Impact of maternal nutrition on breast-milk composition: a systematic review[1,2]

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ABSTRACT

Background: It is widely reported that maternal diet influences the nutritional composition of breast milk. The amount of variability in human milk attributable to diet remains mostly unknown. Most original studies that reported a dietary influence on breast-milk composition did not assess diet directly, did not quantify its association with milk composition, or both.

Objective: To gather the quantitative evidence on this issue, we carried out a systematic PubMed and Medline search of articles published up to January 2015 and filtered the retrieved articles according to predefined criteria.

Design: Only studies that provided quantitative information on both maternal diet and milk data, measured in individual healthy mothers of healthy term infants and based on an original observational or experimental design, were included. Exclusion criteria were a focus on supplements, transfer of toxic metals or other contaminants from diet to milk, or on marginally nourished women.

Results: Thirty-six publications—including data on 1977 lactating women—that matched our criteria were identified. Seventeen studies investigated dietary effects on fatty acids in breast milk. The rest included studies that focused on a diverse spectrum of other nutritional properties of breast milk. The largest evidence, in terms of number of articles, for any link between maternal diet and a nutritive property of breast milk came from 3 studies that supported the link between fish consumption and high docosahexaenoic acid in breast milk and 2 studies that reported a positive correlation between dietary vitamin C and milk concentrations of this vitamin.

Conclusions: The available information on this topic is scarce and diversified. Most of the evidence currently used in clinical practice to make recommendations is limited to studies that only reported indirect associations. *Am J Clin Nutr* 2016;104:646–62.

Keywords: breastfeeding, fatty acids, human milk, maternal diet, nutrients

INTRODUCTION

Human milk provided by healthy, well-nourished mothers represents the best food available for infants born at term to healthy mothers. Exclusive breastfeeding is recommended for the first 6 mo of life, with continued breastfeeding along with appropriate complementary food up to 2 y of age or beyond (1). Unlike infant formula, which has a standardized composition, human-milk composition changes dynamically within a feeding, with time of day, over lactation, and between mothers and populations. It is influenced by genetic and environmental factors, by infant sex (2) and infective status (3), as well as by maternal lifestyle, including dietary habits (4, 5). For example, colostrum, the milk produced in the first few days after birth, is reported to be higher in protein, vitamin A, vitamin B-12, and vitamin K (6). Over the following 4 wk milk composition changes gradually and is only considered "mature" from ∼6 d after birth. However, subtle changes in milk composition do occur over the course of lactation (7).

A woman's diet can influence her milk composition via several intertwined metabolic pathways that produce indirect effects (8). However, the literature suggests that some metabolic pathways modulate certain human-milk components directly through dietary intake (9). In particular, concentrations of fatty acids (FAs)[7] and fat- and water-soluble vitamins—including vitamins A, C, B-6, and B-12—have been reported to reflect the respective dietary intakes of these nutrients in the maternal diet (10, 11). Conversely, the mineral content of human milk is generally considered less related to maternal dietary intakes (11).

Previous narrative reviews considered the issue of maternal diet and breast-milk composition qualitatively and/or focused on selected breast-milk components (4, 9–14). The objective of the present systematic review was to collect and summarize the existing evidence from publications that directly quantify the associations between maternal dietary habits and breast-milk composition in healthy mothers of healthy term infants. Our main aim was to gather the available evidence with regard to the

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[2] Supplemental Material and Supplemental Tables 1 and 2 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://ajcn.nutrition.org.

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[7] Abbreviations used: AA, arachidonic acid; ALA, α-linolenic acid, DPA, docosapentaenoic acid; FA, fatty acid, LA, linoleic acid; TFA, *trans* fatty acid.

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nutritional features of breast milk produced by mothers under normal circumstances.

METHODS

Search strategy

We performed a PubMed and Medline (www.ncbi.nlm.nih.gov/pubmed) search for articles published up to January 2015 with the use of combinations of the terms "breastfeed," "breast feed," "breastfed," "breast fed," "lactation," "maternal milk," "human milk," "breast milk," "maternal diet," "maternal nutrition," "mother diet," and "mother nutrition" following the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) statement for systematic reviews (15). Further details on the search strategy are provided in the **Supplemental Material.** We selected studies in humans published as full-length articles. The electronic search was integrated by searching the reference lists of the selected publications and of reviews on the issue manually to identify any other relevant publications.

Inclusion and exclusion criteria

Studies were included if they provided quantitative information on the direct relation between maternal diet and the nutritional properties of breast milk. For each mother considered in the studies, the relation between maternal nutrition and breast-milk composition was estimated and quantified by indicators including correlation coefficients, means within subgroups, estimates from regression models, or *P* values from comparison tests. Several studies provided descriptions of both maternal nutrition and breast-milk composition and inferred their relation without providing such direct quantification measures; these studies were excluded from the present review. Moreover, to be included, studies had to be based on original observational or experimental designs that investigated the general population and mainly included healthy mothers of healthy term infants.

Publications were excluded if they focused on the following: effects of fortified foods or dietary supplements including probiotics; the transfer of pollutants, toxic metals, or contaminants, such as lead or nickel, from the maternal diet to breast milk; mothers with major chronic diseases (e.g., diabetes, hypertension, or HIV/AIDS); children with health problems (e.g., low birth weight or atopic dermatitis); or marginally nourished populations. For protocols concerning developing countries [according to the WHO classification (16)], we checked if the distribution of energy intake and/or BMI excluded signs of under- or malnutrition. Some articles did not provide complete information on these aspects; thus, we were not able to completely rule out the presence of exclusion criteria among subsamples. However, our aim was to only exclude studies that specifically focused on these issues. When we found multiple publications that considered different outcomes on the basis of the same study, we included all of them. Conversely, when multiple publications considered the same study population and outcome, we included only the most recent and complete publication.

Data extraction and quality assessment

Two authors (FB and ADP) reviewed all of the articles and performed the study selection independently according to the inclusion and exclusion criteria. Disagreements were resolved by discussion and/or involving a third author (MF). For descriptive purposes, we extracted information on study design, geographical area, description of participants (including sample size, age of mothers, if available, and age of children), milk sample collection (including number of samples, characteristics of collection and storage, and exclusivity of breastfeeding, if reported), maternal dietary assessment, nutritional properties in breast milk, and quantitative estimates on the relation between maternal diet and nutritional properties in breast milk from each publication. The main results were summarized in tables according to the following criteria: we reported any quantitative information on the direct relation between maternal diet and breast-milk composition, highlighting significant results in bold, if any. Among FAs examined in breast milk, we reported the following: the major SFAs (lauric acid, myristic acid, palmitic acid, stearic acid, and vaccenic acid), the most prominent MUFA (oleic acid) and the minor MUFA palmitoleic acid, the main n–3 PUFAs [α-linolenic acid (ALA; 18:3n−3), DHA, EPA, and docosapentaenoic acid (DPA; 22:5n−3)] and n–6 PUFAs [linoleic acid (LA; 18:2n−6) and arachidonic acid (AA; 20:4n−6)], and the major *trans* FAs (TFAs) found in hydrogenated vegetable oils (elaidic acid), and rumenic acid, the major nonindustrial TFA. Total SFAs, total MUFAs, total n–6 PUFAs, total n–3 PUFAs, total PUFAs, ratios of PUFAs to SFAs, n–6 to n–3 PUFAs, and AA to DHA are also shown in the tables. Sometimes the selected articles included data on additional minor FAs. For the sake of brevity, these were not reported.

We evaluated the quality of the included studies according to the Study Quality Assessment Tools for cross-sectional studies and controlled intervention studies, developed by the National Heart, Lung, and Blood Institute (http://www.nhlbi.nih.gov/health-pro/guidelines/in-develop/cardiovascular-risk-reduction/tools; accessed 1 February 2016).

RESULTS

Description of the identified studies

Figure 1 shows the publication selection procedure. Our initial search yielded 2984 publications, 2861 of which were excluded after title and abstract evaluation. A further 102 publications were excluded after considering the full text, which left 21 eligible publications. Fifteen additional articles were identified from the reference lists of the included publications and additional reviews on the issue. Thus, we considered 36 publications in the present review, of which 29 concerned observational cross-sectional studies (17–45) and 7 described experimental studies in which maternal diet was controlled and predetermined (46–52). Among the experimental studies, 6 had a crossover design (46–51); in 3 studies, a washout period was included (47, 49, 50). A total of 1977 mother-child pairs were considered. The main characteristics of the studies are described in **Table 1** (including observational studies) and **Table 2** (including experimental studies). The articles were published between 1977 and 2014 and 20 (56%) were published after 2000. Among the identified publications, 2 were based on the same study, including 64 Greek women, but considered different breast-milk components [i.e., FA composition and vitamin E (19, 20), respectively]. Thus, both articles were included and considered as separate studies. Similarly, we included 3 articles based on the

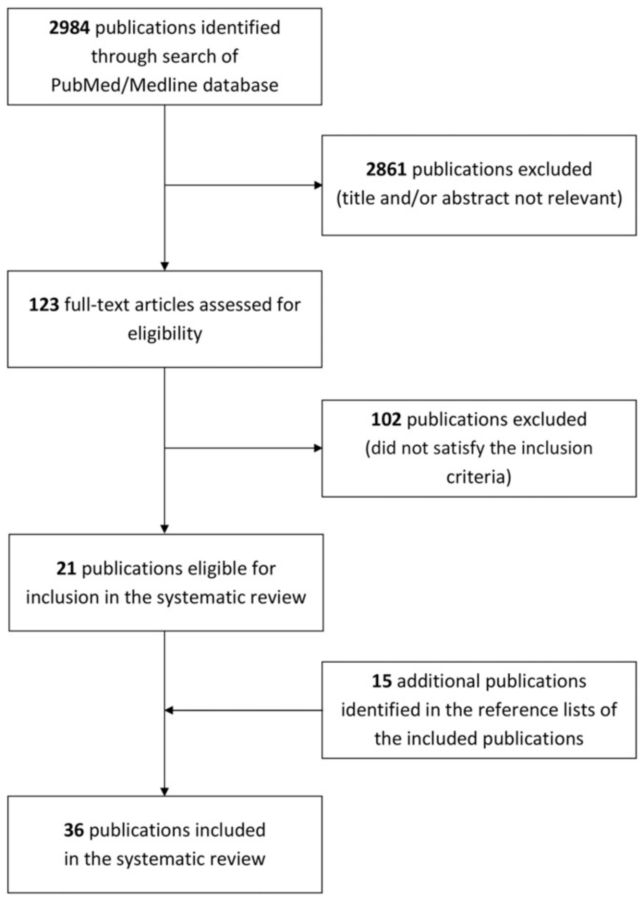

FIGURE 1 Publication selection procedure.

same California population but concerning different milk components (i.e., fat and FAs, selenium, protein, and minerals) (43–45). Two other studies (32, 33), including 57 Spanish women, considered the milk content of vitamin E and zinc, respectively.

Eighteen articles concerned studies conducted in Europe (18–21, 23, 25, 27, 28, 30, 32, 33, 35, 37–40, 47, 52), 10 in North America (17, 36, 43–46, 48–51), 2 in South America (29, 42), 5 in Asia (22, 24, 26, 31, 34), and 1 included 2 groups of women from Asia and Europe (41). All of the studies included women of reproductive age, between 14 and 43 y.

Breast-milk extraction and composition

Five publications considered data on colostrum collected a few hours postpartum (24, 27, 31, 36, 52); in 21 publications, mature breast milk collected when children were between 1 and 12 mo old was considered (19–23, 25, 26, 28–30, 32, 33, 35, 39–41, 46–50); in 5 studies mature breast milk was collected when some of the infants were older than 1 y (17, 43–45, 51); and in 5 studies both colostrum and mature milk were collected (18, 34, 37, 38, 42).

Most (but not all) articles specified that breast milk was stored at a freezing temperature ranging between −20°C and −80°C (17, 19–36, 38, 39, 41–48, 50–52). In 17 studies, breast milk was obtained by manual expression (18, 21, 22, 27–29, 32–34, 36, 38, 39, 41, 42, 46, 47, 50); in 5 studies a breast pump was used (19, 20, 31, 49, 51); in 8 studies both methods were allowed (17, 23, 30, 35, 43–45, 48); and in the remaining 6 publications no information on expression method was given (24–26, 37, 40, 52).

With regard to the breast-milk components of interest, 18 publications examined FA composition (17, 20, 22, 23, 25, 26, 28–31, 35, 38, 41, 44, 46, 50–52), 6 considered total fat (20, 28, 34, 44, 48, 49), 1 examined cholesterol (48), 1 examined phytosterols (48), 5 considered total protein (21, 34, 45, 47, 49), 2 considered total energy (34, 49), 2 examined vitamin C (24, 37), 2 examined group B vitamins (24, 36), 2 considered vitamin E (19, 32), 3 examined zinc (27, 33, 40), 2 examined total carbohydrates (34, 45), 1 considered lactose (49), 3 considered selenium (39, 42, 43), 2 considered iron (40, 45), 1 examined calcium (45), 1 examined magnesium (45), 1 examined potassium (45), and 1 considered oxygen radical absorption capacity (18).

Maternal nutrition

Among the 29 observational studies, information on maternal diet was based on self-administered food-frequency questionnaires or dietary recalls in 11 studies (17, 19–22, 25, 35–37, 40, 41), on food-frequency questionnaires administered by trained health professionals in 8 studies (18, 27, 29–31, 34, 39, 42), on a 5-d diet record in 2 studies (32, 33), and on a baseline interview with 24-h dietary recall followed by self-administered 2-d diet records in 3 studies (43–45), whereas the remaining 5 articles did not specify whether the nutritional information was collected by a health professional (23, 24, 26, 28, 38). Two studies collected information on usual maternal diet (26, 31), 4 studies focused on maternal diet during pregnancy (28, 32, 33, 35), and 18 focused on maternal diet on milk sample collection day (or a few days before) (17, 25, 28, 30, 37–40, 43–52), whereas other articles did not specify the investigated dietary time period (18–24, 27, 29, 34, 36, 41, 42). In one observational study, maternal diet during the third trimester of pregnancy and at milk collection was evaluated according to the Index of Diet Quality, which is a validated score that evaluates adherence to nutritional recommendations (28).

In one crossover study, the 2 experimental diets were similar except for the source of dietary fat (i.e., hydrogenated compared with nonhydrogenated) (46). In a crossover study that included a washout period, diets rich and poor in protein were compared (47). In other crossover studies that included a washout period, a low-carbohydrate, high-fat diet was compared with a high-carbohydrate, low-fat diet (49) and low-fat and high-fat diets were compared (50). A low-dairy diet was compared with a high-dairy diet in one crossover study (51), and another crossover study compared a diet rich in cholesterol and poor in phytosterols with another diet that was poor in cholesterol and rich in phytosterols (48). In the remaining experimental study, a standard hospital diet was compared with an experimental diet characterized by a high PUFA-to-SFA ratio (52).

Study quality

For different reasons, no study obtained the highest quality score: for example, no observational study reported a sample size rationale or power calculation, adjustments for key confounding variables were also missing, and few studies provided a clear description of the study population from which mothers were selected or the participation rate. Thus, the score ranged between 4 and 9 among observational studies and between 7 and 7.5 in the intervention studies.

TABLE 1
Observational studies on the relation between maternal diet and breast-milk composition[1]

First author, year (ref)	Country	Quality score	Study participants	Milk samples	Maternal dietary assessment	Main results
Aitchison,1977 (17)	USA	6	11 mothers, aged 25–35 y	1 sample, collected in the morning before breakfast after nursing the infant, for 1 wk between 4th and 17th month of lactation (all 11 women) and a second sample, collected in the evening after nursing, for 1 wk between fourth and sixth month of lactation (only 5 women); all samples were collected by using whatever method each subject preferred and were then frozen; milk FA composition was examined	Self-administered, 1-wk dietary record; for 3 d a duplicate of each day's food consumption was collected in a separate container and frozen at <−20°C	Pearson's correlation coefficient (*P*) between PUFA-to-SFA ratio in maternal diet and milk (% of total FAs): 0.46 considering diet and milk in the same evening; **0.43 (<0.05)** considering milk in the next morning; other specific FAs were considered
Alberti-Fidanza, 2002 (18)	Italy	5	29 mothers, aged 23–42 y, exclusively breastfeeding	Collected 3, 8, and 20 d postpartum by manual expression; milk vitamin C, vitamin E, retinol, and β-carotene were examined	Dietary history was collected by a dietitian in the third trimester of pregnancy and postpartum	Spearman rank correlation coefficient (*P*) between maternal dietary intake and milk oxygen radical absorption capacity (mmol/L trolox eq.): **retinol, 0.39 (<0.05); retinol equivalent, 0.46 (<0.05); β-carotene, 0.45 (<0.05) in colostrum; vitamin C, 0.63 (<0.001); vitamin E, 0.42 (<0.05); β-carotene 0.42 (<0.05) in transitional milk; vitamin C, 0.59 (<0.001); β-carotene, 0.47 (<0.05) in mature milk**
Antonakou, 2013 (20)	Greece	9	64 mothers, exclusively breastfeeding; mean ± SD age: 32.5 ± 3.1 y	64 samples collected at 20–30 d, 39 samples at third month, 24 samples at sixth month; all samples were collected during morning hours by electric breast pump and stored at −80°C; milk FA composition and fat were examined	Self-administered 3-d dietary record at first, third, and sixth month postpartum	Pearson's correlation coefficient (*P*) between maternal dietary EI (kcal) and milk FAs (% of total FAs) at first month: DHA, −0.08; AA, 0.10; LA, −0.09; n–3, −0.08; n–6, −0.01; SFAs, −0.01; MUFAs, 0.02; PUFAs, −0.03; AA-to-DHA, 0.15; n–6-to-n–3, 0.12; total fat (g/L), −0.04 Correlation between maternal dietary fat (% of EI) and milk FAs (% of total FAs) at first month: **DHA**, **0.25** (**<0.05**); AA, 0.23; LA, 0.15; n–3, 0.24; n–6, 0.17; SFAs, −0.05; MUFAs, −0.05; PUFAs, 0.20; AA-to-DHA, 0.08; n–6-to-n–3, 0.05; total fat (g/L), 0.12 Correlation between maternal dietary MUFAs (% of EI) and milk FAs (% of total FAs) at first month: DHA, 0.18; AA, 0.24; **LA, 0.26** (**<0.05**); n–3, 0.18; **n–6**, **0.27** (**<0.05**); SFAs, −0.16; MUFAs, 0.01; **PUFAs**, **0.29** (**<0.05**); AA-to-DHA, 0.16; n–6-to-n–3, 0.10; total fat (g/L), −0.01 Correlation between maternal dietary PUFAs (% of EI) and milk FAs (% of total FAs) at first month: **DHA**, **0.27** (**<0.05**); AA, 0.16; **LA, 0.26** (**<0.05**); **n–3**, **0.26** (**<0.05**); n–6, 0.22; SFAs, −0.02; MUFAs, −0.09; **PUFAs**, **0.25** (**<0.05**); AA-to-DHA, 0.01; n–6-to-n–3, 0.03; total fat (g/L), 0.08 Correlation between maternal dietary SFAs (% of EI) and milk FAs (% of total FAs) at first month: DHA, 0.16; AA, 0.09; LA, −0.15; n–3, 0.15; n–6, −0.08; SFAs, 0.01; MUFAs, 0.01; PUFAs, −0.05; AA-to-DHA, −0.05; n–6-to-n–3, −0.09; total fat (g/L), 0.10

(Continued)

TABLE 1 (*Continued*)

First author, year (ref)	Country	Quality score	Study participants	Milk samples	Maternal dietary assessment	Main results
						Correlation between maternal dietary carbohydrate (% of EI) and milk FAs (% of total FAs) at first month: **DHA**, **−0.28 (<0.05)**; AA, −0.19; LA, −0.01; **n–3**, **−0.29 (<0.05)**; n–6, −0.05; SFAs, 0.12; MUFAs, −0.07; PUFAs, −0.10; AA-to-DHA, 0.00; n–6-to-n–3, 0.02; total fat (g/L), −0.10 Correlation between maternal dietary protein (% of EI) and milk FAs (% of total FAs) at first month: DHA, 0.10; AA, 0.04; LA, −0.18; n–3, 0.14; n–6, −0.13; SFAs, −0.15; MUFAs, 0.19; PUFAs, −0.10; AA-to-DHA, −0.19; n–6-to-n–3, −0.10; total fat (g/L) −0.02
Antonakou, 2011 (19)	Greece	9	64 mothers, exclusively breastfeeding, aged 25–39 y	64 samples collected at 20–30 d, 39 samples at third month, 23 samples at sixth month; all samples were collected during morning hours by electric breast pump and stored at −80°C; milk vitamin E was examined	Self-administered 3-d dietary record at first, third, and sixth months postpartum	Pearson's correlation coefficient (*P*) between maternal dietary intake and concentration of vitamin E (μmol/L) in mature milk at first month: EI (kcal), −0.027 (0.559); carbohydrate (% of EI), −0.301 (0.081); protein (% of EI), 0.085 (0.088); **total fat (% of EI)**, **0.244 (0.047)**; **SFAs (% of total fat)**, **0.300 (0.034)**; MUFAs (% of total fat), 0.195 (0.062); PUFAs (% of total fat), 0.092 (0.387); vitamin E (μmol/L), 0.002 (0.745)
Bianchi, 1999 (42)	Brazil	6	30 mothers, aged 16–32 y	Collected at 7–210 d; manually expressed and stored at −70°C	24-h recall food-frequency questionnaire administered by a researcher	Pearson's correlation coefficient (*P*) between maternal dietary intake and milk concentration of selenium: −0.103 (0.594)
Boniglia, 2003 (21)	Italy	6	117 mothers; mean ± SD age: 31.2 ± 4.5 y	Collected 1 mo postpartum (±4 d); samples were collected at the end (hind milk) of the second and third feedings in the morning (on the same day) by manual expression and were stored at −20°C; milk protein was examined	2 self-administered, consecutive 24-h recalls at first month postpartum	Spearman's correlation coefficient between maternal intake and milk protein (g/100 mL): total protein (g/d), −0.028; animal protein (g/d), −0.030; vegetable protein (g/d), −0.048; total protein (g/kg), 0.013; protein (%MJ), −0.051; energy (MJ), −0.002
Daud, 2013 (22)	Malaysia	8	101 mothers	Collected for 3 d between 15 d and 6 mo postpartum; samples were collected by manual expression and stored at −80°C; milk TFA composition was examined	Self-administered food-frequency questionnaire over 1-y period	Spearman's correlation coefficient (*P*) between dietary intake and total TFAs in breast milk (% of total fat): intake of fruit, 0.17 (>0.05); intake of vegetables, −0.04 (>0.05); **elaidic acid**, **0.48 (<0.05)**; Spearman's correlation coefficient (*P*) between dietary variables and vaccenic acid in breast milk: elaidic acid, 0.35 (>0.05); linoelaidic acid, 0.18 (>0.05); total TFAs, 0.26 (>0.05) Other specific food items and nutritional proprieties were considered
Debski, 1989 (43)	USA	8	38 mothers; mean age: 29 y	45 milk samples collected by hand expression or with manual breast pump; samples were stored at −70°C; protein and selenium concentrations in breast milk were examined	24-h dietary recall at baseline at initial interview and 2-d intake records were obtained at monthly intervals for 4–6 mo during lactation	Mean ± SEM among vegetarians and nonvegetarians: protein (g/100 mL), 10.2 ± 1.4 vs. 9.9 ± 1.1; **selenium (ng/mL)**, **22.2 ± 0.8 vs. 16.8 ± 1.3 (*P* < 0.01)**

(*Continued*)

TABLE 1 (*Continued*)

First author, year (ref)	Country	Quality score	Study participants	Milk samples	Maternal dietary assessment	Main results
De la Presa-Owens, 1996 (23)	Spain	4	40 mothers, aged 18–39 y	Collected between 20 and 30 d postpartum, by manual expression or electric withdrawal (foremilk); samples were stored at −20°C; milk FA composition was examined	Dietary questionnaire	Lower LA (% of total FAs) content was observed between mothers consuming olive oil (n = 15) or sunflower oil (n = 6) as the preferential fat source ($P < 0.0005$); differences in DHA (% of total FAs) and EPA (% of total FAs) content between mothers reporting high fish consumption and those reporting low or no consumption were highly significant ($P < 0.001$); other specific FAs were considered
Finley, 1985 (44)	USA	7	57 mothers, aged 22–37 y	172 samples collected in the morning between 1 mo and 31 mo postpartum, by hand or manual breast pump extraction; samples were stored at −20°C; fat and FA composition in milk was examined	24-h dietary recall at initial interview, 2-d diet record monthly before breast-milk collection; women were classified as vegetarians, semivegetarians (fish eaters), and omnivores	Percentage of fat or FAs (±SDs) in breast milk and percentage of FAs (±SDs) in milk fat for vegetarians vs. nonvegetarians: milk fat, 3.21 ± 1.78 vs. 3.23 ± 2.13; lauric acid, 5.98 ± 1.81 vs. 5.08 ± 1.49; myristic acid, 8.23 ± 2.39 vs. 7.67 ± 2.60; palmitic acid, 22.50 ± 3.63 vs. 23.96 ± 2.92; stearic acid, 7.44 ± 1.53 vs. 8.70 ± 1.31; oleic acid, 30.74 ± 4.13 vs. 32.98 ± 3.51; LA, 18.38 ± 4.67 vs. 14.65 ± 4.24; ALA, 1.59 ± 0.45 vs. 1.51 ± 0.41; AA, 0.30 ± 0.10 vs. 0.28 ± 0.07; DHA, 0.05 ± 0.004 vs. 0.06 ± 0.004 None of the correlations between FAs in milk and maternal dietary intakes of total fat, animal fat, and vegetable fat were significant; partial correlation from stepwise multiple regression analysis between stearic acid in milk and maternal dietary intake of total fat, r = 0.61; maternal intake of animal fat, r = −0.02; maternal intake of vegetable fat, r = −0.56
Finley, 1985 (45)	USA	7	52 mothers; mean age: 29 y	222 samples collected in the morning between 3–4 wk postpartum and 20 mo postpartum, by hand or manual breast pump extraction; samples were stored at −20°C; protein, lactose, lipid, minerals, and trace elements in milk were examined	24-h dietary recall at initial interview, 2-d diet record monthly before breast-milk collection; women were classified as vegetarians, semivegetarians (fish eaters), and omnivores	Pearson's correlation coefficient between maternal nutrient intake and breast-milk composition: protein, 0.06; carbohydrate (correlated with milk lactose), 0.04; fat, 0.03; iron, −0.06; calcium, 0.10; magnesium, −0.08; potassium, −0.07
Kodentsova, 2006 (24)	Russia	6	25 mothers	Collected between 3 and 10 d postpartum from fasting mothers in the morning; samples were stored at −20°C; milk vitamin C, thiamin, and riboflavin were examined; vitamin C was examined in freshly expressed milk	Dietary regimen was studied during hospital stay by master menu	Pearson's correlation coefficient (P) between maternal dietary vitamin intake and milk vitamins: **vitamin C (mg/L)**, **0.841 (0.01)**; **thiamin (μg/L)**, **0.751 (0.001)**; **riboflavin (μg/L)**, **0.739 (0.001)**
Lauritzen, 2002 (25)	Denmark	7	12 mothers	Collected ∼4 mo postpartum; in the 7-d study 12 mothers provided 7 consecutive hind milk samples; samples were collected after the first feeding in the morning and stored at −80°C; milk FA composition was examined	Self-administered dietary record of the day before milk sample collection every day for 1 wk	Mean ± SD FA composition (% of total FAs) in breast milk with fatty fish (n = 11) and lean fish (n = 12) vs. no fish (n = 12) consumption: SFAs, 48.9 ± 11.6, 43.2 ± 4.6 vs. 44.1 ± 3.6; MUFAs, 36.6 ± 11.3, 39.5 ± 2.6 vs. 39.0 ± 2.1; LA, 10.0 ± 3.4, 11.0 ± 2.3 vs. 10.2 ± 1.6; AA, 0.40 ± 0.13, 0.41 ± 0.07 vs. 0.42 ± 0.06; ALA, 1.4 ± 0.5, 1.5 ± 0.5 vs. 1.4 ± 0.2; **EPA**, **0.24 ± 0.12****, 0.15 ± 0.04 vs. 0.16 ± 0.06; **DPA**, **0.31 ± 0.10***, 0.24 ± 0.06 vs. 0.25 ± 0.06; **DHA**, **0.73 ± 0.36****, 0.49 ± 0.14 vs. 0.41 ± 0.15; total n–6, 11.0 ± 3.7, 12.1 ± 2.4 vs. 11.3 ± 1.7; total n–3, **2.9 ± 1.1***, 2.7 ± 0.6 vs. 2.5 ± 0.4; total n–6-to-n–3, 3.8 ± 1.8, 4.6 ± 1.1 vs. 4.7 ± 0.8 (different from the no-fish group: *$P < 0.05$, **$P < 0.01$)

(*Continued*)

TABLE 1 (*Continued*)

First author, year (ref)	Country	Quality score	Study participants	Milk samples	Maternal dietary assessment	Main results
						Mean ± SD (*P*) DHA (% of total FAs) in breast milk with fish consumption (fatty or lean) (n = 12) vs. no fish (n = 12): **0.63 ± 0.31 vs. 0.41 ± 0.15 (0.018)**
Lee, 2013 (26)	Sri Lanka	5	119 mothers; mean ± SD age: 29.6 ± 5.8 y	Collected 6–12 mo postpartum and stored at −20°C; milk FA composition was examined	Food-frequency questionnaire evaluated average weekly consumption	Pearson's correlation coefficient (*P*) between breast-milk DHA (% of total fat) and weekly servings of specific food items: **fish**, **0.30 (<0.001)**; **milk**, **−0.30 (0.002)**; meat, −0.145 (0.132); eggs, −0.148 (0.123) Pearson's correlation coefficient (*P*) between breast-milk EPA (% of total fat) and fish: 0.16 (0.07)
Leotsinidis, 2005 (27)	Greece	6	180 mothers, aged 16–39 y	Collected 3 d postpartum, by manual expression in the morning, 2 h after the previous breastfeeding; samples were stored at −20°C; a second sample was obtained 14 d postpartum (subsample of 95 mothers); milk zinc was examined	Food-frequency questionnaire administered by a dietitian	ORs (95% CIs) for the association between maternal food consumption and breast-milk minerals: fruit (portions/wk) and zinc (μg/L), 2.87 (0.99, 8.34); **rice (portions/wk) and zinc (μg/L)**, **3.85 (1.20, 12.30)**
Makela, 2013 (28)	Finland	8	100 mothers, aged 17–43 y	Collected 3 mo postpartum, by manual expression in the morning (foremilk); samples were stored at −70°C; milk FA composition and total fat were examined	Food-frequency questionnaire covering 1 wk before milk sample collection; at the third trimester of pregnancy maternal diet was analyzed with the Index of Diet Quality	Pearson's correlation coefficient (*P*) between the Index of Diet Quality at third trimester and FA composition (% of total FAs) in breast milk: **PUFAs**, **0.25 (0.012)**; SFAs, −0.145 (0.15); MUFAs, −0.05 (0.96); total fat (mg/mL), −0.177 (0.078); the use of **fatty fish** in the last 2 d before milk sample collection was associated with a **34% increase in milk n–3 FAs (0.007)** Mean ± SD (*P*) FA composition (% of total FAs) in breast milk among women consuming vegetable oil–based spreads (n = 66) vs. other (n = 34): **PUFAs**, **15.1 vs. 12.8 (0.001)**; **total n–6**, **12.5 vs. 10.5 (<0.0001)** Pearson's correlation coefficient (*P*) between high-fat dairy products and breast-milk SFAs: **0.21 (0.04)**
Nishimura, 2014 (29)	Brazil	7	45 mothers, aged 18–35 y	Collected 5–12 wk postpartum, by manual expression, in the morning after the first feeding and before mother's breakfast; samples were stored at −80°C; milk FA composition was examined	Five 24-h dietary recalls (1 in each trimester of pregnancy and 2 postpartum), administered by a nutritionist	β (95% CIs), r^2, from linear models considering breast-milk FA content (% of total fat) as a dependent variable and maternal FA intake as an independent variable—ALA: 0.115 (−0.040, 0.271), 0.051; EPA: −0.044 (−0.338, 0.251), 0.095; DHA: 0.015 (−0.121, 0.151), 0.100; LA: 0.139 (−0.016, 0.294), 0.077; AA: 0.135 (−0.092, 0.362), 0.045; **n-3-to-n-6: 0.074 (0.006, 0.143), 0.124**
Olafsdottir, 2006 (30)	Iceland	7	77 mothers; mean ± SD age: 31 ± 4 y	Collected 2–4 mo postpartum, by either manual expression or breast pump; samples were stored at −70°C; milk FA composition was examined	Professional administered 24-h recalls and questionnaire on fish consumption and dietary habits; mothers were divided into 2 groups: consuming vs. not consuming cod liver oil	Correlation coefficient (*P*) between maternal diet and milk FA composition (% of total FAs): **maternal PUFAs:SFAs and milk LA**, **0.303 (0.007)**; **maternal PUFAs:SFAs and milk ALA**, **0.336 (0.003)**; **maternal PUFAs and milk ALA**, **0.432** (**<0.001**); **maternal PUFAs and milk EPA**, **0.302 (0.008)**; **maternal protein and milk EPA**, **0.362 (0.001)**; **maternal protein and milk DPA**, **0.373 (0.001)**; **maternal protein and milk DHA**, **0.346 (0.002)**

(*Continued*)

TABLE 1 (*Continued*)

First author, year (ref)	Country	Quality score	Study participants	Milk samples	Maternal dietary assessment	Main results
Olang, 2012 (31)	Iran	8	106 mothers, aged 14–43 y	Collected 8–72 h after delivery by hand pumping and stored at −20°C; milk FA composition was examined	Food-frequency questionnaire referring to diet during pregnancy administered by a researcher	Mean ± SD FA composition (molar % concentration) in breast milk for non/seldom intakes (n = 64), 1 portion/wk (n = 25), and ≥2 portions/wk (n = 17) of fish and seafood during pregnancy—**DHA**: 0.52 ± 0.23, 0.62 ± 0.27, and **0.69 ± 0.34***; **AA/DHA**: 3.2 ± 2.4, **2.4 ± 1.1***, and **2.45 ± 1.6*** (different from non/seldom, *$P < 0.05$)
Ortega, 1999 (32)	Spain	8	57 mothers, aged 18–35 y	Collected at 13–14 d (transitional milk) and 40 d (mature milk); samples were collected during morning hours at the beginning and end of feeding by manual expression and were stored at −20°C; milk vitamin E was examined	5-d dietary record verified by a nutritionist	Mean ± SD (P) vitamin E (μmol/L) in breast milk among mothers with vitamin E intake <75% of RI (= 15 mg/d) (n = 39) vs. vitamin E intake ≥75% of RI (n = 18): **3.80 ± 1.32 vs. 5.01 ± 1.81 (<0.05) in transitional milk**; 2.20 ± 0.72 vs. 2.27 ± 0.77 in mature milk
Ortega, 1997 (33)	Spain	8	57 mothers, aged 18–35 y	Collected at 13–14 d (transitional milk) and 40 d (mature milk); samples were collected during morning hours at the beginning and end of feeding by manual expression and were stored at −20°C; milk zinc was examined	5-d dietary record verified by a nutritionist	Correlation coefficient (P) between maternal zinc intake and content of zinc in transitional milk (**r = 0.35, P < 0.05**) and zinc in mature milk (**r = 0.45, P < 0.05**) Mean ± SD (P) zinc (μmol/L) in breast milk among mothers with zinc intakes <50% of RI (= 20 mg/d) (n = 25) vs. vitamin E intake ≥50% of RI (n = 32): 46.7 ± 7.3 vs. 51.0 ± 9.2 in transitional milk; **28.7 ± 6.2 vs. 33.1 ± 8.0 (<0.05) in mature milk**
Quinn, 2012 (34)	Philippines	6	102 mothers; age range: 23–24 y	A single morning sample collected 0–18 mo postpartum; samples were collected by manual expression and stored at −35°C; milk energy, fat, protein, and sugar were examined	Single dietary recall administered by an interviewer	R^2 from unadjusted linear regression model between maternal EI (kcal/d) and breast-milk content: EI (kcal/d), 0.02; fat (% of EI), 0.02; sugar (% of EI), 0.07
Rist, 2007 (35)	Netherlands	6	312 mothers (mean ± SD age): (1) nonorganic diet (32.5 ± 3.8 y); (2) 50–90% organic, both meat and dairy products (34.2 ± 3.6 y); (3) >90% organic, both meat and dairy products (35.4 ± 4.0 y); (4) other combination of organic meat and organic dairy products (33.9 ± 3.7 y)	Collected 1 mo postpartum in the morning, before breastfeeding, either by manual expression or electric breast pump; samples were stored at −80°C; milk FA composition was examined	Self-administered food-frequency questionnaire in week 34 of the pregnancy; participants specified whether the aliments had originated from conventional or organic production (<50%, 50–90% or >90% of the food, within the corresponding food group)	Mean ± SD FA composition (% of total FAs) in breast milk among (1) nonorganic diet (n = 186); (2) 50–90% organic diet, both meat and dairy products (n = 33); (3) >90% organic diet, both meat and dairy products (n = 37); and (4) other combination of organic meat and organic dairy products (n = 56)—total SFAs: (1) 40.71 ± 4.33, (2) 42.25 ± 5.82, (3) 41.91 ± 5.36, (4) 42.07 ± 4.75; **total MUFAs**: (1) 40.84 ± 3.08, (2) 39.48 ± 4.12, **(3) 38.57 ± 3.20*****, (4) 40.28 ± 3.97; total PUFAs: (1) 18.45 ± 3.53, (2) 18.27 ± 4.36, (3) 19.51 ± 4.67, (4) 17.66 ± 2.95; **ALA**: (1) 1.05 ± 0.38, **(2) 0.89 ± 0.41***, **(3) 0.82 ± 0.28*****, **(4) 0.93 ± 0.27***; LA: (1) 13.73 ± 3.19, (2) 13.81 ± 4.28, (3) 14.90 ± 4.40, (4) 13.06 ± 2.87; **rumenic acid**: (1) 0.25 ± 0.07, **(2) 0.29 ± 0.10***, **(3) 0.34 ± 0.10*****, (4) 0.27 ± 0.11; palmitic acid: (1) 22.62 ± 2.30, (2) 22.79 ± 2.54, (3) 22.63 ± 2.86, (4) 23.21 ± 2.57; stearic acid: (1) 7.02 ± 1.48, (2) 6.60 ± 1.49, (3) 6.87 ± 1.15, (4) 6.95 ± 1.66; **myristic acid**: (1) 5.63 ± 1.50, **(2) 6.65 ± 1.74****, **(3) 6.42 ± 1.78***, **(4) 6.20 ± 1.80***; lauric acid: (1) 4.56 ± 1.70, (2) 4.95 ± 1.90, (3) 4.69 ± 1.52, (4) 4.61 ± 1.57; *trans*-vaccenic acid: (1) 0.48 ± 0.21, (2) 0.54 ± 0.26, (3) 0.59 ± 0.16***, (4) 0.53 ± 0.16* (different from the conventional group: *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$); other specific FAs were considered

(*Continued*)

TABLE 1 (*Continued*)

First author, year (ref)	Country	Quality score	Study participants	Milk samples	Maternal dietary assessment	Main results
Roepke, 1979 (36)	USA	5	61 mothers; age range: 18–37	Collected in the early morning between 3rd and 14th day postpartum, by manual expression; samples were stored at −30°C; milk vitamin B-6 was examined	Self-administered 24-h diet recall and a 3-d diet record, in accordance with instructions given by a dietitian	Mean ± SE (*P*) milk vitamin B-6 (μg/L) among mothers with dietary intakes of vitamin B-6 ≤2.5 vs. >2.5 mg/d: **8.1 ± 1.5 vs. 16.1 ± 3.0 (0.02)** at 3 d postpartum; 40.1 ± 1.03 vs. 57.4 ± 7.2 (0.05) at 14 d postpartum
Salmenpera, 1984 (37)	Finland	7	47 mothers	All collected at 2, 4, 6, 9, and 12 mo and in the exclusively breastfed infants also at 7.5, 10, and 11 mo; in addition a maternal sample was collected on the third or fourth day postpartum; all samples were obtained after breakfast and before mother's lunch; milk vitamin C was examined	7-d food consumption record collected on 2 occasions: 1–2 and 4–5 mo postpartum, in accordance with instructions given by a dietitian	Pearson's correlation coefficient (*P*) between maternal dietary intake and breast-milk concentration of vitamin C (mg/100 mL): **0.39 (<0.01)** at 1–2 mo; **0.46 (<0.01)** at 4–5 mo
Scopesi, 2001 (38)	Italy	7	34 mothers, aged 25–35 y	Collected on day 1 postpartum (colostrum); days 4 and 7 (transitional milk); and days 14, 21, and 28 (mature milk) after colostrum appearance by manual expression and stored at −20°C; milk FA composition was examined	6 dietary questionnaires administered 1 d postpartum and on days 4, 7, 14, 21, and 28 after colostrum appearance; referred to maternal dietary intake from the previous day	Pearson's correlation coefficient (*P*) between maternal dietary intake and corresponding breast-milk concentrations (% of total FAs): **SFAs**, **0.60 (<0.01) in transitional milk**; **MUFAs**, **0.63 (<0.01) in transitional milk**; **PUFAs**, **0.65 (*P* < 0.01) in mature milk**
Valent, 2011 (39)	Italy	8	100 mothers (82 exclusively breastfeeding), aged 18–42 y	Collected 3 mo postpartum, without indication of the time of the day or with regard to the infant's feeding; samples were collected by manual expression and stored at −20°C; milk selenium was examined	Semistructured questionnaire administered by trained interviewers ∼3 mo postpartum referred to maternal dietary intake during pregnancy and lactation	Spearman's correlation coefficients (*P*) between weekly intakes of food items/groups during pregnancy and selenium breast-milk concentrations: vegetables (servings), −0.02 (0.80); fruit (servings), −0.18 (0.07); milk and dairy products (servings), −0.16 (0.12); meat (servings), −0.06 (0.54); all fish and seafood (servings), 0.12 (0.22); pasta, rice, bread, pizza, and cakes (servings), −0.01 (0.89); **eggs (1/wk)**, **0.20 (0.04)**; other food items were considered
Vuori, 1980 (40)	Finland	7	15 mothers, aged 24–35 y	Collected at the beginning and end of each feeding during 24 h and then pooled, 6–8 wk and 17–22 wk postpartum; milk iron and zinc were examined	Two self-administered 7-d food records, in accordance with instructions provided, collected 6–8 wk and 17–22 wk postpartum	Correlation coefficient (*P*) between EI (kcal) and breast-milk minerals (mg): **iron**, **0.478 (<0.01)**; **zinc**, **0.554 (<0.01)**
Xiang, 2005 (41)	China and Sweden	5	23 Chinese mothers; mean ± SD age: 27.4 ± 0.8 y; 17 Swedish mothers; mean ± SD age: 29.5 ± 1.0; all exclusively breastfeeding	A single sample collected 3 mo postpartum by manual expression and stored at −70°C; milk FA composition was examined	Self-administered 3-d dietary record collected at third month postpartum	Pearson's correlation coefficient (*P*) between dietary intake of DHA (g/d) and breast-milk DHA (% of total FAs): **0.71** (<0.001) among Chinese mothers and **0.54** (<0.05) among Swedish mothers

[1]Significant results (when not otherwise specified, $P < 0.05$) are shown in bold type. AA, arachidonic acid; ALA, α-linolenic acid; DPA, docosapentaenoic acid, EI, energy intake; FA, fatty acid, LA, linoleic acid; ref, reference; RI, recommended intake; TFA, *trans* fatty acid.

Main results

Hereafter, we describe the results concerning the relations between maternal nutrition and breast-milk nutritional properties reported in the identified articles, ordered by type of milk component examined. We do not report results from studies with a quality score <6 and those for FA ratios.

A synthesis of the main results reported in the studies is provided in **Supplemental Tables 1** and **2**, which report the quantitative measures used to evaluate the relation between breast-milk nutritional properties and nutrients in the maternal diet (Supplemental Table 1) and any other maternal dietary characteristic (Supplemental Table 2).

Total energy

A crossover study from the United States reported a higher breast-milk total energy content for a diet low in carbohydrate and high in fat than with a diet high in carbohydrate and low in fat (654 compared with 619 kcal/d; $P < 0.05$) (49). However, an observational study from the Philippines did not find an influence of maternal energy intake on breast-milk total energy (34).

Total protein

A crossover study from Sweden reported a higher breast-milk total protein content for a maternal diet high in protein than with a low-protein diet (8.83 compared with 7.31 g/d; $P < 0.05$) (47); in the same study, no difference was observed for lactoferrin and α-lactalbumin in breast milk. Other studies from Europe and the United States did not report any relation between breast-milk total protein and a diet rich in carbohydrate and poor in fat compared with a diet low in carbohydrate and high in fat (49) or a vegetarian compared with a nonvegetarian diet (44) or between breast-milk total protein content and maternal total energy (21), total protein (21), animal protein (21), or vegetable protein (21) intakes.

Fat

A crossover study from the United States found a higher proportion of breast-milk total fat with a maternal diet characterized by low carbohydrate and high fat compared with a high-carbohydrate, low-fat diet (4.8 compared with 4.3 g/dL; $P < 0.05$) (49). Another crossover study reported a higher concentration of total fat in milk with the high-dairy diet than with the low-dairy diet (45.6 compared with 38.3 mg/g; $P < 0.05$) (51). However, no relation was observed between breast-milk total fat and the Index of Diet Quality in the third trimester of pregnancy (28), a diet rich in phytosterols and PUFAs and poor in cholesterol (48), a vegetarian compared with a nonvegetarian diet (45), or with maternal total energy (20, 34), total fat (20), total MUFA (20), total PUFA (20), total SFA (20), carbohydrate (20), and total protein (20) intakes.

A crossover study from the United States reported a higher value of breast-milk phytosterols with a maternal diet rich in phytosterols and PUFAs and poor in cholesterol than with a diet rich in cholesterol and poor in phytosterols and PUFAs (2.2 compared with 0.7 mg fat/g milk; $P < 0.0001$) (48). In the same study, no difference was observed in breast-milk cholesterol in the 2 dietary regimens.

SFAs

An Italian observational study found a positive correlation between total SFAs in transitional breast milk (collected 4–7 d postpartum) and maternal dietary intake ($r = 0.60$, $P < 0.01$) (38). A Finnish observational study reported a moderate positive correlation between breast-milk total SFAs and maternal intakes of high-fat dairy products ($r = 0.21$, $P = 0.04$) (28). However, other studies from Europe and North America did not find any relation between breast-milk total SFAs and maternal total energy, total fat, total MUFA, total PUFA, total SFA, carbohydrate, total protein intakes (20); fish consumption compared with no fish consumption (25); a high-fat compared with a low-fat diet (50); a strict organic diet compared with a nonorganic diet (35); or with the Index of Diet Quality in the third trimester of pregnancy (28).

A Canadian crossover study found a higher proportion of breast-milk lauric acid with a low-fat diet than with a high-fat diet (5.38% compared with 3.98%; $P = 0.01$) (50). However, no difference in breast-milk lauric acid was observed with a hydrogenated- compared with a non–hydrogenated-fat diet (46), consumers of organic products (>90% of both dairy products and meats from organic production) compared with consuming a nonorganic diet (35), or a vegetarian compared with a nonvegetarian diet (44).

A crossover study from the United States found a higher proportion of breast-milk myristic acid with a diet including nonhydrogenated fat than with a diet with hydrogenated fat (6.58% compared with 4.24%; $P < 0.01$) (46). A Dutch study reported a higher breast-milk myristic acid content among mothers with a strict organic diet than for those with a nonorganic diet (6.42% compared with 5.63%; $P < 0.05$) (35). Another crossover study from the United States found a higher value of breast-milk myristic acid with the high-dairy diet than with the low-dairy diet (264.7 compared with 195.2 μmol/g fat; $P < 0.05$) (51). However, other studies from North America and Europe reported no difference in breast-milk myristic acid between mothers with a low-fat and a high-fat diet (50), for mothers consuming a diet with a high PUFA-to-SFA ratio compared with a standard hospital diet (52), or for vegetarian compared with nonvegetarian mothers (44).

A crossover study from the United States reported a higher breast-milk palmitic acid among consumers of a diet rich in dairy products than in mothers consuming a diet low in dairy products (707.0 compared with 511.3 μmol/g fat; $P < 0.05$) (51). Another crossover study from the United States reported a higher proportion of palmitic acid for the nonhydrogenated fat diet than with the hydrogenated fat diet (27.85% compared with 23.93%; $P < 0.01$) (46). Another experimental study reported a lower proportion of palmitic acid with a diet with a high PUFA-to-SFA ratio than with a standard hospital diet (26.16% compared with 29.95%; $P < 0.001$) (52). However, other studies from North America and Europe did not find any difference in breast-milk palmitic acid with regard to a low-fat compared with a high-fat diet (50), a vegetarian compared with a nonvegetarian diet (44), or an organic compared with a nonorganic diet (35).

A Canadian crossover study reported a higher proportion of breast-milk stearic acid with a high-fat diet than with a low-fat diet (6.08% compared with 5.00%; $P = 0.01$) (50). Another crossover study from the United States reported a higher breast-milk stearic acid content with a high-dairy diet than with a low-dairy diet (219.0 compared with 154.3 μmol/g fat; $P < 0.05$) (51). A Finnish experimental study reported a lower proportion of breast-milk stearic acid with a diet with a high PUFA-to-SFA ratio than with a standard hospital diet (7.63% compared with 9.60%; $P < 0.001$) (52). However, no difference in breast-milk

TABLE 2
Experimental studies on the relation between maternal diet and breast-milk composition[1]

First author, year (ref)	Country	Quality score	Study design	Study participants	Milk samples	Maternal diet	Main results
Craig-Schmidt, 1984 (46)	USA	7.5	Crossover experimental study	8 mothers, all exclusively breastfeeding, aged 21–36 y	Collected daily 2 mo postpartum during the 5 d of both dietary periods, as well as on the day after each dietary period; samples were collected by manual expression after the first nursing period of the day and stored at −80°C ; milk FA composition was examined	Two 5-d diets (with an intervening 2-d period) identical except for the sources of fat: H vs. NH	Mean ± common SEM (*P*) FA composition (% of total FAs) in breast milk for diet with H vs. NH fat source: lauric acid, 2.66 vs. 3.52 ± 0.30; **myristic acid**, **4.24 vs. 6.58 ± 0.23 (<0.01)**; **palmitic acid**, **23.93 vs. 27.85 ± 0.87 (<0.01)**; **palmitoleic acid**, **2.54 vs. 2.85 ± 0.07 (<0.05)**; stearic acid, 7.34 vs. 7.09 ± 0.35; **elaidic acid**, **6.53 vs. 1.84 ± 0.33 (<0.01)**; **oleic acid**, **33.35 vs. 31.57 ± 0.46 (<0.05)**; LA, 12.98 vs. 14.40 ± 0.85; other specific FAs were considered
Forsum, 1980 (47)	Sweden	7	Crossover experimental study	3 mothers, aged 27–30 y	Collected 13–20 wk postpartum on the fourth day of both experimental diets, before and after feeding; samples were collected by manual expression or by a manual breast pump and stored at −20°C; milk protein and nitrogen composition were examined	4 d of low-protein diet, 1 d of washout, and then 4 d of high-protein diet	Mean ± SD (*P*) protein content in breast milk (g/d) for low-protein diet vs. high-protein diet: **true protein**, **7.31 ± 0.74 vs. 8.83 ± 0.44 (<0.05)**; lactoferrin, 2.52 ± 0.17 vs. 3.01 ± 0.36; α-lactalbumin, 1.50 ± 0.20 vs. 1.75 ± 0.12; lactose, 58.1 ± 13.2 vs. 63.5 ± 5.6
Mellies, 1978 (48)	USA	7	Crossover experimental study	14 mothers	Collected 1 mo postpartum, and subsequently 1 time/wk, at the beginning or end of the second nursing period of the day, by either manual expression or breast pump; samples were frozen; milk cholesterol, phytosterols, and total fat were examined	2-wk baseline nutrition history collected 1 mo postpartum by a nutritionist; mothers were randomly assigned to 1 of the diets followed by the other; diet 1: cholesterol-poor, phytosterol-rich, polyunsaturated-rich (PUFAs:SFAs: 1.8); diet 2: cholesterol-rich, phytosterol-poor, polyunsaturated-poor (PUFAs:SFAs: 0.12)	Means ± SEs for baseline diet vs. diet 1 vs. diet 2: milk cholesterol (mg/g milk fat), 2.4 ± 0.4 vs. 2.4 ± 0.1 vs. 2.5 ± 0.2; milk phytosterols (mg/g milk fat), **0.17 ± 0.03 vs. 2.2 ± 0.3* vs. 0.7 ± 0.1**; total milk fat, 3.58 ± 0.56 vs. 2.69 ± 0.16 vs. 2.66 ± 0.16 (**P* < 0.0001)
Mohammad, 2009 (49)	USA	7	Crossover experimental study	7 mothers; mean ± SD age: 29.3 ± 1.0 y	Collected between 6 and 14 wk postpartum for 4 d and 3 nights; samples were collected every 3 h at the beginning, middle, and end of feeding (8 samples daily), by breast pump; milk energy, lactose, protein, and fat were examined	Two 8-d diets (separated by 1–2 wk): H-F diet (30% carbohydrate, 55% fat, 15% protein) vs. H-CHO diet (60% carbohydrate, 25% fat, 15% protein)	Mean ± SEM (significant at *P* < 0.05) breast-milk composition for H-CHO vs. H-F diet: **EI (kcal/d)**, **619 ± 23 vs. 654 ± 24**; lactose (g/dL), 7.3 ± 0.2 vs. 7.3 ± 0.2; lactose (g/d), 0 ± 3 vs. 60 ± 2; protein (g/dL), 1.8 ± 0.1 vs. 1.9 vs. 0.1; protein (g/d), 15 ± 0.9 vs. 16 ± 0.8; **fat (g/dL)**, **4.3 ± 0.3 vs. 4.8 ± 0.3; fat (g/d)**, **34 ± 2 vs. 39 ± 2**

(Continued)

TABLE 2 (*Continued*)

First author, year (ref)	Country	Quality score	Study design	Study participants	Milk samples	Maternal diet	Main results
Nasser, 2010 (50)	Canada	7.5	Crossover experimental study	14 mothers, exclusively breastfeeding, aged 18–40 y	Collected between 2 and 6 mo postpartum, the third and fourth day of each controlled dietary period; samples were collected by a manual breast pump and stored at −70°C; milk FA composition was examined	Women were randomly assigned to receive each dietary intervention (low-fat and high-fat diet) for 4 d, each with a washout period of 3 d, during which mothers consumed their usual diet (evaluated through a 3-d dietary record); low-fat diet: fat = 17.6% of EI, protein = 14.4% of EI, carbohydrate = 68.0 of EI; high-fat diet: fat = 40.3% of EI, protein = 14.4% of EI, carbohydrate = 45.3 of EI	Mean ± SEM (*P*) FA composition (% of total FAs) in breast milk for low-fat vs. high-fat diet: total SFAs, 41.1 ± 0.82 vs. 40.40 ± 0.85 (0.46); **lauric acid**, **5.38 ± 1.16 vs. 3.98 ± 0.37 (0.01)**; myristic acid, 7.31 ± 0.35 vs. 6.76 ± 0.48 (0.07); palmitic acid, 22.70 ± 0.45 vs. 23.43 ± 0.24 (0.43); **stearic acid**, **5.00 ± 0.11 vs. 6.08 ± 0.14 (0.01)**; MUFAs, 38.70 ± 0.80 vs. 39.90 ± 0.65 (0.10); **palmitoleic acid**, **1.95 ± 0.29 vs. 1.31 ± 0.23 (0.046)**; oleic acid, 36.16 ± 0.86 vs. 37.81 ± 0.67 (0.08); PUFAs, 16.90 ± 0.66 vs. 16.40 ± 0.48 (0.54); LA, 14.65 ± 0.62 vs. 13.82 ± 0.45 (0.27); **ALA**, **1.22 ± 0.04 vs. 1.69 ± 0.06 (0.01)**; **AA**, **0.34 ± 0.01 vs. 0.30 ± 0.02 (0.02)**; DHA, 0.12 ± 0.02 vs. 0.14 ± 0.04 (0.77); other specific FAs were considered
Park, 1999 (51)	USA	7	Crossover experimental study	16 mothers, aged 21–38 y	Collected between 1 and 26 mo postpartum on days 3 and 7 in each period; samples were collected by electric breast pump and stored at −80°C; milk rumenic acid and FA composition were examined	Women were asked to consume diets low in rumenic acid throughout the experiment (3 wk), except during the assigned week; group A: high-fat dairy period during week 2; group B: high-fat dairy period during week 3; current intakes of rumenic acid were estimated by using dietary records during the last 3 d of each period; usual intakes of rumenic acid were estimated by using a semiquantitative food-frequency questionnaire	Pearson's correlation coefficient between milk rumenic acid concentration (μmol/g fat) and current dietary intake: rumenic acid (mg) **0.32**; oleic acid (g), **−0.41**; MUFAs (g), **0.38** Mean ± SEM (significant at $P < 0.05$) FA composition (μmol/g fat) in breast milk for high- vs. low-dairy periods: **rumenic acid**, **13.5 ± 1.1 vs. 8.2 ± 0.4; myristic acid**, **264.7 ± 34.3 vs. 195.2 ± 11.0; palmitic acid**, **707.0 ± 51.5 vs. 511.3 ± 16.4;** palmitoleic acid, 81.7 ± 10.2 vs. 65.8 ± 3.1; **stearic acid**, **219.0 ± 23.1 vs. 154.3 ± 7.4**; **oleic acid**, **1055.0 ± 103.4 vs. 874.3 ± 33.3**; LA, 328.2 ± 56.5 vs. 419.2 ± 18.1; **ALA**, **10.7 ± 3.6 vs. 17.6 ± 1.2** Mean ± SD (significant at $P < 0.05$) lipid concentration in breast milk (mg/g) for high- vs. low-dairy periods: **45.6 ± 5.0 vs. 38.3 ± 1.6**

(*Continued*)

TABLE 2 (*Continued*)

First author, year (ref)	Country	Quality score	Study design	Study participants	Milk samples	Maternal diet	Main results
Uhari, 1985 (52)	Finland	7	Experimental study	34 mothers admitted to 1 of 3 postpartum wards after delivery	Collected on days 3, 4, and 5 postpartum in the morning, at the end of feeding; samples were collected from mothers with extra excretion and stored at −60°C; milk FA composition was examined	Standard hospital diet (PUFAs:SFAs = 0.1) vs. experimental diet high in PUFAs:SFAs (PUFAs:SFAs = 1.5)	Mean ± SD (significant at $P < 0.001$) FA composition (% of total FAs) in breast milk for ordinary (n = 15) vs. experimental (n = 19) diets 3 d postpartum: ALA, 0.60 ± 0.07 vs. 0.64 ± 0.08; AA, 0.70 ± 0.17 vs. 0.81 ± 0.18; EPA, 0.09 ± 0.03 vs. 0.09 ± 0.02; DHA, 0.66 ± 0.17 vs. 0.62 ± 0.16; myristic acid, 7.68 ± 1.14 vs. 7.53 ± 1.52; **palmitic acid**, **29.95** ± **2.14 vs. 26.16** ± **2.00**; palmitoleic acid, 3.00 ± 0.53 vs. 2.92 ± 0.59; **stearic acid**, **9.60** ± **1.03 vs. 7.63** ± **1.00**; **oleic acid**, **35.79** ± **2.32 vs. 31.05** ± **2.57**; **LA**, **8.07** ± **1.93 vs. 18.66** ± **4.52** Mean ± SD FA composition (% of total FAs) in breast milk for ordinary (n = 15) vs. experimental (n = 19) diets 4–5 d postpartum (significant at $P < 0.05$): ALA, 0.60 ± 0.18 vs. 0.69 ± 0.09; AA, 0.59 ± 0.09 vs. 0.68 ± 0.18; EPA, 0.09 ± 0.02 vs. 0.09 ± 0.03; DHA, 0.55 ± 0.13 vs 0.59 ± 0.14 Other specific FAs were considered

[1]Significant results (when not otherwise specified, $P < 0.05$) are shown in bold type. AA, arachidonic acid; ALA, α-linolenic acid; EI, energy intake; FA, fatty acid, H, hydrogenated fat; H-CHO, high-carbohydrate and low-fat; H-F, low-carbohydrate and high-fat; LA, linoleic acid; NH, nonhydrogenated fat; ref, reference.

stearic acid was observed for hydrogenated compared with nonhydrogenated fat in the diet (46), a vegetarian compared with a nonvegetarian diet (44), or for an organic compared with a nonorganic diet (35).

An observational study from the United States reported a higher proportion of breast-milk *trans*-vaccenic acid among mothers who consumed an organic diet than in those who consumed a nonorganic diet (0.59% compared with 0.48%; $P < 0.001$) (35). An observational study from Malaysia observed no significant correlation between breast-milk vaccenic acid and maternal intakes of elaidic acid, linoelaidic acid, or total TFAs (22).

MUFAs

An Italian observational study found a positive correlation between total MUFAs in transitional milk (collected 4–7 d postpartum) and total MUFAs in maternal nutrition ($r = 0.63$, $P < 0.01$) (38). A Dutch observational study reported a lower proportion of breast-milk total MUFAs among mothers consuming a strict organic diet than in mothers consuming nonorganic foods (38.57% compared with 40.84% of total FAs) (35). Other studies from Europe and North America did not report significant relations between breast-milk MUFAs and maternal total energy, total fat, PUFA, total SFA, carbohydrate, or total protein intakes (20); the Index of Diet Quality in the third trimester of pregnancy (28); fatty fish consumption compared with no fish consumption (25); or a low-fat diet compared with a high-fat diet (50).

A crossover study from the United States showed a higher proportion of breast-milk oleic acid with a diet that included hydrogenated fat than with a non–hydrogenated-fat diet (33.35% compared with 31.57%; $P < 0.05$) (46). A Finnish experimental study reported a lower proportion of oleic acid in colostrum for the experimental diet with a higher PUFA-to-SFA ratio than with a standard hospital diet (35.79% compared with 31.05%; $P < 0.001$) (52). Another crossover study from the United States reported a higher content of breast-milk oleic acid with a diet rich in dairy products than with a low-dairy diet (1055.0 compared with 874.3 μmol/g fat; $P < 0.05$) (51). However, in 2 studies from North America, no difference was observed in the proportion of breast-milk oleic acid on total FAs with a low-fat compared with a high-fat diet (50) or with a vegetarian compared with a nonvegetarian diet (44).

In the same study from Canada, the proportion of breast-milk palmitoleic acid on total FAs was higher with the low-fat diet than with the high-fat diet (1.95 compared with 1.31 g/100 g total FAs; $P = 0.046$) (50). The crossover study from the United States reported a higher proportion of breast-milk palmitoleic acid with the non–hydrogenated-fat diet than with the hydrogenated-fat diet (2.85% compared with 2.54%; $P < 0.05$) (46). However, no significant difference in breast-milk palmitoleic acid was observed in 2 experimental studies that considered high- compared with low-dairy diets (51) and a diet with a high PUFA-to-SFA ratio compared with a standard hospital diet (52).

PUFAs

A Greek observational study showed significant correlations between breast-milk total PUFAs and maternal intakes of MUFAs ($r = 0.29$, $P < 0.05$) and total PUFAs ($r = 0.25$, $P < 0.05$) (20). An Italian observational study found a positive correlation between breast-milk total PUFAs and maternal intakes of total PUFAs ($r = 0.65$, $P < 0.01$) (38). A Finnish observational study reported a correlation between breast-milk PUFAs and the Index of Diet Quality in the third trimester of pregnancy ($r = 0.25$, $P = 0.012$) (28). In the same study, the proportion of breast-milk PUFAs was higher among women who consumed vegetable oil–based spreads than in those who consumed other fat (15.1% compared with 12.8%; $P < 0.001$) (28). Again, other studies from Europe and North America reported no significant relation between breast-milk total PUFAs and maternal total energy, total fat, SFA, carbohydrate, and total protein intakes (20); a strict organic compared with a nonorganic diet (35); or a low-fat compared with a high-fat diet (50).

An observational study from Iceland reported a positive correlation between breast-milk LA and PUFA-to-SFA ratio in the maternal diet ($r = 0.30$, $P = 0.007$) (30). An observational study from Greece reported a positive correlation between breast-milk LA and both maternal dietary MUFAs ($r = 0.26$, $P < 0.05$) and PUFAs ($r = 0.26$, $P < 0.05$) (20). A Finnish experimental study found a higher proportion of colostrum LA with a diet characterized by a high PUFA-to-SFA ratio than with a standard hospital diet (18.66% compared with 8.07%; $P < 0.001$) (52). A Spanish observational study found a lower breast-milk LA content among mothers who consumed olive oil than in those who consumed sunflower oil ($P < 0.0005$) (23). However, a number of studies from Europe, North America, and South America found no associations between breast-milk LA and maternal total energy, total fat, SFA, carbohydrate, total protein intakes (20), LA intake (29), consumption of fatty fish compared with no consumption of fish (25), a strict organic diet compared with a nonorganic diet (35), a low-fat compared with a high-fat diet (50), a hydrogenated-fat compared with a non–hydrogenated-fat diet (46), a high- compared with a low-dairy diet (51), or a vegetarian compared with a nonvegetarian diet (44).

The observational study from Iceland reported a positive correlation between the proportion of ALA on total FAs and maternal intakes of PUFAs ($r = 0.43$, $P < 0.001$) and maternal PUFA-to-SFA ratio ($r = 0.34$, $P = 0.003$) (30). Another observational study from the Netherlands showed a lower proportion of breast-milk ALA with a strict organic diet than with nonorganic diet (0.82% compared with 1.05%; $P < 0.001$) (35). A crossover study from Canada reported a higher breast-milk ALA content with a high-fat diet than with low-fat diet (1.69% compared with 1.22%; $P = 0.01$) (50). Another crossover study showed a higher proportion of breast-milk ALA with a low-dairy diet than with a high-dairy diet (17.6 compared with 10.7 μmol/g fat; $P < 0.05$) (51). However, other studies from North and South America and Europe did not show any influence on breast-milk ALA with maternal intakes of ALA (29), fish (25), vegetarian or nonvegetarian diet (44), or with a diet with a high PUFA-to-SFA compared with a standard hospital diet (52).

A Greek observational study reported that breast-milk n–3 PUFA content was positively correlated with maternal dietary intakes of total PUFAs ($r = 0.26$, $P < 0.05$), inversely correlated with maternal carbohydrate intakes ($r = –0.29$, $P < 0.05$), and unrelated to maternal total energy, total fat, total MUFA, total SFA, and total protein intakes (20). An observational study from Denmark reported a higher breast-milk n–3 PUFA content among mothers who consumed fatty fish than in mothers who did not eat fish (2.9% compared with 2.5%; $P < 0.05$) (25). A Finnish observational study found that fatty fish consumption was associated with a 34% increase in the content of breast-milk n–3 PUFAs (28). In the Greek observational study, breast-milk n–6 PUFA content was positively correlated with maternal dietary intakes of total MUFAs ($r = 0.27$, $P < 0.05$) but not with total energy, total fat, total PUFA, total SFA, carbohydrate, and total protein intakes (20). The Finnish observational study reported a higher breast-milk n–6 PUFA content among mothers who consumed vegetable oil–based spreads (12.5% compared with 10.5%; $P < 0.0001$) (28). However, another study from Denmark reported no association between fish consumption and breast-milk n–6 PUFAs (25).

An observational study from Iceland showed a positive correlation between DHA in breast milk and maternal intakes of total protein ($r = 0.35$, $P = 0.002$) (30). A Greek observational study showed a positive correlation between DHA in breast milk and maternal intakes of total fat ($r = 0.25$, $P < 0.05$) and total PUFAs ($r = 0.27$, $P < 0.05$) and an inverse association with carbohydrate intake ($r = –0.28$, $P < 0.05$) (20). A Danish observational study reported a higher proportion of breast-milk DHA in mothers who consumed fish than in mothers who did not consume fish (0.63% compared with 0.41%; $P = 0.018$) and in women who consumed fatty fish compared with mothers who did not consume fish (0.73% compared with 0.41%; $P < 0.01$) (25). Another observational study from Iran showed a higher concentration of breast-milk DHA among mothers who consumed 2 portions of fish/wk during pregnancy than in mothers who did not consume fish (0.69% compared with 0.52%; $P < 0.05$) (31). In contrast, other studies from North America, South America, Europe, and Asia found no significant relation between breast-milk DHA and maternal intakes of DHA (29); total energy, total MUFA, and total SFA intakes (20); a high- compared with a low-fat diet (50); a vegetarian compared with a nonvegetarian diet (44); or a diet with a high PUFA-to-SFA ratio compared with a standard hospital diet (52).

A crossover study from Canada showed a higher proportion of breast-milk AA with a low-fat diet than with a high-fat diet (0.34% compared with 0.30%; $P = 0.02$) (50). However, other studies from North America and Europe reported no significant relation between breast-milk AA and maternal dietary intakes of AA (29); total energy, total fat, total MUFA, total PUFA, total SFA, carbohydrate, and total protein intakes (20); fish consumption (25); a vegetarian compared with a nonvegetarian diet (44); or with a diet with a high PUFA-to-SFA ratio compared with a standard hospital diet (52).

The observational study from Iceland reported a positive correlation between breast-milk EPA and maternal total PUFA ($r = 0.30$, $P = 0.008$) and total protein ($r = 0.36$, $P = 0.001$) intakes (30). The observational study from Denmark reported a higher proportion of breast-milk EPA among mothers who consumed fatty fish than in those who did not consume fish (0.24% compared with 0.16%; $P < 0.01$) (25). However, other studies from South America and Europe did not find any relation between breast-milk EPA and maternal dietary intakes of EPA (29) or with a diet with a high PUFA-to-SFA ratio compared with a standard hospital diet (52).

The observational study from Iceland also reported a positive correlation between breast-milk DPA and maternal total protein intakes ($r = 0.37$, $P = 0.001$) (30). The observational study from Denmark reported a higher proportion of breast-milk DPA among mothers who consumed fatty fish than in those who did not consume fish (0.31% compared with 0.25%; $P < 0.01$) (25).

TFAs

An observational study from Malaysia reported no correlations between maternal dietary intakes of fruit and vegetables and breast-milk total TFAs (22). In the same study, a positive association was reported between breast-milk total TFAs and dietary elaidic acid ($r = 0.48$, $P < 0.05$).

In a crossover study from the United States, the proportion of breast-milk elaidic acid was higher with a diet that included hydrogenated fat than with a non–hydrogenated-fat diet (6.53% compared with 1.84%; $P < 0.01$) (46).

A Dutch observational study reported a higher proportion of breast-milk rumenic acid with a strict organic diet than with a nonorganic diet (0.34% compared with 0.25%; $P < 0.001$) (35). An experimental study from the United States reported a higher breast-milk rumenic acid content with a high-dairy diet than with a low-dairy diet (13.5 compared with 8.2 μmol/g fat; $P < 0.05$) (51). In the same study, a positive correlation was observed between breast-milk rumenic acid and maternal dietary intakes of rumenic acid ($r = 0.32$) and total MUFAs ($r = 0.38$), whereas an inverse correlation was found with maternal intakes of oleic acid ($r = –0.41$) (51).

Carbohydrate

No significant relations were found between breast-milk total carbohydrate and maternal dietary energy intakes (34) or with a vegetarian compared with a nonvegetarian diet (45); in addition, no significant relations were found between breast-milk lactose and a high-protein diet (47) and breast-milk lactose and a maternal diet high in fat and low in carbohydrate compared with a diet low in fat and high in carbohydrate (49).

Vitamins

A Russian observational study reported a positive correlation between breast-milk vitamin C and maternal dietary intakes of vitamin C ($r = 0.84$, $P = 0.01$) (24). Another observational study from Finland reported a significant correlation between breast-milk vitamin C and maternal dietary intake of vitamin C at 1–2 mo postpartum ($r = 0.39$, $P < 0.01$) and 4–5 mo postpartum ($r = 0.46$, $P < 0.01$) (37). An observational study from Greece reported a positive correlation between breast-milk vitamin E content and maternal intakes of total fat ($r = 0.24$, $P = 0.047$) and total SFAs ($r = 0.30$, $P = 0.034$) but not with total energy, total MUFA, total PUFA, carbohydrate, total protein, or vitamin E intakes (19). Another observational study from Spain reported a higher concentration of vitamin E in breast transitional milk (collected 13–14 d postpartum) among mothers with a dietary intake of vitamin E $\geq$75% of the recommended intake than in women with <75% of the recommended intake of vitamin E (5.01 compared with 3.80 μmol/L; $P < 0.05$), whereas no significant difference was observed in mature breast milk (32). The Russian observational study reported significant correlations between thiamin in breast milk and in the maternal diet ($r = 0.75$, $P = 0.001$) and between riboflavin in breast milk and in the maternal diet ($r = 0.74$, $P = 0.001$) (24).

Minerals

An observational study from Greece reported that the breast-milk zinc was significantly influenced by maternal rice consumption (OR: 3.85; 95% CI: 1.20, 12.30) but not significantly by fruit consumption (OR: 2.87; 95% CI: 0.99, 8.34) (27). An observational study from Spain reported a significant correlation between maternal dietary intakes of zinc and the content of zinc in transitional ($r = 0.35$, $P < 0.05$) and mature ($r = 0.45$, $P < 0.05$) breast milk (33). Another observational study from Finland reported a significant correlation between breast-milk zinc and maternal total energy intakes ($r = 0.55$, $P < 0.01$) (40).

An Italian observational study reported a positive correlation between breast-milk selenium and maternal intakes of eggs ($r = 0.20$, $P = 0.04$) but not of vegetables, fruit, milk and dairy products, meat, fish, pasta, and cereal dishes (39). A study from the United States reported a higher concentration of breast-milk selenium among vegetarian mothers than in nonvegetarian mothers (22.2 ± 0.8 compared with 16.8 ± 1.3 ng/mL; $P < 0.01$) (43). Another observational study from Brazil found no correlation between breast-milk selenium and maternal dietary intakes of the same nutrient (42).

An observational study from Finland reported a significant correlation between breast-milk concentrations of iron and maternal total energy intakes ($r = 0.48$, $P < 0.01$) (40). In a study from North America no correlation was observed between breast-milk iron, calcium, magnesium, and potassium and corresponding maternal dietary intakes (45).

DISCUSSION

The direct relation between the dietary intake of single nutrients and their presence within human milk has not been studied in a satisfactory manner, for many reasons. These include the difficulties in the collection of dietary data and the availability of reliable human milk samples. To our knowledge, this is the first review that collects evidence from publications that studied healthy mothers and infants and that quantify the associations between maternal diet and breast-milk composition directly on the basis of individual measurements of both variables in each subject.

Previous reviews investigated the role of maternal diet on breast-milk composition by using a qualitative approach, including publications that focused on selected breast-milk components or on supplements and/or based on ecologic designs with aggregate data (4, 9–14). Undoubtedly, these studies provide some plausibility to the claim that a woman's diet influences the nutritional quality of her milk. However, in most of these studies, the implicit assumption that variability in maternal dietary intakes produces measurable effects on breast-milk composition was not tested quantitatively.

Among the vast number of publications on the general topic, only 36 fulfilled our inclusion requirements. We selected studies from well-nourished populations in developed countries, because the impact of maternal malnutrition was beyond the scope of our investigation. Furthermore, we also excluded several studies on preterm births, or pathological conditions, including low birth weight, atopic dermatitis, or infants born to HIV-infected mothers. Finally, we did not include studies that specifically focused on the role of dietary supplements and fortified foods on human-milk composition, because our aim was to investigate breast-milk composition under "normal conditions," although it is possible that some of the participants in the included studies used these types of products without reporting it. These selection criteria restricted the range of eligible publications.

The information compiled from the publications that met our criteria concerns different components of maternal diet and breast milk. In most of the included studies, the outcome of interest concerned breast-milk FA profile (17, 20, 22, 23, 25, 26, 28–31, 35, 38, 41, 46, 50–52), whereas information on other nutritional proprieties was limited; for example, only a few studies analyzed the impact of maternal diet on breast-milk protein profile (21, 47, 49) or total energy (34, 49). Indeed, the direct association between a dietary compound and its presence in milk can be only assessed in the case of an adequate protein-energy balance, to exclude a contribution from endogenous catabolic processes.

Overlap with regard to both exposure and outcome variables between studies was still rare. The maximum number of studies on the same combination of any exposure and outcome was 3 for breast-milk DHA depending on maternal fish consumption (23, 25, 26) and 2 for breast-milk vitamin C concentrations depending on dietary vitamin C intake (24, 37). Hence, it was not possible to apply meta-analytic methods.

The comparability of the included studies is compromised by their heterogeneous designs with respect to the following: the reference periods of maternal diet (day or week before milk collection during lactation, or periods during or before pregnancy), the time point of milk collection relative to childbirth (colostrum, transitional milk, or mature milk), the study design (observational or experimental), and/or the statistical methods used. The selected studies are limited by their small sample size, which, in most studies, was <50; the low statistical power, combined with low intakes of certain FAs and nutrients, may have led to inconsistent or null results, even in the presence of real associations.

Another limitation that deters us from attributing a causal association between maternal diet and breast-milk composition is the nearly complete lack of control for confounding factors. Some of these uncontrolled covariates could influence target milk compounds, mother metabolic genotypes, and the interactions between these.

In conclusion, the present systematic review gathered the available literature on quantitative relations between maternal diet and breast-milk composition. This work made us realize how scattered and weak the evidence is that is currently used in everyday clinical practice. Recommendations on these issues are still mostly based on studies that reported indirect associations. Much needed further studies on the role of maternal diet on breast-milk composition should be quantitative in nature and should adopt standard methods for milk storage and analysis, a clear definition of the time lag between the investigated diet and milk analysis, and possibly in the association analysis adjust for maternal energy intakes and maternal anthropometric characteristics.

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