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Association between breast-feeding exposure and duration with offspring's dietary patterns over 1 year of age: a systematic review of observational studies

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Abstract

Some evidence suggests that breast-feeding may modify food preferences in the later years of life. The present study aimed to provide a systematic review of observational studies investigating the association between exposure to breast milk and its duration with data-driven or hypothesis-driven (or diet quality scores) dietary patterns over 1 year of age. The databases of PubMed, Scopus and Web of Science were searched for observational studies published from January 2010 until July 2021, which led to the identification of twenty-two eligible articles. There was considerable heterogeneity between studies in terms of assessment of exposure and outcome. Of the eleven studies that assessed data-driven dietary patterns, ten reported a significant association for at least one identified dietary pattern. Overall, being breast-fed and a longer duration of any/exclusive breast-feeding were associated with higher scores on healthy dietary patterns characterised mainly by high loadings of fruits, vegetables and whole grains. In comparison, a negative association was found for unhealthy dietary patterns rich in foods with high content of added sugar, salt and saturated fats. In terms of diet quality scores, nine out of eleven studies reported a significant positive association between the duration of any breast-feeding and adherence to recommended healthy diets or dietary guidelines. In conclusion, the evidence from this review was generally in support of the hypothesis indicating breast-feeding is associated with healthy dietary patterns at later ages. However, due to the methodological limitations in the available studies, further research is warranted to elucidate solid evidence on this topic.

Keywords: **Breast-feeding: Diet: Western dietary pattern: Principal component analysis: Healthy eating index: Prudent diet: Child**

Over the last decades, there has been a dramatic shift in the dietary patterns in children and adolescents globally toward the consumption of discretionary foods (i.e., energy-dense, nutrient-poor foods rich in added sugars, added salt, saturated fat and alcohol), while a low intake of nutrient-dense foods, particularly whole grains, fruits and vegetables[1–4]. This is particularly important since the statistics indicate that unhealthy dietary patterns are responsible for over 11 million deaths globally. Nearly half of the deaths are attributed to the three dietary factors, including high Na intake and low intake of whole grains and fruits[5]. Notably, dietary patterns established in childhood could persist during the later ages and even influence the risk of diet-related diseases in adulthood, particularly CVD[6–8]. In addition, the nutritional programming theory indicates that the intake of specific nutrients in certain quantities during the first years of life may have a long-term influence on health mainly through epigenetic mechanisms[9]. Therefore, identifying the factors that affect food preferences, particularly at an early age, is a key step in promoting healthy dietary patterns as a global public health priority.

Recently, there has been a growing interest in the contribution of early-life exposures, particularly breast-feeding, in determining long-term food preferences. Exclusive breast-feeding is the preferred method of infant feeding from birth up to 6 months, accompanied by solid foods until 2 years of age. Such a feeding pattern has been shown to provide optimal growth and reduce the risk of infections in the first years of life[10]. Besides, accumulating evidence from epidemiological studies has shown that breast-feeding is associated with a higher intake of nutrient-dense foods such as fruits and vegetables while a lower intake of discretionary foods during childhood[11–13].

It is hypothesised that breast-feeding may influence the acceptability of certain foods mainly by introducing various flavours to infants[14]. The repeated exposure to these flavours, which are transferred through the maternal diet, could modify the infant's innate inclination to sweet and savoury tastes, while a disinclination to sour and bitter tastes at birth[13,15]. Interestingly, these flavours have been shown to share some similarities in terms of molecular structure and sensory properties with flavours found in fruits and vegetables[13]. Hence, continued breast-feeding might familiarise infants with the flavours of healthy foods with less palatable tastes and facilitate their acceptance during the weaning period. In addition to the flavour experiences, another possible mechanism of

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breast-feeding in modifying food preferences might be attributed to the hormones in breast milk, particularly leptin. Leptin, an anorexigenic hormone, can pass from breast milk and be uptaken by the infant's circulatory system[16]. Evidence from animal models has demonstrated that administration of leptin orally in breast-fed infants was accompanied by lower energy intake as well as a reduced preference for high-fat foods compared with the control during the weaning period[17,18]. Thus, it raises the hypothesis that exposure to breast milk may lead to the low consumption of high-fat, energy-dense foods at later ages.

To the best of our knowledge, there is a lack of comprehensive review regarding the relationship between breast-feeding with dietary patterns during early childhood and later ages. With this regard, the present study aimed to systematically review the association between exposure to breast-feeding as well as its duration with data-driven and hypothesis-driven (diet quality scores) dietary patterns in individuals aged 1-year-old and older.

Materials and methods

The present systematic review was performed in accordance with the principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement[19]. The protocol of this report was registered at PROSPERO (PROSPERO ID: CRD42021265491). The study selection, data extraction and quality assessment were conducted by both authors, and any disagreement was settled by consensus.

Search strategy

The databases of PubMed, Scopus and Web of Science were searched for the English language documents published from January 2010 until July 2021 using the following keywords: ('Breast Feeding' OR 'breastfed') AND ('diet*' AND 'pattern*') OR ('diet* AND quality') OR ('diet*' AND 'index*') OR ('diet*' AND 'indices') OR ('diet*' AND 'score*') OR ('eating' AND 'pattern*') OR ('food' AND 'pattern*'). In addition, the bibliographies of the relevant articles were hand-searched to ensure all eligible studies have been included.

Study selection

Following the removal of the duplicates, the title and abstract of the reaming records were screened to withdraw those with irrelevant topics, conference/meeting abstracts and narrative reviews. Thereafter, the full text of the remaining articles underwent a rigorous evaluation to select those that had met the Participants, Exposure, Comparison, Outcomes and Study design (PECOS) criteria for inclusion in the review (Table 1). Studies with the following outcomes were outside the scope of this review and thus were excluded: nutrient intakes; food items/groups; eating habits, for example, breakfast consumption and meal skipping, etc.; feeding difficulties such as food neophobia and picky/fussy eating; eating disorders and combination of diet quality with non-dietary components such as physical activity.

Table 1. PECOS criteria for identification of eligible articles

Items	Criteria
Participants	Participants aged 1 year old and older. No restrictions were given based on sex and baseline health condition of participants.
Exposure(s)	(I) Exposure to any or exclusive breast-feeding (II) Duration of any or exclusive breast-feeding
Comparison(s)	(I) Never breast-feeding or formula (bottle) feeding (II) Highest *v.* lowest category of any/exclusive breast-feeding duration
Outcome(s)	(I) Data-driven dietary patterns: dietary patterns extracted using the statistical methods, for example, principal component analysis, latent class analysis or reduced rank regression (II) Hypothesis-driven dietary patterns: diet quality scores/indices that assess the adherence to established dietary recommendations or dietary guidelines.
Study design	Observational studies

Data extraction

Following data were extracted from the eligible studies: First author's surname, publication year, study location (country), population's age and sex, sample size, study design, type of exposure, the method of dietary data collection, the identified dietary patterns or the diet scores used, covariates and study outcomes. For all studies, we extracted the estimates in the fully adjusted model for confounding factors.

Quality assessment

We have adapted the criteria introduced by the Joanna Briggs Institute for qualitative assessment of bias in the methodology of included studies[20]. For the purpose of this review, we assessed the following four domains: (1) definition of inclusion criteria in the study sample; (2) validity and reliability of exposure assessment; (3) validity and reliability of outcome measurement and (4) identification of confounding factors. We did not apply scoring criteria for quality assessment since it might not accurately reflect the overall study quality. Instead, we presented a qualitative evaluation of each domain in line with the Joanna Briggs Institute recommendations.

Results

Study selection

Figure 1 provides details on literature search and study selection according to the PRISMA guideline. The search strategy yielded the extraction of 4573 records. After removing the duplicates (n 1783), screening the title and abstract of the retrieved records (n 2790) excluded 2737 not-relevant documents and one narrative review article. In addition, three articles were added through hand searching of the literature. Then, the full texts of the fifty-five remaining articles were meticulously reviewed, which led to the exclusion of further thirty-three articles due to the following reasons: (1) the outcome was the intake of food items or food groups (n 12); (2) the outcome was feeding difficulties or eating behaviours (n 11); (3) the outcome was nutrient intake (n 3);

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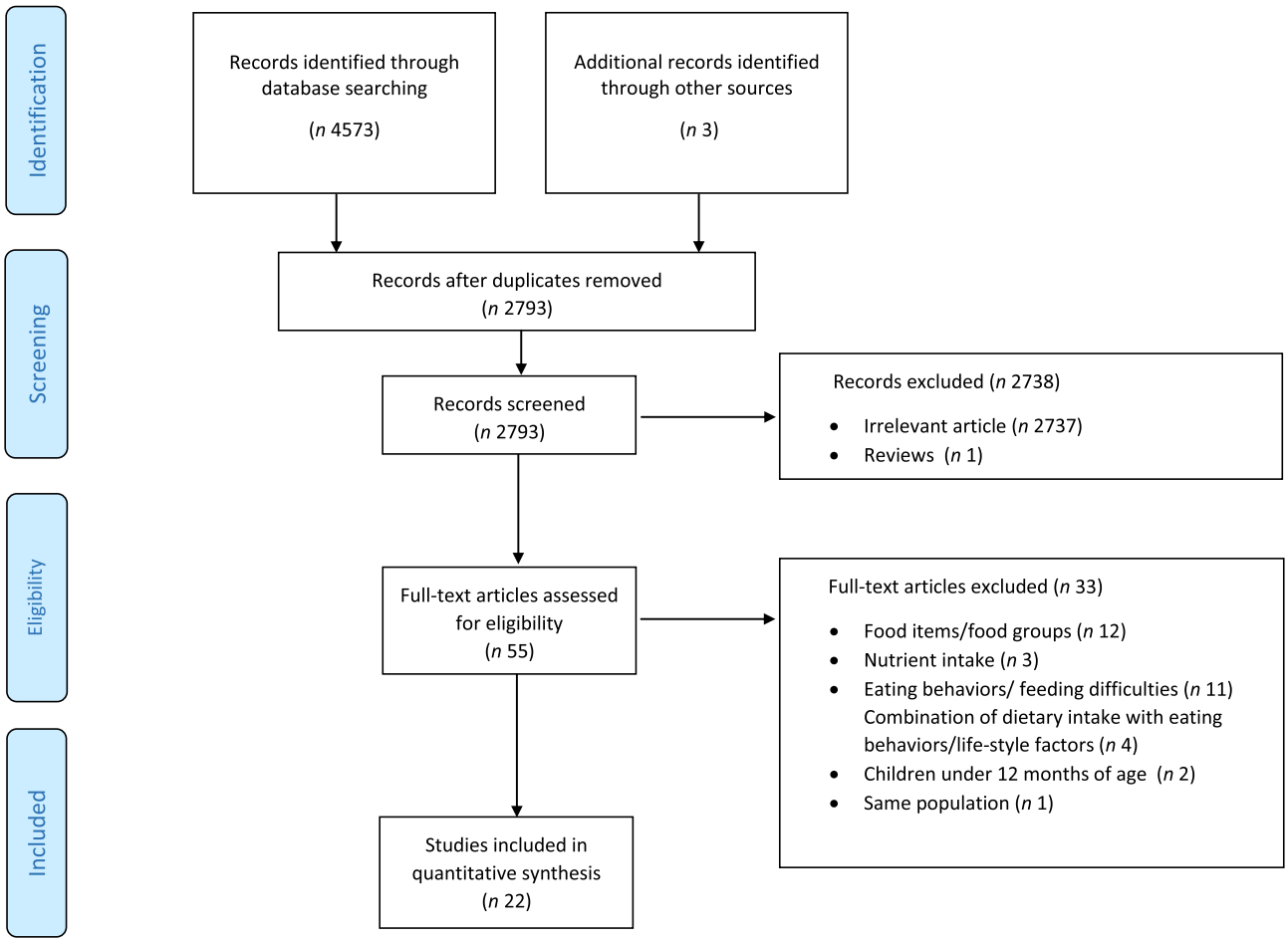

Fig. 1. The PRISMA flow diagram for literature search and selection.

(3) diet quality index was a combination of dietary intakes and eating behaviours or lifestyle-related practices (*n* 4); (4) the study sample's age was under 12 months old (*n* 2) and (6) the study was conducted in the same population (*n* 1). Finally, twenty-two eligible articles were included in the review.

Study characteristics

Table 2 summarises the characteristics and main outcomes of the eligible studies. The majority of studies were conducted in European countries (*n* 8), and the rest in Australia (*n* 6), USA (*n* 3), Brazil (*n* 3), Canada (*n* 1) and Singapore (*n* 1). Two[21,22] out of twenty-two studies were conducted in adults (i.e., age ≥ 18 years old), while others were conducted in children at ages ranging from 12 months up to 10 years old. Except for the study by Eshriqui *et al.*[21], which was comprised of only women, the rest included both sexes, with females comprising 42·9 % to 54 % of the participants across the studies. The sample size ranged between 206 and 8884. Nine studies had a cross-sectional design[21,23–30]. While one study was a historical cohort[22], and the rest had a longitudinal design.

In terms of the exposure of interest, exposure to any breast-feeding was assessed in five studies[26,29,31–33]. While two studies collected the data on exposure to exclusive breast-feeding[22,33]. Similarly, fourteen studies had assessed the duration of any breast-feeding in months[21,23–25,27,28,34–41]. While the duration of exclusive breast-feeding (in months) was assessed in only three studies[30,41,42]. With regard to the method of dietary data collection, about half of the studies had used a FFQ that was validated in their target population. The outcome of interest was diet quality scores in eleven studies[23,25,27,29,32,35–37,39–41], although the rest had assessed data-driven dietary patterns. The diet quality indices varied in terms of their food components and scoring criteria. In all diet quality indices used, a higher score indicated a better diet quality, except for the Dietary Risk Score[25] and Dietary Inflammatory Index[29], in which a higher score reflected a poorer diet quality. Regarding the data-driven dietary patterns, a total of forty-two dietary patterns were identified in the included studies. All studies had extracted dietary patterns using principal component analysis, except for the study by Sitarik *et al.*[31], which used the latent class analysis.

The quality assessment of included studies revealed that only seven out of twenty-two studies had clarified the inclusion criteria in their study sample[21,23,25,27,30,32,36]. In addition, the exposure (i.e., breast-feeding) was assessed in all studies self-reported through interviews, questionnaires, and medical records, and none had provided details on the validity and reliability of their collection method. Moreover, nine studies[24,26,27,30,32,34,39–41] did not clarify

Table 2. Summary of characteristics and main findings of studies investigating the association between breast-feeding exposure and duration with offspring's dietary patterns over 1 year of age

Reference	Country	Population	Exposure	Method of diet collection	Dietary patterns identified/diet scores used	Food items	Main findings	
Grieger *et al.*[26]	Australia	Age: 2–8 years old *n* 2287 F: 49 %	aBF exposure: ever breast-fed *v.* never breast-fed	1 × 24-h recall	Data-driven DP:		OR of DP for the ever breast-fed *v.* never breast-fed:	95 % CI
					(I) Non-core food groups	Whole-fat dairy products, cheese, luncheon and deli-type meats, medium– high sugar-sweetened breakfast cereals, and sweet biscuits	1·08	0·901, 1·299
					(II) Healthy, meat and vegetable	Vegetables, red meat, fruit, and wholegrain/whole meal breads	1·26	1·022, 1·550
					(III) Combination	Candy, other dairy products, pasta/rice products, reduced/low-fat milk, nuts/seeds, cakes, and chocolate	0·85	0·685, 1·044
Navarro *et al.*[29]	Ireland	Age: 5 years old *n* 551 F: 52 %	aBF exposure Breast fed *v.* not breast fed	52-item FFQ	Dietary inflammatory index (DII) at age 5	The index comprises twenty-four items, including carbohydrate; protein; fat; alcohol; fibre; cholesterol; SFA; MUFA; PUFA; niacin; thiamine; riboflavin; folic acid; vitamin B_{12}; vitamin B_6; vitamin A; vitamin C; vitamin D; vitamin E; beta-carotene; Fe; Mg; Zn and Se.	OR of DII in breast fed children: 0·54; $P = 0·004$	95 % CI 0·33, 0·93
Sitarik *et al.*[31]	USA	Age: 10 years old *n* 471 F: 49·9 %	aBF exposure at 6 months: Breast-fed *v.* formula fed (never breast-fed)	41-item Block Kids Food Screener	Data-driven DP: (I) Processed/energy-dense food	Fried potatoes, hamburgers/cheeseburgers, hotdogs/sausages, pizza, snack chips, ice cream and cake	OR of 'processed/energy-dense food' DP *v.* 'Healthy' DP in Breast-fed *v.* Formula Fed: 0·06	95 % CI 0·001, 5·23
					(II) Healthy	Unprocessed/whole foods, including milk, cooked cereal, other vegetables (like maize, carrots, greens, and broccoli), beans and vegetable soup	OR of 'Variety plus high intake' DP *v.* 'Healthy' DP in Breast-fed *v.* Formula Fed: 0·46	95 % CI 0·12, 1·72
					(III) Variety plus high intake	a variety of healthy and unhealthy foods, at higher intakes than the DP(1) and DP (II)		
Woo *et al.*[32]	USA	Children aged 3 years old followed up until the age of 7 *n* 349 F: 47 %	aBF exposure: Breast-fed *v.* never breast-fed	3 × food records	Healthy Eating Index (HEI)-2005: linear trends of HEI-2005 scores from ages 3 to 7 years (diet quality trajectories)	HEI-2005 components: total fruit; whole fruit; total vegetables; dark green-orange vegetables and legumes; total grains; whole grains; milk; meat and beans; oils; saturated fat; Na; SoFAAS (energies from solid fat, alcoholic beverages and added sugar)	OR of higher diet quality trajectory (highest HEI score) in breast-fed: 2·2; $P < 0·0001$	95 % CI 1·4, 3·6
Kiefte-de Jong *et al.*[33]	The Netherlands	Age:14 months old *n* 2420 F: 50 %	aBF/eBF exposure in the first 4 months of life: Never *v.* partial (mixed) feeding (aBF) *v.* full breast-feeding (eBF)	211-item FFQ	Data-driven DP: (I) Health conscious	Fruits, vegetables, legumes and fish	β for any full breast-feeding *v.* never (Ref): 0·22, $P = 0·04$	95 % CI 0·02, 0·41
							β for any partial breast-feeding *v.* never (Ref): 0·05, $P = 0·59$	95 % CI –0·22, 0·12
					(II) Western-like	Savoury and snacks and animal fats confectionery and sugar-containing beverages	β for any full breast-feeding *v.* never (Ref): –0·11, $P = 0·23$	95 % CI –0·28, 0·08
							β for any partial breastfeeding *v.* never (Ref): –0·08, $P = 0·32$	95 % CI –0·23, 0·07
Robinson *et al.*[22]	The UK	Age: 59–73 years old *n* 3217 F: 48 %	eBF exposure: Breast-fed only *v.* Breast-fed + bottle-fed / Breast-fed only *v.* bottle-fed only (never breast-fed)	129-item FFQ	Data-driven DP: (I) Prudent	fruit, vegetables, whole-meal cereals and oily fish	β of Prudent diet score: *P*-for-trend = 0·009	95 % CI
							'breast-fed + bottle-fed' *v.* 'breast-fed only' (Ref): –0·16	–0·31, –0·02
							'bottle-fed only' *v.* 'breastfed only' (Ref): –0·22	–0·45, 0·02
Barros *et al.*[23]	Portugal	Age: 4 years old *n* 3962 F: 48·5 %	aBF duration < 4 months/never *v.* ≥ 6 months	35-item FFQ	Healthy Dietary Variety Index (HDVI)	The index assesses variety and adequacy within and between five food groups, including starchy foods; fruits; vegetables; meat, fish, and alternatives and dairy food products.	β for aBF < 4 months / never *v.* ≥ 6 months: –0·010	95 % CI –0·018, –0·003

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Table 2. (*Continued*)

Reference	Country	Population	Exposure	Method of diet collection	Dietary patterns identified/diet scores used	Food items	Main findings	
Bell *et al.*[24]	Australia	Age: 14 months old *n* 552 F: 54 % and Age: 24 months old *n* 493 F: 54 %	aBF duration Continuous variable	1 × 24-h food recall and 2 × food record	Data-driven DP: (I) 14-month core foods	Fruit, vegetables, grains, non-white bread, nuts, seeds, cheese and eggs	*β* DPs' scores: 0·232; $P < 0·001$	95 % CI 0·160, 0·366
					(II) Basic combination (14 months old)	White bread, spreads, milk, juice and frozen milk products	–0·151; $P < 0·001$	–0·245, –0·070
					(III) 24-month core foods	Fruit, vegetables, nuts, seeds, dairy products, meat and water	0·040; $P = 0·429$	–0·058, 0·137
					(IV) Non-core foods (24 months old)	Sweetened beverages, chocolate, snacks, spreads, high-fat potatoes and processed meat	–0·124; $P = 0·013$	–0·213, –0·025
Bell *et al.*[25]	Australia	Age: 1 to 5 years old *n* 206 F: 53·9 %	aBF duration Continuous variable	19-item Toddler (1–< 3 years) and Preschooler (> 3–< 5 years) Dietary Questionnaires	Dietary Risk Score	The index components: (1) Core foods: fruits, orange vegetables, other vegetables, yogurt/custard, grains, red meat, and fish. (2) Non-core foods: spreadable fats, vegemite- type spreads, snack products, hot potato products, meat products, sweet biscuits/cakes, chocolate, and ice-cream/frozen yogurt (3) Usual intake: bread type, milk drinks, and non-milk drinks.	*β*: –0·21; $P = 0·001$	95 % CIs –7·08, –1·79
Bell *et al.*[34]	Australia	Mean age: 13·1 months old *n* 680 F: 46 %	aBF duration Continuous variable	1 × 24-h recall and 2× food record	Data-driven DPs: (I) Family diet	Fresh fruit, vegetables, non-white bread, cheese and non-discretionary red meat and poultry	*β* of DPs' scores: 0·036; $P = 0·275$	95 % CIs –0·029, 0·100
					(II) Cow's milk and discretionary combination	Cow's milk, white bread, cheese, fluoridated water, processed meat, sugary products, sugar-sweetened beverages, and discretionary potato products.	–0·098; $P = 0·003$	–0·162, –0·033
Chen *et al*[35]	Singapore	Age: 18-months old *n* 561 F: 48·5 %	aBF duration: Never *v.* ≥ 12 months	FFQ (number of items: NR)	Diet Quality Index (DQI)	The index has seven components, including rice, bread and alternatives; fruit; vegetables; meat and alternatives; milk and dairy products; whole grains and foods high in sugar.	*β* of DQI score for Never breastfeed *v.* ≥ 12 months (ref): –6·89; $P = 0·008$	95 % CIs –11·98, –1·81
da Costa *et al.*[36]	Portugal	Age:7 years old *n* 5013 F: 49·1 %	aBF duration: < 4 months *v.* > 5 months	38-item FFQ	Researcher-made Healthy eating index	The index has eight components including fruits; vegetables; dairy products; fish and eggs; meat; meat products; salty snacks and sweet foods and soft drinks.	*β* of HEI score for aBF duration > 5 months *v.* < 4 months: 0·065	95 % CIs –0·122, 0·25
Eshriqui *et al.*[21]	Brazil	Median age: 22 years old *n* 587 F: 100 %	aBF duration: < 6 months *v.* ≥ 12 months	101-item FFQ	Data-driven DPs:		OR of moderate-to-high adherence to the DPs for TBF ≥ 12 months *v.* TBF < 6 months:	95 % CI
					(I) Processed	Fried white meat, processed and pork meat, sweets, snacks, fast food, baked salted pastries, noodles, roots/soups, alcoholic beverages and industrialised sauces and beverages	1·03; $P = 0·921$	0·57, 1·87
					(II) Prudent	Fruits, vegetables, brown rice, whole grain bread, oats, nuts, lentil, yogurt, roasted white meat, beef, eggs, oil (for salad dressing), roots/soups, salt and tea	0·53; $P = 0·039$	0·29, 0·97
					(III) Brazilian	White rice, white bread, bean, whole milk, processed meat, beef, salt, spreading fat and coffee	0·95; $P = 0·860$	0·52, 1·73
					(IV) Lacto-vegetarian	Whole grain bread, brown rice, oats, spreading fat, cheese, skimmed milk and alcoholic beverages	1·20; $P = 0·505$	0·70, 2·08
Jones *et al.*[37]	Four European birth cohorts: ALSPAC (UK); EDEN (France); Generation XXI; (Portugal); and EuroPrevall (Greece)	Age: 2 to 4 years old *n* 245 to 8884 F: 42·9 % to 48·4 %	aBF duration: never *v.* 3–6 months	FFQ-specific for each cohort ranging from 31 to 61 items	The Healthy Plate Variety Score (HPVS): at ages 2,3 and 4 years-old	The index assesses the variety of healthy foods within and between the five main food groups including starchy foods (including potatoes); fruits; vegetables; meat, fish and alternatives; and dairy products.	*β* of HPVS score for Never breastfeed *v.* 3–6 months (ref): The ALSPAC cohort at 2 years: – 0·16 The ALSPAC cohort at 3 years: – 0·098 The ALSPAC cohort at 4 years: –0·14 The EDEN cohort at 2 years: –0·20 The EDEN cohort at 3 years: –0·10	95 % CIs –0·21, –0·11 –0·14, –0·06 –0·18, –0·09 –0·3, –0·10 –0·25, 0·00

Table 2. (*Continued*)

Reference	Country	Population	Exposure	Method of diet collection	Dietary patterns identified/diet scores used	Food items	Main findings	
Kheir *et al.*[27]	Canada	Age: 8 to10 years old *n* 630 F: 45·6 %	aBF duration: Never *v.* > 6 months	3 × 24 h dietary recall	Diet Quality Index – International (DQI-I) Score ≥ 60: good diet quality Score < 60: poor diet quality	The DQI-I comprises four components including: (1) Variety: (1–1) overall food group variety (meat/poultry/fish/eggs; dairy/beans; grain; fruit; vegetable) (1–2) Within-group variety for protein source (meat, poultry, fish, dairy products, beans, eggs) (2) Adequacy: grain group, fruit group, vegetable group, fibre, protein, Fe, Ca and vitamin C. (3) Moderation: total fat, saturated fat, cholesterol, sodium, empty energy foods (4) Overall balance: macronutrient ratio (carbohydrate:protein: fat), fatty acid ratio (PUFA:MUFA:SFA)	OR of good diet quality for never-breast fed *v.* Breast-fed > 6 months (ref): 0·98	95 % CI 0·60, 1·61
Kristiansen *et al.*[28]	Norway	Two groups of children aged 2 years old at two-time points: The year 1999 *n* 1373 F: 50 % The year 2007 *n* 1472 F: 51 %	aBF duration: < 12 months *v.* ≥ 12 months	131-item FFQ (1999) and 151-item FFQ (2007)	Data-driven DPs:		Mean of DPs' scores	95 % CIs
					(I) Unhealthy (1999)	Sugar-sweetened drinks, sweet/salty snacks, pizza, cakes/biscuits, hamburger buns, fried potatoes, ketchup and ice cream/puddings	–0·17; *P* = 0·002	–0·28, –0·06
					(II) Healthy (1999)	Fruits, vegetables, berries, rice, pasta, poultry, fish, and water	0·05; *P* = 0·432	–0·07, 0·17
					(III) Bread and spread-based (1999)	Semi-/whole-grain bread, meat, cheese, sweet spreads, and butter/margarine	–0·10; *P* = 0·102	–0·21, 0·02
					(IV) Low-fat milk, pancakes, fruits, and berries (1999)	Low-fat milk, pancakes, fruits and berries	0·11; *P* = 0·068	–0·08, 0·22
					(V) Unhealthy (2007)	Sugar-sweetened drinks, sweet/salty snacks, pizza, cakes/biscuits, hamburger buns, fried potatoes, ketchup, and ice cream/puddings	–0·14; *P* = 0·009	–0·25, –0·04
					(VI) Healthy (2007)	Fruits, vegetables, berries, rice, pasta, poultry, fish, tomato soup/other soup, cakes/biscuits, pizza, pancakes, and water	–0·01; *P* = 0·852	–0·12, 0·10
					(VII) Traditional (2007)	Vegetables, semi-/whole-grain bread, potatoes, meat, fish, eggs, stew with meat, sauce, and butter/margarine	–0·07; *P* = 0·200	–0·19, 0·04
					(VIII) Baby food (2007)	Commercial baby food, porridge/unsweetened cereals and sugar	–0·004; *P* = 0·940	–0·11, 0·12
Leventakou *et al.*[38]	Greece	Age: 4 years old *n* 1081 F: 48·1 %	aBF duration Continuous variable	118-item FFQ	Data-driven DPs:		*β* of DPs' scores:	95 % CIs
					(I) Mediterranean	Fruits, vegetables, pulses, olive oil, fish and seafood	0·02; *P* = 0·039	0·001, 0·04
					(II) Snacky	Salty snacks, sugar preserves/confectionery, potatoes/other starchy roots, and eggs	–0·002; *P* = 0·805	–0·02, 0·02
					(III) Western	Sweetened beverages, cereals/bakery products, cheese, meat products, lipids of animal and vegetable origin	– 0·01; *P* = 0·436	–0·02, 0·01
Scott *et al.*[39]	Australia	Age: 2 years old *n* 1905 F: 47·8 %	aBF duration: Continuous variable	1 × 24 h dietary recall	Core food variety score (CFVS) at age 2	The index includes five core Food groups including milk, dairy products; grains and grain products; vegetables; fruits; and meat or other non-dairy protein sources	*β* of CFVS: 0·046; *P* < 0·001	95 % CIs 0·029, 0·063
Weinfield *et al.*[40]	USA	Age: 3 years old *n* 1223 F: 49·1 %	aBF duration in the first 13 months: Continuous variable	1 × 24 h dietary recall	Healthy Eating Index (HEI)-2015	The index components: total fruits; whole fruits; total vegetables; greens and beans; whole grains; dairy products; total protein foods; seafood and plant proteins; fatty acids; refined grains; NA; added sugars and SFA	*β* of HEI score: 0·09; *P* = 0·001	95 % CI 0·04, 0·14
Meyerkort *et al.*[41]	Australia	Age: 1 to 3 years old *n* 2562 F: 48·7 %	aBF/eBF duration Continuous variable	1 × 24 h dietary recall	the Raine Eating Assessment in Toddlers (EAT) score at ages 1, 2 and 3 years-old	The index comprises seven components including whole grains; vegetables; fruit; meat ratio; dairy products; snack foods and soda and drinks.	*β* of The Raine EAT score for aBF duration:	S.E.
							1 year old: 0·142; *P* = 0·001	0·041
							2 years old: 0·095; *P* = 0·037	0·045
							3 years old: 0·125; *P* = 0·003	0·043
							β of The Raine EAT score for eBF duration:	S.E.
							1 year old: 0·659; *P* < 0·001	0·137
							2 years old: 0·469; *P* = 0·002	0·154
							3 years old: 0·780; *P* < 0·001	0·150

Table 2. (*Continued*)

Reference	Country	Population	Exposure	Method of diet collection	Dietary patterns identified/diet scores used	Food items	Main findings	
Santos *et al.*[42]	Brazil	Age: 6 years old *n* 3427 F: 48·1 %	eBF duration: ≥ 3 months	54-item FFQ	Data-driven DP:		*β* of DPs' scores for eBF ≥ 3 months:	95 % CIs
					(I) Fruits and vegetables	Fruits/fresh fruit juice, and raw/cooked vegetables	0·13; *P* = 0·004	0·04, 0·21
					(II) Snacks and treats	Sweetened beverages, candies, and crisps	–0·11; *P* = 0·004	–0·18, –0·04
					(III) Coffee and bread	Coffee, bread, butter, mayonnaise, margarine, and sugar	–0·10; *P* = 0·034	–0·18, –0·02
					(IV) Milk	Milk drinks and chocolate milk powder	0·05; *P* = 0·419	–0·04, 0·14
					(V) Cheese and processed meats	Cheese, sliced meat and sausages	0·10; *P* = 0·061	0·01, 0·18
					(VI) Rice and beans	Rice and beans	–0·04; *P* = 0·548	–0·12, 0·05
					(VII) Carbohydrates	Potato, pasta and cassava	–0·01; *P* = 0·851	–0·10, 0·08
Vieira *et al.*[30]	Brazil	Age: 4–7 years old *n* 403 F 44·9 %	eBF duration: < 4 mo *v.* ≥ 4 mo	3 × food record	Data-driven DP:		OR of DPs for EBF ≤ 4 months *v.* ≥ 4 months:	95 % CI
					(I) Traditional	Vegetables, white rice, beans, polenta and flours, tubers, eggs, meat and fish	NR	
					(II) Unhealthy	Artificial juice/soft drinks, stuffed cookies, sausages, fried foods, snacks and sweets	1·71; *P* = 0·040	1·02, 2·86
					(III) Milk and chocolate	Milk/milk products, chocolate, and sugar	Data not reported: NS	
					(IV) Snack	Bread, cakes/cookies, butter/margarine, coffee and tea	1·76; *P* = 0·027	1·06, 2·90
					(V) Healthy	Fruits, vegetables, natural juice, broths and soups	NR	

F, female; aBF, any breast-feeding; DP, Dietary pattern; eBF, exclusive breast-feeding; NR, not reported; NS, not significant.

whether the outcome assessment was validated in their study population. In terms of the confounding factors, all studies had adjusted the association for a variety of maternal and child characteristics (online Supplementary Materials: Table S1). However, only seven studies[21,31,33,35,37–39] had clearly indicated the rationale for the selection of potential confounders in their study sample.

Main findings

The considerable heterogeneity across the studies in terms of the population's characteristics, assessment of exposure and outcome and the statistical methods used did not allow us to perform a meta-analysis. Therefore, we relied on the qualitative data synthesis stratified by the type of exposure (i.e., breast-feeding exposure/duration) and outcome (data-driven dietary patterns and diet quality scores).

Exposure to any/exclusive breast-feeding and data-driven dietary patterns. Two studies[26,31] assessed the relationship between exposure to any breast-feeding with a total of five dietary patterns. Of the identified dietary patterns, two were loaded with healthy foods labelled as '*Healthy, meat and vegetable*' and '*Healthy*', while one labelled as '*Processed/energy-dense food*' comprising discretionary foods. The three remaining dietary patterns included healthy and unhealthy foods, labelled as '*Non-core food groups*', '*Combination*' and '*Variety plus high intake*'. The qualitative analysis demonstrated that compared with never breast-feeding (or formula/bottle feeding), exposure to any breast-feeding was positively associated with '*Healthy, meat and vegetable*' pattern score at ages 2–8 years old[26]. However, the association with other identified dietary patterns did not reach a statistically significant level.

Regarding the exposure to exclusive breast-feeding, two studies[22,33] with three major dietary patterns, two loaded with healthy foods ('*Health conscious*' and '*Prudent*' patterns) and the latter comprised of discretionary foods ('*Western-like*') were included. The findings showed a positive association between exposure to exclusive breast-feeding with '*Health conscious*' pattern score at 14 months old[33] and '*Prudent*' pattern score at ages 59–73 years old[22]. In contrast, no significant association was found for '*Western-like*' pattern[33].

Exposure to any/exclusive breast-feeding and diet quality scores. Two studies[29,32] evaluated the association between exposure to any breast-feeding with two different diet quality scores, namely Dietary Inflammatory Index and Healthy Eating Index-2005. However, no study was found for exclusive breast-feeding exposure. The results indicated that exposure to any breast-feeding was significantly associated with a lower Dietary Inflammatory Index (i.e., a more anti-inflammatory diet) at age 5[29] and a higher Healthy Eating Index-2005 score between 3 and 7 years of age[32].

Duration of any/exclusive breast-feeding and data-driven dietary patterns. Five studies assessed the association of the duration of any breast-feeding with twenty-one extracted dietary patterns[21,24,28,34,38]. Of the twenty-one dietary patterns, six were loaded with healthy foods labelled as '*14-month core foods*',

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'*24-month core foods*', '*Family diet*', '*Prudent*', '*Healthy, 1999*' and '*Mediterranean*'. While six other dietary patterns were comprised of only discretionary foods labeled as '*Non-core foods*', '*Cow's milk and discretionary combination*', '*Processed*', '*Unhealthy, 1999*', '*Unhealthy, 2007*' and '*Western*'. The nine remaining dietary patterns were loaded with a mixture of both healthy and unhealthy foods and labeled as '*Basic combination*', '*Brazilian*', '*Lacto-vegetarian*', '*Bread and spread-based, 1999*', '*Low-fat milk, pancakes, fruits, and berries*', '*Traditional, 2007*', '*Healthy, 2007*', '*Baby food*' and '*Snacky*'. The findings indicated that a longer duration of any breast-feeding was significantly associated with higher scores on '*14-month core foods*'[24], '*Prudent*'[21] and '*Mediterranean*'[38] patterns. While it was inversely related to '*Non-core foods*'[24], '*Cow's milk and discretionary combination*'[34], '*Unhealthy (1999 & 2007)*'[28] and '*Basic combination*'[24] patterns.

The association between exclusive breast-feeding duration with dietary patterns was evaluated in two studies[30,42], with eleven identified dietary patterns combined. Of these, six were comprised of healthy foods ('*Fruits and vegetables*', '*Milk*', '*Rice and beans*', '*Carbohydrates*', '*Traditional*' and '*Healthy*'), while two were loaded with discretionary foods, namely *'Snacks and treats'* and *'Unhealthy'* patterns. The three remaining dietary patterns labelled as *'Coffee and bread', 'Cheese and processed meats', 'Milk and chocolate' and 'Snack'* were a combination of both healthy and discretionary foods. The qualitative analysis demonstrated that a longer duration of exclusive breast-feeding was significantly associated with higher scores on *'Fruits and vegetables'* pattern[42]. In comparison, it was negatively associated with *'Snacks and treats'*[28], *'Unhealthy'*[42], *'Coffee and bread'*[42] and *'Snack'*[30] patterns scores.

Duration of any/exclusive breast-feeding and diet quality scores. Nine studies investigated the association between the duration of any breast-feeding and diet quality scores. Of these, three studies reported that the duration of any breast-feeding was positively associated with diet variety between the ages 2–4 years old, as shown by higher scores on '*Healthy Dietary Variety Index*'[23], *'The Healthy Plate Variety Score'*[37] and *'Core food variety score'*[39]. Similarly, the results of four studies in children aged 1–5 years old indicated that a longer duration of any breast-feeding was significantly associated with higher scores on '*Diet Quality Index*'[35], '*the Raine Eating Assessment in Toddlers*'[41] and '*HEI–2015*'[40], while it was inversely associated with the '*Dietary Risk Score*'[25]. However, two studies that used the 'Diet Quality Index – International' and a researcher-made 'Healthy Eating Index' among children at ages 7–10 years old did not report such a significant association[27,36]. Unlike any breast-feeding, none of the included studies had investigated the association between the duration of exclusive breast-feeding and diet quality scores.

Discussion

The present study summarised the results of observational studies investigating the association between exposure to breast milk and its duration with dietary patterns over 1 year of age. We observed a remarkable heterogeneity across studies in terms of exposure and outcome reporting. Of the twenty-two eligible studies, nineteen reported a significant association between breast-feeding exposure and duration with at least one dietary pattern or diet quality score. Overall, being exposed to breast milk as well as a longer duration of any/exclusive breast-feeding were associated with healthy dietary patterns and better diet quality in both children and adults.

The relationship between breast-feeding and diet has already been investigated at the level of food items and food groups. Some studies reported that a longer duration of any or exclusive breast-feeding was associated with a higher intake of fruits[43–46] and vegetables[43–51] in children, while a lower consumption of processed foods and sugar-sweetened beverages[45,46,52,53]. However, in nutritional epidemiology, the reductionist approach, which only considers a particular food or food group, might not provide a comprehensive picture of dietary intake since people do not consume foods in isolation. In contrast, data-driven and hypothesis-driven dietary patterns assess food items in combination and capture a snapshot of the whole diet more accurately[54,55]. The hypothesis-driven dietary patterns are based on the existing knowledge of healthy diets, and they measure the degree of adherence to the recommended healthy diets and dietary guidelines. Although in data-driven dietary patterns, statistical techniques are employed to extract dietary patterns, and contrary to the diet quality scores, they might not completely comply with the dietary recommendations since they depend on the study's population[56]. Moreover, the diet quality scores used across studies varied considerably in terms of their scoring components as they were based on the dietary intake of only nutrients (e.g., Dietary Inflammatory Index), nutrient plus foods/food groups (e.g., Healthy Eating Index and Diet Quality Index-I) or only foods/food groups. Taken together, the aforementioned factors should be taken into account when interpreting the relationship between breast-feeding and data-driven dietary patterns and diet quality scores.

Formula feeding, another early feeding practice, is also suggested that could affect food acceptance through flavour experiences[57–59]; for example, a survey among 133 adults who were breast-fed or bottle-fed with vanilla-flavoured formula showed that a majority of formula-fed subjects had a preference to the vanilla-flavoured ketchup, while the breast-fed ones showed a greater tendency to the plain ketchup[57]. Moreover, the taste preferences and food choices are varied based on the type of formula consumed since it is demonstrated that children who had received a protein hydrolysate formula showed a higher tendency to the sour-flavoured juices as well as a higher preference to broccoli compared with those who were fed milk-based formulas[59]. Thus, in addition to breast-feeding, formula feeding might also contribute to the taste experiences and subsequently eating patterns in the later ages. However, in this review, except for four studies[22,30,33,42] that had just evaluated exclusive breast-feeding, the rest have focused on any breast-feeding, which might include both breast-feeding and formula-feeding. Hence, the hypothesis that whether formula feeding has provided a synergistic effect, in conjunction with breast-feeding, toward healthy food choices could not be ruled out. However, they did not consider the duration of formula feeding in the study

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sample, which made it difficult to elucidate concrete evidence on this topic.

Besides the feeding practices in the first years of life, maternal influences might also determine the dietary patterns at later ages. Accumulating evidence from experimental studies indicates that maternal intake of foods rich in fat, sugar and Na during pregnancy and lactation is accompanied by a higher preference for these foods in their offspring[60,61]. Similarly, several observational studies have shown a positive association between maternal and child dietary intakes and diet quality[62–64]. Furthermore, mothers might affect their child's food preferences mainly by controlling the portion sizes and the amount of foods that their child consumes, pressure or encouragement to eat, and indirectly, by providing (purchasing) only healthy foods at home and eliminating them the takeaway and junk foods. Even it is shown that parents who are worried about the risk of becoming obese in children, those parents who are overweight/obese, or those with overeating, might influence their children's dietary patterns by taking several restrictive measures[65,66]. In our review, only two out of twenty-two studies assessed the maternal diet during pregnancy at the level of macronutrients (i.e., dietary carbohydrate, fibre and fat intake) and diet quality (i.e., diet variety score) in the study sample[33,37]. However, the remaining studies did not consider the potential contribution of maternal dietary intakes during pregnancy/lactation as well as parental modelling when interpreting the relationship between breast-feeding and dietary patterns. Therefore, further studies are warranted to explore the mediating role of parents' lifestyle components on the association between feeding experiences in the first year of life and later dietary patterns.

The studies included in this review had some limitations that should be considered when interpreting the results. First, both exposure and outcome were collected using the self-reporting method. Furthermore, except for two studies[21,22] that were conducted in adults, the rest were comprised of children within the age range of 1–10 years old, and their dietary intakes were collected through interviews with their parents/caregivers. Thus, the possibility of recall and reporting biases could not be ruled out. Second, 40% of studies had a cross-sectional design, which cannot determine the causality of the relationship. Third, most studies did not provide a clear definition of inclusion criteria of the study sample, for example, whether their sample had followed any special diets such as gluten-free diets and low-energy diets, which might affect the study outcome. Fourth, most studies had not clarified whether they had considered under/over-reporting the total energy intake that could potentially affect the accuracy of reported dietary intakes[67]. Fifth, the majority of studies did not clarify how they identified potential confounding factors in their study population, which raised the possibility that the results might be affected by over- or under-adjustment.

Besides, several limitations of the present review should be acknowledged. Most of the evidence on breast-feeding and later dietary patterns were related to any breast-feeding, while only four studies[22,30,33,42] had evaluated exclusive breast-feeding. In addition, the evidence came from the population living in developed or high-income countries. Whether the findings of this review are also generalisable to the population from developing or low-income countries remains to be answered. Furthermore, due to the methodological variations, the present report relied on the qualitative synthesis of outcomes instead of a quantitative synthesis (i.e., meta-analysis).

In conclusion, this systematic review suggests that exposure to breast milk and a longer duration of breast-feeding is associated with greater adherence to the healthy dietary patterns characterised mainly by high consumption of nutrient-dense foods, particularly fruits, vegetables and whole grains. While they are inversely associated with unhealthy dietary patterns loaded with discretionary foods. Nevertheless, in light of the above-mentioned limitations, further research is warranted to elucidate more rigorous evidence on this topic.

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Supplementary material

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