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Dietary patterns affect maternal macronutrient intake levels and the fatty acid profile of breast milk in lactating Chinese mothers

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ABSTRACT

Objectives: Fatty acids (FA) in human milk play an important role in meeting the nutritional demands and promoting the growth and development of breastfeeding infants. Breast milk FA is sensitive to maternal dietary habits, and dietary patterns are better used to explain the effect of diet on FA. Few studies have examined the association between maternal dietary patterns and the FA components of breast milk in developing countries. In this study, we aimed to determine whether dietary patterns affect the FA profile of breast milk in lactating Chinese mothers with the overall goal to optimize the management of infant feeding.
Methods: A total of 274 lactating women ranging from 22 d to 6 mo postpartum were included, and samples of their breast milk were collected together with completed questionnaires. Using a principal component analysis, four dietary patterns were identified in a rotated component matrix. FA profiles were detected using capillary gas chromatography and presented as the percentage by weight of total FA.
Results: Maternal intake of energy, carbohydrates, and proteins showed differences between the different dietary patterns. In addition, there were significant differences in the total proportions of saturated, polyunsaturated, and ω-6 polyunsaturated fatty acids in breast milk among the four patterns ($P < 0.001$; $P = 0.025$; $P = 0.038$, respectively).
Conclusions: The results demonstrate that maternal dietary patterns can affect macronutrient intake levels and milk FA profiles in lactating Chinese women. These results are of great significance in understanding how a maternal diet can both improve maternal macronutrient intake and the FA nutritional status of breast milk.

Introduction

Breast milk provided by healthy, well-nourished, lactating mothers is a unique and ideal source of food that ensures the proper growth and development of infants. Approaches to optimize the nutritional status of breast milk receive increasing attention. Carbohydrates, proteins, and fats in milk are sources of energy, and especially fat plays an important role. However, whether an association exists between maternal diet and the macronutrients in breast milk remains unclear [1]. Recent reviews have suggested that maternal nutrition has little or no effect on the amount of macronutrients in breast milk [1–3], but fatty acids (FAs) are one of the components of human milk that are the most sensitive to maternal dietary habits [2].

FAs are divided into three groups according to their different structures: saturated FAs (SFAs), monounsaturated FAs (MUFAs), and polyunsaturated FAs (PUFAs). These different types of FAs play different roles in the human body. A high intake of SFA is a risk factor for cardiovascular disease [4]. However, a diet that is high in MUFAs can improve serum lipid ratios by reducing total low-density lipoprotein cholesterol levels and increasing high-density lipoprotein cholesterol levels [5]. The ω-3 PUFAs, including the best known docosahexaenoic acid (DHA), can contribute to the improvement of brain function and cognition [6], prevent morbidity associated with atherosclerosis and cardiovascular disease, and reduce retinal and choroidal angiogenesis in neovascular eye diseases [7–9]. On the other hand, ω-6 PUFAs are confirmed proinflammatory factors, and the ratio of total ω-3/ω-6 FAs is associated with good health conditions [10,11].

The World Health Organization recommends that infants be fed exclusively by breastfeeding during their first 6 mo of life, but breast milk remains an important source of nutrients for children until ≥2 y

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of age [12]. Human milk provides different types of FAs that are required for the growth of infants. Moreover, DHA undergoes pronounced accumulation in the brain from halfway through gestation to 2 y after birth [13]. Milk must contain sufficient amounts of all types of FAs to meet the demands of infants during lactation because any deficiencies may have long-term adverse effects [14].

The composition of FAs in human milk is influenced by environmental and genetic factors. Recent research has demonstrated that the FA profile, particularly the PUFA profile, varies depending on the maternal diet. DHA levels are low in mothers from North America because their dietary intake is skewed toward the ω-6 and suboptimal ω-3 FA [15]. Regular consumption of freshwater fish and wild game could contribute to higher levels of ω-3 and ω-6 PUFAs in the breast milk of lactating mothers in the United States [16]. In Greece, researchers found that the FA profile of breast milk is affected by maternal PUFA and MUFA intake during the first half year in lactating women [17]. Similar conclusions were made in an Asian study. FA levels in human milk are positively correlated with maternal FA intake in mothers from South Korea, Malaysia, and southeast China [18–20]. Nevertheless, these findings are contradictory to the results by Kumar and Su, who showed that factors other than maternal diet such as geographic location and ethnic group play a vital role in the composition of FAs in breast milk [21,22].

The majority of research in this field has focused on the connection between individual FAs from maternal diets (or in different types of food) and FA levels in breast milk, and the results to date are varied. Lactating mothers do not consume only one nutrient or food in their daily diets, but take in large amounts of nutrients from various types of food and have specific dietary patterns. There are close correlations between a variety of nutrients and certain types of food. In addition, the maternal intake of food with each meal is not independent of the intake of other foods; thus, the dietary pattern represents the combined effects of food intake [23] and is better suited to explain the effects of maternal food intake on milk composition.

Recent studies have indicated that maternal dietary patterns may not only affect maternal health but may be associated also with the nutritional status of offspring [24,25]. However, the results of previous studies are not clear regarding whether maternal dietary patterns can influence FA levels in breast milk. China is the biggest developing country in the world and has a large number of lactating women. Moreover, dietary patterns differ among different populations, and milk FA levels vary from area to area [26]. Because studies on the relationship between maternal dietary patterns and milk FA are rare, our research focuses on the associations between dietary patterns and the FA profile of breast milk in lactating Chinese mothers to determine an optimal way to manage infant feeding.

Methods

Participants

This study was a cross-sectional survey that was conducted from January 2015 to June 2017 in Changchun city, Jilin province of China. Study participants were healthy Chinese Han lactating mothers from three sources: online community recruitment, a women and children health care hospital, and a postpartum care center. The eligibility criteria were breastfeeding, no maternal pregnancy complications, and no use of FA-containing supplements postpartum. The babies were healthy singleton infants born at a gestational age of ≥37 wk and with a weight of ≥2500 g. There were 313 women included in the original study. The flow diagram of the study participants is shown in Figure 1. All participants signed the informed consent form, and the study procedure was approved by the ethics committee of the School of Public Health, Jilin University in China.

Breast milk collection and questionnaires

The first few drops of milk were discarded by manual expression, and a total of 30 mL breast milk was collected in clean tubes between 9:00 h to 11:00 h from each volunteer. The breast milk was mature milk, and all lactating mothers were 22 d to 6 mo postpartum. The milk samples were kept in a 4°C ice-box, then stored in a −80°C refrigerator, and detected within 2 wk.

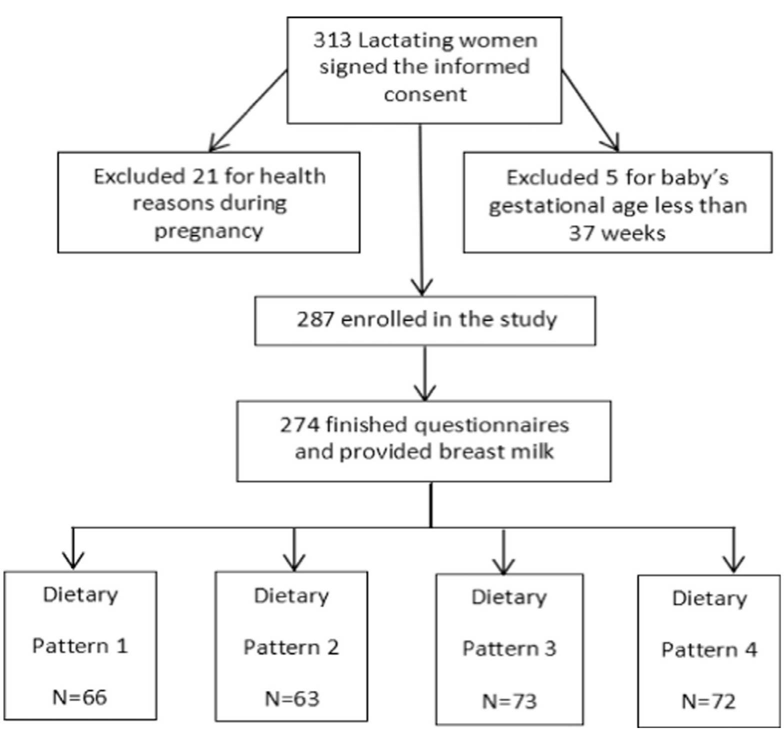

Fig. 1. Flow diagram of study participants.

We used a basic information questionnaire to obtain information on participants' age, family income, height, weight, and lifestyles. A 24-h dietary recall questionnaire was used to obtain detailed dietary information including types and weight of food consumed with each meal in the last 3 d, and a food frequency questionnaire was used to investigate participants' consumption of 176 types of common foods to obtain dietary patterns. The questionnaires were implemented through one-on-one interviews by trained investigators preceding the milk collection.

Dietary patterns division

We calculated the weights of 176 items consumed each day as derived from the food frequency questionnaires by the 274 study participants and combined the weights of the same types of food for each day (g/d). Subsequently, we combined the different foods together to make 10 groups: grains/potatoes and beans, soybean products, mushrooms and algae, fruits, vegetables, nuts, meat, eggs, marine products, and dairy products. These groups were assigned to one of four dietary patterns using a rotated component matrix. The rotated component matrix of each food among the different dietary patterns is shown in Table 1. For each volunteer, four values for the four different dietary patterns were calculated and the largest value represents the dietary pattern.

Fatty-acid analysis

The profile of FAs in breast milk was detected by capillary gas chromatography and calculated with FA methyl esters (FAME) using the internal standard method. The protocol of the experiment was described in a previous study [27]. We used the Supelco 37-component FAME Mix (Sigma, Catalog No. 18919-1 AMP) to confirm the retention time of each component and calculated the correction factor by weight percentage in the mixture. A total of 35 types of FAME were detected in the breast milk, including 15 SFAs, 9 MUFAs, and 11 PUFAs. Each type of FA was confirmed with the retention time, and the amount of FAs was calculated using the area of peeks. The profile of FAs in breast milk was presented with each FA weight percentage of total FA.

Statistical analysis

Epidata v3.0 software was used to establish the basic information questionnaire database, and two trained clerks entered the data to check typing errors. Intakes of dietary nutrients were calculated with the Golden Key maternal nutrition software (Wincome, Shanghai) and 2009 Chinese food composition [28].

In the dietary patterns, the extraction method for the 10 food groups was principal component analysis, and the rotation method of each food was Varimax by Kaiser Normalization. The Kaiser-Meyer-Olkin (KMO) value should be above 0.6 (KMO value is the measure of sampling adequacy) and the P value of Bartlett's test of sphericity approximately <0.05. With the measurement data, we used mean ± standard deviation to express the values of normally distributed data and median (25th and 75th percentiles) to express skewed data. The Kruskal Wallis test was used to compare the differences among the four dietary patterns. The categorical data were expressed as the number (percentage) and compared with the χ^2 test among the different groups. All statistical tests were two-tailed, and $P < 0.05$ was considered significant. The analyses were conducted using the SPSS Statistics software (v16.0; IBM Corporation).

Results

Participants and dietary pattern characteristics

The mean age of the 274 mothers was 30.1 y (range, 21.0–45.0 y), and more than half came from middle-income households (56.2%). The mean preconception body mass index (BMI) was 21.08 ± 3.28 kg/m^2, and the women gained an average of 16.80 ± 5.41 kg of weight during pregnancy. Just less than half (49.6%) of the mothers had a natural delivery, and the rest underwent cesarean sections. The mean gestational age of the infants was 39.51 ± 0.97 wk, and the mean birth weight was 3.43 ± 0.40 kg. With respect to feeding, 73.4% of infants were exclusively breastfed while the remaining received mixed-type feeding.

A total of 66, 63, 73, and 72 participants were divided into Patterns 1, 2, 3, and 4, respectively (Fig. 1). The maternal characteristics of the four dietary patterns are shown in Table 2. The age, preconception BMI, gestational weight gain, family income, and mode of delivery of the mothers as well as the gestational age, birth weight, and feeding patterns of the babies were not statistically different among the four groups. Lactating women with dietary Pattern 1 mainly ate mushrooms and algae, meat, and marine products; those with Pattern 2 mainly ate soybean products, nuts, and dairy products; Pattern 3 mothers mainly ate fruits and vegetables; and Pattern 4 mothers mainly ate grains/potatoes and beans as well as eggs. The KMO value was 0.649, and there were significant differences among the four dietary patterns (P value of Bartlett's test of sphericity approximately <0.001). The scree plot for the 10 different types of food is shown in Figure 2.

Table 1
Rotated component matrix among the different dietary patterns

Food group	Pattern 1	Pattern 2	Pattern 3	Pattern 4
Grain/potato and beans	−0.001	0.125	0.034	***0.792***
Soybean products	−0.001	***0.663***	−0.199	0.072
Mushroom food and algae	***0.678***	0.260	0.076	0.040
Fruit	0.309	0.052	***0.667***	−0.413
Vegetables	0.010	-0.102	***0.808***	0.249
Nuts	0.354	***0.579***	−0.108	0.061
Meat	***0.773***	0.008	0.131	−0.052
Eggs	0.231	0.350	0.288	***0.379***
Marine products	***0.574***	-0.176	−0.019	0.475
Dairy	−0.063	***0.684***	0.349	0.005

Maternal energy and macronutrient intake

Table 3 shows the amount of daily energy as well as the intake of three macronutrients and their rates (i.e., amount of actual intake divided by the recommended nutrient intake) in lactating mothers with different dietary patterns. There were significant differences in energy, carbohydrate, protein intake, and their rates among the four dietary patterns ($P = 0.014$; $P = 0.004$; $P = 0.002$, respectively) but the amount of daily fat intake and rate exhibited no differences ($P = 0.556$). Lactating mothers with Pattern 4 had the highest energy, carbohydrate, and protein intake levels. Almost half of the lactating mothers from each pattern had higher actual fat intakes than those recommended.

Fatty-acid profiles of the four different dietary patterns

The profile of fatty acids in breast milk for the four dietary patterns is summarized in Table 4. The fatty acid profile incorporated SFA, MUFA, and PUFA (including ω-6 and ω-3). The total proportions of both SFA and PUFA in milk exhibited significant differences ($P < 0.001$ and $P = 0.025$ respectively), and the difference in ω-6 PUFA was also significant ($P = 0.038$). However, no statistically significant differences were found for MUFA, ω-3 PUFA, and ω-6/ω-3 values among the patterns.

Discussion

The participants in our study (274 lactating women) are representative of the population in northeast China because all samples were collected from three sources. We conducted this study on maternal diet and breast milk to determine the associations between maternal dietary habits in northeast Chinese and FA profiles in milk. According to the results of the questionnaires, four dietary patterns could be distinguished. We found significant differences with respect to energy, carbohydrate, and protein intake by lactating mothers among the four dietary patterns. Moreover, the total proportions of SFA, PUFA, and ω-6 PUFA in breast milk showed significant differences among these patterns. The results suggest that the FA composition of milk and maternal dietary patterns are tightly linked with one another.

Table 2
Maternal demographic characteristics by dietary pattern

Characteristics	Pattern 1	Pattern 2	Pattern 3	Pattern 4	*P*-value
Maternal age* (y)	30.0 (28.8, 32.0)	29.0 (27.0, 32.0)	30.0 (28.0, 32.0)	30.0 (28.0, 31.8)	0.783
Preconception BMI* (kg/m^2)	20.4 (18.9, 22.0)	20.7 (19.1, 23.4)	20.7 (18.8, 23.1)	20.4 (18.5, 22.7)	0.891
Gestational weight gain* (kg)	15.0 (13.0, 18.0)	17.0 (13.6, 20.0)	17.5 (12.0, 20.0)	16.0 (14.3, 20.0)	0.782
Gestational age* (wk)	39.8 (39.0, 40.3)	39.7 (39.0, 40.3)	39.7 (39.0, 40.1)	39.1 (38.7, 40.0)	0.199
Birth weight* (kg)	3.4 (3.1, 3.8)	3.4 (3.2, 3.7)	3.4 (3.2, 3.6)	3.5 (3.2, 3.7)	0.977
Family income† (yuan/month)					
<5000	8 (12.1)	16 (25.4)	9 (12.3)	13 (18.1)	0.284
5000–9999	35 (53.0)	33 (52.4)	45 (61.6)	41 (56.9)	
≥10 000	23 (34.9)	14 (22.2)	19 (26.1)	18 (25.0)	
Mode of delivery†					
Vaginal	34 (51.5)	30 (47.6)	35 (47.9)	37 (51.4)	0.947
Cesarean	32 (48.5)	33 (52.4)	38 (52.1)	35 (48.6)	
Feeding patterns†					
Breastfeeding	54 (81.8)	40 (63.5)	55 (75.3)	52 (72.2)	0.124
Mixed feeding	12 (18.2)	23 (36.5)	18 (24.7)	20 (27.8)	

BMI, body mass index.
*Values are expressed as medians (25th and 75th percentiles) for skewed data (compared by Kruskal Wallis test).
†Values are expressed as n (%) for categorical data (compared by χ^2 test).

Research has shown that the FA composition of breast milk is influenced by maternal age, family income, and gestational age [18,29,30]. There were no differences in the demographic characteristics of mothers and babies with respect to the different patterns identified in this study. This indicates that the fundamental health status of mothers from the four different patterns is comparable and that FA profiles in breast milk are not affected by demographic factors. The median energy intakes for participants from all four patterns were <2000 kcal/d and thus lower than the estimated energy requirement of 2300 kcal/d for lactating mothers as recommended by the Chinese Nutrition Society [31]. In addition, the level of energy intake is approximately equal to that of lactating mothers from South Korea, which was determined to be 8173.2 KJ/d (1953.4 kcal/d) [18]. One of the main reasons for these observations is that some mothers lose weight intentionally postpartum, and the most direct way to achieve this is by dieting and reducing energy intake.

Mothers with Pattern 4 mainly eat grains/potatoes and beans and eggs and consume the highest amounts of energy of all groups. This result is consistent with previous research [32] because grains, potatoes, and beans contain high levels of carbohydrates and are the main source of energy for mothers. Most of these foods in Pattern 4 are staples and also represent the main sources of dietary protein. Eggs are an additional source of high-quality protein [33]. Therefore, Pattern 4 mothers consume more carbohydrates and protein than the mothers with the other patterns.

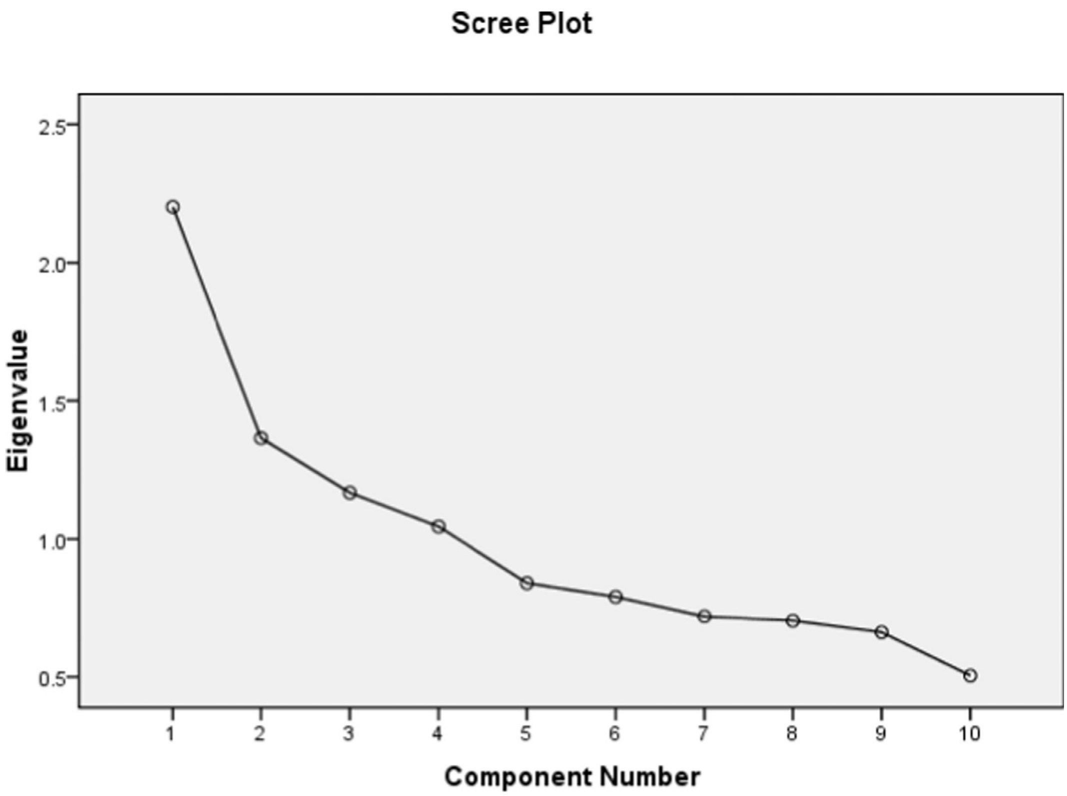

Fig. 2. Scree plot for the 10 different types of food.

Table 3
Energy and macronutrient intake with different dietary patterns (median [25th and 75th percentiles])

Variables	Pattern 1	Pattern 2	Pattern 3	Pattern 4	*P*-value
Energy (k cal/d)	1762.65 (1414.51, 2065.66)	1732.44 (1455.54, 2186.97)	1674.01 (1460.23, 2217.38)	1949.03 (1625.91, 2682.68)	***0.014***
Energy rate*	76.64 (61.50, 89.81)	75.32 (63.28, 95.09)	72.78 (63.49, 96.41)	84.74 (70.69, 116.64)	
Carbohydrate (g/d)	219.99 (177.37, 301.81)	232.46 (190.86, 313.3)	229.26 (184.37, 290.72)	274.97 (218.52, 360.78)	***0.004***
Carbohydrate rate*	66.54 (53.65, 91.28)	70.31 (57.73, 94.76)	69.34 (55.76, 87.93)	83.17 (66.09, 109.12)	
Protein (g/d)	61.58 (45.34, 74.81)	70.61 (55.90, 87.32)	66.10 (49.08, 79.67)	74.26 (57.19, 119.3)	***0.002***
Protein rate*	76.97 (56.67, 93.51)	88.26 (69.88, 109.15)	82.63 (61.35, 99.59)	92.82 (71.48, 149.13)	
Fat (g/d)	64.45 (49.51, 81.41)	67.85 (54.59, 81.79)	62.62 (50.66, 80.81)	70.20 (56.98, 84.87)	0.556
Fat rate*	100.87 (77.48, 127.43)	106.20 (85.44, 128.02)	98.01 (79.28, 126.48)	109.88 (89.18, 132.84)	

*Actual intake divided by the recommended nutrient intake per the Chinese Nutrition Society (%).

Table 4
Proportions of fatty acids in breast milk for dietary patterns (median [25th and 75th percentiles], %)

FA	Pattern 1	Pattern 2	Pattern 3	Pattern 4	*P*-value
SFA	40.38 (37.41, 44.25)	42.92 (38.61, 49.62)	39.10 (34.65, 45.04)	42.92 (40.31, 49.93)	<***0.001***
MUFA	34.40 (31.20, 36.84)	33.53 (29.91, 36.42)	34.85 (31.39, 39.58)	33.45 (29.09, 35.39)	0.053
PUFA	24.49 (21.73, 28.43)	22.09 (19.92, 27.08)	24.63 (20.37, 29.17)	22.77 (19.49, 26.38)	***0.025***
ω-6	20.71 (18.11, 23.27)	18.24 (16.41, 22.71)	20.11 (17.33, 24.22)	18.49 (16.11, 21.89)	***0.038***
ω-3	3.96 (2.70, 5.01)	3.55 (2.98, 4.46)	3.56 (2.32, 4.98)	3.86 (3.09, 4.56)	0.292
ω-6/ω-3	4.83 (3.80, 7.32)	4.76 (4.14, 6.30)	5.34 (3.74, 9.39)	4.69 (3.85, 5.74)	0.341

FA, fatty acid; SFA, saturated fatty acid; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid.

Pattern 3 mothers have the lowest energy intake due to their larger intake of low-calorie food such as fruits and vegetables. Although the intake of carbohydrates and proteins differed significantly between the various patterns, all median rates were lower than recommended [31]. This indicates that the maternal intake of these two macronutrients falls short of the recommendations, which is consistent with the results of previous research from southeast China and Italy [34,35]. Recent meta-analyses have reported similar findings for pregnant women in developed countries [36,37]. This phenomenon suggests that importance should be attached to the energy and nutrient intake of pregnant and lactating women to meet their nutritional needs and those of their babies. Although no differences in fat intake were found for lactating women among the different groups, the amount of fat intake by mothers is higher than that recommended [31], and this was also observed for mothers from southeast China [34]. These results raise the possibility that Chinese mothers generally consume too much fat during lactation and that the adoption of measures to rectify this problem through nutritional education is necessary.

The SFA proportions of breast milk in this study are similar to those reported for South Korean mothers (39.10%–42.92% vs 42.1%), the MUFA proportions are close to those of Greek women (33.45%–34.85% vs 35%), and the PUFA proportions are higher than those in these two countries (22.09%–24.63% vs 18% and 21.5%) [17,18]. This suggests that SFA and MUFA proportions might be relatively constant and that PUFA levels in human milk vary from country to country, as described in a previous study [38].

The distribution of FA profiles varies among the different dietary patterns identified in this study. The highest proportions of SFA were observed in the milk of Pattern 2 mothers who mainly eat soybean products, nuts, and dairy products, and Pattern 4 mothers who mainly eat grains/potatoes, beans, and eggs. In agreement with our results, recent research has shown that mothers who consume more whole milk had a higher proportion of SFA in their breast milk [39]. The lowest proportion of SFA was identified in the milk of Pattern 3 mothers because vegetables and fruits contain few FAs. However, Pattern 3 mothers had the highest PUFA levels, which is perhaps due to the protective effects of these foods and likely mediated through multiple beneficial nutrients such as PUFA [40]. The highest proportions of ω-6 PUFA were observed for mothers from Pattern 1, who mainly eat mushrooms and algae, meat, and marine products. The mothers in our study eat more meat and poultry than in other areas because the Jilin province is located in a landlocked region of northeast China and mothers here eat fewer aquatic products than those from coastal areas. Meat and poultry have been clearly demonstrated to be important sources of ω-6 PUFA [41].

There are several limitations to our study. All breast milk samples were of mature human milk; the mature period can last for as little as 1 mo and as long as the entire period of lactation. The FA profile of milk may be affected by the dietary patterns of mothers and also by month of lactation. Nevertheless, the World Health Organization recommends that babies be fed exclusively with breast milk up to 6 m of age, and our milk samples were collected from 22 d to 6 mo postpartum; thus, the samples are representative of the mature period. Furthermore, the participants are from an inland region in northeast China, and the dietary habits of mothers from this province include little intake of marine products. In the future, we plan to collect samples from mothers in broader areas as well as include mothers from coastal regions [26].

Conclusions

This study is, to our knowledge the first research in China to examine the association between dietary patterns and the FA profile of breast milk in lactating mothers. We found that maternal dietary patterns can affect the macronutrient intake of lactating mothers and the proportions of SFA, total PUFA, and ω-6 PUFA in the FA profile of the milk produced. These results are of great significance to improve maternal macronutrient intake and FA status of breast milk by maternal dietary intake and ensure that maternal milk provides sufficient amounts of all types of FAs to meet the demands of infants during lactation.

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