNICEF (2003) *Global Strategy for Infant and Young Child Feeding*. Geneva: WHO.
2. Burnier D, Dubois L & Girard M (2011) Exclusive breastfeeding duration and later intake of vegetables in preschool children. *Eur J Clin Nutr* **65**, 196–202.
3. Maier AS, Chabanet C, Schaal B *et al.* (2008) Breastfeeding and experience with variety early in weaning increase infants' acceptance of new foods for up to two months. *Clin Nutr* **27**, 849–857.
4. Mennella JA, Jagnow CP & Beauchamp GK (2001) Prenatal and postnatal flavor learning by human infants. *Pediatrics* **107**, e88.
5. Schwartz C, Chabanet C, Boggio V *et al.* (2010) To which tastes are infants exposed during the first year of life? *Arch Pediatr* **17**, 1026–1034.
6. Hausner H, Nicklaus S, Issanchou S *et al.* (2009) Breastfeeding facilitates acceptance of a novel dietary flavour compound. *e-SPEN, Eur e-J Clin Nutr Metab* **4**, e231–e238.
7. Möller LM, de Hoog ML, van Eijsden M *et al.* (2013) Infant nutrition in relation to eating behaviour and fruit and vegetable intake at age 5 years. *Br J Nutr* **109**, 564–571.
8. Armstrong J, Abraham EC, Squair M *et al.* (2014) Exclusive breastfeeding, complementary feeding, and food choices in UK infants. *J Hum Lact* **30**, 201–208.
9. Caton SJ, Blundell P, Ahern SM *et al.* (2014) Learning to eat vegetables in early life: the role of timing, age and individual eating traits. *PLoS One* **9**, e97609.
10. Cooke LJ, Wardle J, Gibson EL *et al.* (2004) Demographic, familial and trait predictors of fruit and vegetable consumption by pre-school children. *Public Health Nutr* **7**, 295–302.
11. De Kroon ML, Renders CM, Buskermolen MP *et al.* (2011) The Terneuzen Birth Cohort. Longer exclusive breastfeeding duration is associated with leaner body mass and a healthier diet in young adulthood. *BMC Pediatr* **11**, 33.
12. Carter P, Gray LJ, Troughton J *et al.* (2010) Fruit and vegetable intake and incidence of type 2 diabetes mellitus: systematic review and meta-analysis. *BMJ* **341**, c4229.
13. Riboli E & Norat T (2003) Epidemiologic evidence of the protective effect of fruit and vegetables on cancer risk. *Am J Clin Nutr* **78**, 3 Suppl., 559S–569S.
14. Horta BL, Bahl R, Martines JC *et al.* (2007) *Evidence on the Long-term Effects of Breastfeeding: Systematic Review and Meta-Analyses*. Geneva: WHO.
15. Victora CG, Bahl R, Barros AJD *et al.* (2016) Breastfeeding in the 21st century: epidemiology, mechanisms, and lifelong effect. *Lancet* **387**, 475–490.
16. Hulshof K & Ter Doest D (2006) *De consumptie van groenten en fruit in meer detail op basis van voedselconsumptiepeilingen in Nederland* (*The Consumption of Fruit and Vegetables in More Detail on the Basis of Food Consumption Surveys in The Netherlands*). Zeist: TNO Kwaliteit van Leven.
17. Ocké M, Van Rossum C, Fransen H *et al.* (2008) *Dutch National Food Consumption Survey Young Children 2005/2006*. Bilthoven: RIVM.
18. Ocke MC, Hulshof K, Buurma-Rethans E *et al.* (2004) *Voedselconsumptiepeiling 2003: Samenvatting werkwijze en evaluatie* (*Food Consumption Survey, 2003: Summary of Procedures and Evaluation*). Bilthoven: RIVM.
19. Yngve A, Wolf A, Poortvliet E *et al.* (2005) Fruit and vegetable intake in a sample of 11-year-old children in 9 European countries: the Pro Children Cross-sectional Survey. *Ann Nutr Metab* **49**, 236–245.
20. Alexy U, Sichert-Hellert W & Kersting M (2002) Fifteen-year time trends in energy and macronutrient intake in German children and adolescents: results of the DONALD study. *Br J Nutr* **87**, 595–604.
21. Nicklaus S, Chabanet C, Boggio V *et al.* (2005) Food choices at lunch during the third year of life: increase in energy intake but decrease in variety. *Acta Paediatr* **94**, 1023–1029.
22. Zeinstra GG, Koelen MA, Kok FJ *et al.* (2009) Children's hard-wired aversion to pure vegetable tastes. A 'failed' flavour–nutrient learning study. *Appetite* **52**, 528–530.
23. de Wild VW, de Graaf C, Boshuizen HC *et al.* (2015) Influence of choice on vegetable intake in children: an in-home study. *Appetite* **91**, 1–6.
24. Zeinstra G, Kooijman V, Costarelli V *et al.* (2013) Strategies to increase vegetable consumption in 3- to 6-year-olds: theory and practice. *Ann Nutr Metab* **63**, Suppl. 1, 40.
25. Zeinstra GG, Valesca K & Kremer S (2017) My idol eats carrots, so do I? The delayed effect of a classroom-based intervention on 4–6-year-old children's intake of a familiar vegetable. *Food Qual Prefer* **62**, 352–359.
26. World Health Organization (2011) Child growth standards | WHO Anthro (version 3.2.2, January 2011) and macros. http://www.who.int/childgrowth/software/en/ (accessed March 2018).
27. Wardle J, Guthrie CA, Sanderson S *et al.* (2001) Development of the children's eating behaviour questionnaire. *J Child Psychol Psychiatry* **42**, 963–970.
28. Pliner P (1994) Development of measures of food neophobia in children. *Appetite* **23**, 147–163.
29. Cooke L, Carnell S & Wardle J (2006) Food neophobia and mealtime food consumption in 4–5 year old children. *Int J Behav Nutr Phys Act* **3**, 14.
30. Cooke LJ & Wardle J (2005) Age and gender differences in children's food preferences. *Br J Nutr* **93**, 741–746.
31. Scott JA & Binns CW (1999) Factors associated with the initiation and duration of breastfeeding: a review of the literature. *Breastfeed Rev* **7**, 5–16.
32. Gudnadottir M, Sigurdur Gunnarsson B & Thorsdottir I (2006) Effects of sociodemographic factors on adherence to breastfeeding and other important infant dietary recommendations. *Acta Paediatr* **95**, 419–424.
33. de Lauzon-Guillain B, Jones L, Oliveira A *et al.* (2013) The influence of early feeding practices on fruit and vegetable intake among preschool children in 4 European birth cohorts. *Am J Clin Nutr* **98**, 804–812.
34. Zeinstra GG, Vrijhof M & Kremer S (2018) Is repeated exposure the holy grail for increasing children's vegetable intake? Lessons learned from a Dutch childcare intervention using various vegetable preparations. *Appetite* **121**, 316–325.
35. Howard AJ, Mallan KM, Byrne R *et al.* (2012) Toddlers' food preferences. The impact of novel food exposure, maternal preferences and food neophobia. *Appetite* **59**, 818–825.
36. Mennella JA (1995) Mother's milk: a medium for early flavor experiences. *J Hum Lact* **11**, 39–45.
37. Mennella JA & Beauchamp GK (1991) The transfer of alcohol to human milk: effects on flavor and the infant's behavior. *N Engl J Med* **325**, 981–985.

38. Mennella JA & Beauchamp GK (1996) The human infants' response to vanilla flavors in mother's milk and formula. *Infant Behav Dev* **19**, 13–19.
39. Mennella JA & Beauchamp GK (1998) Smoking and the flavor of breast milk. *N Engl J Med* **339**, 1559–1560.
40. Mennella JA & Beauchamp GK (1999) Experience with a flavor in mother's milk modifies the infant's acceptance of flavored cereal. *Dev Psychobiol* **35**, 197–203.
41. Mennella JA & Beauchamp GK (2005) Understanding the origin of flavor preferences. *Chem Senses* **30**, i242–i243.
42. Maier-Noth A, Schaal B, Leathwood P *et al.* (2016) The lasting influences of early food-related variety experience: a longitudinal study of vegetable acceptance from 5 months to 6 years in two populations. *PLoS One* **11**, e0151356.
43. Lange C, Visalli M, Jacob S *et al.* (2013) Maternal feeding practices during the first year and their impact on infants' acceptance of complementary food. *Food Qual Prefer* **29**, 89–98.
44. Cashdan E (1994) A sensitive period for learning about food. *Hum Nat* **5**, 279–291.
45. Cashdan E (1998) Adaptiveness of food learning and food aversions in children. *Soc Sci Inform* **37**, 613–632.
46. Rasmussen M, Krolner R, Klepp K-I *et al.* (2006) Determinants of fruit and vegetable consumption among children and adolescents: a review of the literature. Part I: quantitative studies. *Int J Behav Nutr Phys Act* **3**, 22.
47. van der Horst K (2012) Overcoming picky eating. Eating enjoyment as a central aspect of children's eating behaviors. *Appetite* **58**, 567–574.
48. Perrine CG, Galuska DA, Thompson FE *et al.* (2014) Breastfeeding duration is associated with child diet at 6 years. *Pediatrics* **134**, Suppl. 1, S50–S55.
49. Li R, Scanlon KS & Serdula MK (2005) The validity and reliability of maternal recall of breastfeeding practice. *Nutr Rev* **63**, 103–110.