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Nutrition support team (NST) guide to Maternal Diet for the Human Milk Fed Infant

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Abstract

Background—Human milk feeding is encouraged for all infants; however, the mammary gland depends on maternal dietary intake of vitamins A, B1, B2, B6, B12, D, docosahexaenoic acid (DHA), choline, and iodine. Nutrition support team (NST) knowledge of maternal feeding guidelines for these nutrient sources can therefore impact infant intake. We hypothesized that these key nutrients for lactation in the mother's diet would be less than the dietary guidelines in the United States (US).

Methods—This was a secondary analysis of nutritional data collected during a randomized, controlled trial. Dietary records were analyzed from 16 mothers (13 with singleton and 3 with multiple births) completing the study. Mean dietary intakes of selected nutrients were calculated and compared to current Dietary Reference Intakes (DRI).

Results—Mean maternal dietary intake for singletons was significantly ($p < 0.05$) lower than the DRI for vitamin A 58%, vitamin D 44%, and choline 58%; DHA comprised only 5% of current expert recommendation. Based on singleton recommendations, mothers to twins consumed an adequate intake except for DHA.

Conclusions—Women providing breast milk for singleton preterm infants did not consume Dietary Reference Intakes for key nutrients. Twin mothers' diets were adequate except for DHA,

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but these guidelines are based on singleton pregnancies and remain poorly understood for twin needs. The NST can have a unique role in maternal dietary education to impact human milk nutrient delivery to the infant.

INTRODUCTION

Infants born prematurely miss the nutrient accretion that occurs in utero during the third trimester and optimizing nutrition for these infants presents unique challenges^{1, 2}. It is well documented that preterm infants often suffer from extrauterine growth restriction, meaning that after birth they are below the 10th percentile of fetuses of the same gestational age^{3, 4}. Growth velocity correlates with developmental outcome thus making nutritional strategies vital to intercept this growth crisis^{5, 6}. Exclusive breastfeeding when possible for the first six months of life is recommended for all infants by the World Health Organization, the American Academy of Pediatrics and the American College of Obstetricians and Gynecologists and diet needs for the mother during lactation are therefore a global concern⁷⁻¹⁰. Mother's own milk feeding has been shown to lower rates of infection and necrotizing enterocolitis, as well as shortening length of stay and readmissions due to illness in the year following discharge from the Neonatal Intensive Care Unit (NICU)^{8, 11, 12}. Human milk feeding in the NICU can be associated with growth deficits even when fortified, and thus targeting nutritional strategies and interventions in the mother may provide a personalized approach to growth failure¹³. While pediatricians support human milk feeding, many do not recognize the need to counsel mothers on dietary guidelines as a first step in human milk fortification¹⁴.

Human milk provides many biologic factors contributing to these benefits however nutritional content varies widely among lactating women¹⁵. While calorie and protein content are largely unaffected by a woman's diet, there are some micronutrients that are only expressed in breast milk at adequate levels if there is sufficient maternal dietary intake¹⁶. Allen describes these as Group I nutrients, and they include thiamin, riboflavin, vitamin B-6, vitamin B-12, choline, retinol, vitamin A, vitamin D, selenium and iodine¹⁷. Many NICUs use an estimated baseline nutrient in mother's milk to fortify or use milk analyzers but these measure the macronutrients exclusively^{18, 19}.

Maternal diets can be supplemented to raise levels of specific nutrients in their breast milk, but insufficiencies in mothers' diets must first be identified²⁰. Only a few studies have reported micronutrient quantities in the diets of lactating women. In this study, we analyzed the nutrient intake of lactating mothers with early preterm infants (born <29 weeks) to delineate the micronutrient intake of their diets and to identify dietary insufficiencies that could benefit from nutrition counseling and supplementation.

METHODS

Study design

We performed a secondary analysis of nutritional data collected from women who participated in a randomized control trial conducted through the NICU (NCT#01732874, IRB#2012-0329, FDA IND#108241). In this trial, after informed consent,

mothers of preterm infants born at <29 weeks of gestational age who planned to provide human milk to their newborns were randomized to dietary supplementation of docosahexaenoic acid (DHA) at either the standard dose of 200mg/d or 1000mg/d by the Investigational Pharmacy. The original trial was designed to determine serum cytokine differences at 4 weeks after DHA supplementation with a power of 0.8.

Data Collection

Demographics of the women were collected at baseline. Women enrolled in the trial were instructed and trained by a study coordinator to collect a detailed food record listing all oral intake over 3-day period at four time points during the study. Three-day dietary records were collected at baseline (enrollment) and then again at two, four, and eight weeks after initiation of supplementation. Demographics of the infants were collected at birth.

Data Analysis

Diet records were analyzed by a trained individual using Nutrition Data Systems for Research (NDSR) nutritional analysis program (Nutrition Coordinating Center, University of Minnesota, Minneapolis, MN). The primary source of nutrient data is the United States Department of Agriculture's (USDA) Nutrient Data Laboratory²¹.

Nutrients analyzed in this study included total fat, protein, carbohydrates, vitamin A, vitamin D, thiamin, riboflavin, vitamin B6, vitamin B-12 and DHA, in addition to total energy. Means and standard deviations of selected nutrients were calculated for the entire sample population and compared to Dietary Recommended Intakes (DRI), Recommended Dietary Allowances (RDA) or Adequate Intakes (AI) respectively, using unpaired t tests and percent differences. DRIs were obtained from the Food and Nutrition Board of the Institute of Medicine²². The study sample was stratified by singleton versus twin gestation and mean intakes of select nutrients were compared across groups with t tests. Statistical calculations and tests were performed using STATA 12.1 software (StataCorp, College Station, TX). Comparisons with p-values < 0.05 were considered statistically significant.

Birthweight, gender and gestational age of infants were used to calculate growth status at delivery as Appropriate for Gestational Age (AGA), Small for Gestational Age (SGA) or Large for Gestational Age (LGA) using the PediTools Fenton growth calculator²³. SGA and LGA were defined as a birthweight in grams below the 10th percentile and above the 90th percentile respectively.

RESULTS

Sixteen women provided at least one three-day dietary record to be analyzed (Figure 1). The study population was comprised primarily of non-Hispanic white mothers (75%). The mean age of study participants was 29.3 ± 5 years, and the majority delivered by Cesarean (56.2%). Three of the women delivered preterm twins who were in the NICU at the time nutrient intake diaries were obtained. Overall, the mean gestational age of the preterm neonates was 26.5 ± 1.6 weeks. Maternal and infant characteristics are demonstrated in Table 1.

The mean dietary intake of women in the study was sufficient compared to the DRIs for vitamins B1, B2, B6 and B12 (Table 2). The mean intake of vitamins A and D were significantly lower than the corresponding DRIs- women consumed 58% ($p<0.001$), and 44% ($p<0.001$) respectively. Women in the study also had insufficient dietary intake of choline 58% ($p<0.001$)-see figure 2 and docosahexaenoic acid (DHA) when compared to current expert recommendations- 5% ($p<0.001$)- figure 3. When stratified by singleton versus twin gestation, it was observed that mothers of twins consumed significantly more total protein, vitamin A, thiamin, riboflavin and vitamin B-12 on average than singleton mothers (Table 3).

Table 4 lists nutrient content of foods selected by the authors that are high in the nutrients observed to be insufficient in the diets of this study population.

DISCUSSION

Fortified human milk is the recommended source of nutrition for preterm infants in the NICU, but composition of human milk can vary widely between lactating women and few studies have investigated the nutritional adequacy of maternal diets for milk composition. Our data support our hypothesis that key nutrients for lactation are insufficient in the diet of mothers with infants in the NICU. While these mothers had adequate macronutrient intakes, they were significantly lacking in four important micronutrients: vitamin A, vitamin D, choline, and the long-chain fatty acid-DHA.

Each of these nutrients contributes to key functions important in the healthy outcomes in infants, particularly the vulnerable preterm infant who misses the last trimester of nutrient accretion.. Dietary DHA supplementation of mothers providing milk impacts their offspring's cognition and indeed Jensen et al found improved sustained attention among five year olds whose mothers received DHA supplementation while breastfeeding^{34, 35}. The resultant expert panel, International Society for the Study of Fatty Acids and Lipid recommends a minimum intake of 200mg/day-1000mg/day for lactating women³⁶. A randomized control trial supplemented human milk donors with varying levels of DHA and found that supplementation of 1g/day can raise maternal milk concentrations to mimic the rate of intrauterine accretion suggesting that 1 gram may be a more adequate supplementation for mothers feeding their preterm infants²⁰. An association of low DHA status and chronic lung disease has been demonstrated in preterm infants, thus making it imperative to ensure an enteral source of DHA is available³⁷. Furthermore, adequate intakes of DHA can be beneficial for the mother's overall health and the American Heart Association recommends consumption of fish twice a week to lower the risk of cardiovascular disease in women³⁸.

Choline has been shown to be important for neurodevelopment in utero, specifically for closure of the neural tube³⁰. After birth, choline intake is especially important for providing substrate for neuronal myelination, a process which continues through two years of age^{31, 32}. Caudill draws attention to the importance of choline in maternal diet and suggests various foods high in choline such as eggs for lactating mothers³³.

Studies have found that preterm and extremely low birth weight (ELBW) infants who have lower levels of vitamin A at birth are at higher risk to develop chronic lung disease and that supplementation with vitamin A may decrease the risk^{24, 25}. Vitamin D deficiency in infants, in combination with a lack of exposure to sunlight, can lead to rickets and for this reason the American Academy of Pediatrics (AAP) advises that infants who are breastfed should receive 400 IU/day supplementation of Vitamin D²⁶. An alternative approach may be to supplement the diet of the mother to increase breast milk content, keeping in mind that supplementation must be higher than the requirements of the infant because only a portion will be present in the breastmilk²⁹.

There are no recently published studies assessing the micronutrient quantity in the diets of lactating women in the NICU, and yet pediatric practitioners are fortifying human milk without analyzing micronutrient quantity but rather based on assumed baseline nutrient values. Meier et al highlights the need for studies measuring the composition of human milk to determine if nutrient or volume inadequacy can explain in part the slower growth in infants that are fed exclusively human milk³⁹. A study of women nursing term infants at 3 and 6 months postpartum found that the mean dietary intakes of vitamin D and E were below the RDA⁴⁰. A dietary analysis using a 24-hour recall method found that among 52 lactating women, intakes of niacin and vitamin B6 were insufficient⁴¹. A previous study by Valentine et al found that women providing milk for the Mother's Milk Bank of Ohio had a dietary intake of DHA significantly less than the 200mg/day recommendation²⁰.

This is the first study to target the dietary intake of high risk infant mothers. The use of a 3-day diet record to obtain nutritional data is a strength of our study as this method limits reliance on participant memory. A study found a 10% underestimation of energy intake by food records compared to observed intake⁴². Alternatively, a limitation of the diet record method is that women may change what they normally would eat while they are keeping a diet record, this phenomenon is called reactivity⁴³. Another limitation is that some vitamins, such as vitamin A, have high day to day variability for one person and are available from relative few sources, which may be eaten less than daily⁴³.

CONCLUSIONS

To our knowledge, there is no prospective study in the NICU to assess the micronutrient quality of a woman's diet while she is providing milk for her preterm infant. We found that while the women in our cohort had adequate intake of macronutrients and many micronutrients, their dietary intake fell short of recommendations for vitamin A, vitamin D, choline, and DHA. Insufficient dietary intake of vitamin A has not been previously reported in the literature for mothers breastfeeding preterm infants. Because the provision of mother's own milk is the current recommendation for preterm infants, it is important to draw attention of both mothers and health care providers to this potential insufficiency.

Comerford et al describes how practitioners can provide more impactful specific high nutrient food recommendations to improve nutrition⁴⁴. As a resource, we have provided various food recommendations that are high in the nutrients we found to be insufficient in our cohort (Table 4). We encourage health care providers to consider counseling their

lactating patients on the inclusion of nutrient rich foods in their diet. This resource provides an opportunity for value to add to both mother and infant diet.

The next step in investigating maternal diet would be to improve the analysis of breastmilk to include micronutrients, so that fortification can focus on achieving adequate micronutrient content in addition to macronutrient content. Although it is understood that supplementation of maternal diet with vitamin D and DHA can increase breastmilk content of these nutrients, further studies are required to fully understand the relation between maternal dietary intake and nutrient content in breastmilk^{20, 27–29}.

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Figure 1.
Consort Framework.

Figure 2. Mean Dietary intake of lactating mothers compared to Dietary Reference Intake for Choline. Choline was calculated for each individual participant using all provided dietary measurements, and for the whole cohort (n=16). Average intake of the cohort of lactating mothers is compared to Dietary Reference Intake, represented by the blue arrows (not to scale).

Figure 3.

Mean Dietary intakes of lactating mothers of Docosahexaneic acid (DHA) compared to current expert opinion.

Mean intake of DHA was calculated for each individual participant using all provided dietary measurements, and for the whole cohort (n=16). Average intake of the cohort of lactating mothers is compared to current recommendation from experts in the field, represented by the blue arrow (not to scale).

Table 1

Population Characteristics of Mothers and Infants

Maternal Characteristics	n=16
Maternal age in years at delivery, mean (SD)	29.3 (5.5)
Race	
Non-Hispanic white, no. (%)	12 (75)
Non-Hispanic black, no. (%)	3 (18.8)
Hispanic, no. (%)	1 (6.3)
Maternal Body Mass Index, mean (SD)	32.2 (7.3)
Insurance	
Medicaid, no. (%)	7 (43.8)
Private, no. (%)	9 (56.2)
Mode of Delivery	
Vaginal, no. (%)	7 (43.8)
Cesarean section, no. (%)	9 (56.2)
Gravidity (median, IQR)	1.5 (1,4)
Parity (median, IQR)	1 (1,3)
Prior Preterm Birth (%)	2 (12.5)
Pregestational Diabetes (%)	0
Gestational Diabetes (%)	0
Hypertension (%)	3 (27)
Preeclampsia (%)	2 (18)
Tobacco Use (%)	4 (28.5)
Twin Gestation Current Delivery (%)	3 (18.8)
Infants Characteristics	n=19
GA at delivery (weeks)	26.5 (1.6)
Sex	
Female (%)	11 (58)
Male (%)	8 (42)
Birthweight (g)	926.2 (221)
Small for Gestational Age (%)	1 (5)
Large for Gestational Age (%)	0
Head Circumference (cm)	24.2 (2.2)
Mean Length (cm)	35.5 (3.8)

Continuous variables are displayed as mean ($\pm$ standard deviation) or median (interquartile range)

GA, gestational age

Table 2

Mean Dietary Intakes of lactating mothers compared to Dietary Reference Intake

Energy and nutrient	Mean Observed and SD	DRI	% consumed of DRI	p value
Energy (kcal)	2138 (707)			
Total fat (g)	91.3 (35.3)	ND		
Linoleic acid (g)	18.6 (7.2)	13	143	0.007
Linolenic acid (g)	2.0 (0.9)	1.3	152	0.009
Total protein (g)	86.2 (22.3)	71	121	0.016
Total carbohydrate (g)	249.4 (97.3)	210	119	0.126
Total vitamin A activity RAE (µg)	753.1 (327.9)	1300	58	<0.001
Vitamin D (calciferol) (µg)	6.6 (4.2)	15	44	<0.001
Thiamin (vitamin B1) (mg)	1.9 (0.7)	1.4	134	0.016
Riboflavin (vitamin B2) (mg)	2.2 (1.0)	1.6	138	0.025
Vitamin B6 (mg)	1.9 (0.6)	2	94	0.459
Vitamin B-12 (cobalamin) (µg)	5.0 (2.0)	2.8	177	0.001
Choline (mg)	317.1 (135)	550	585	<0.001
PUFA 22:6 (docosahexaenoic acid [DHA]) (g)	0.05 (0.02)	1	5	<0.001

DRI, Dietary Reference Intake; g, grams; kcal, kilocalorie; mg, milligrams; µg, micrograms; ND, not determined; RAE, retinol activity equivalents; SD, standard deviation

Table 3

Dietary Intake stratified by singleton and twin gestation

	Mean Observed Singleton	Mean Observed Twins	p value
Total grams	2547 (937.2)	2504 (673)	0.943
Energy (kcal)	1997 (643)	2749 (763)	0.098
Total fat (g)	84.6 (32.1)	120.3 (39.9)	0.117
Linoleic acid (g)	17.5 (7.3)	23.4 (5.5)	0.212
Linolenic acid (g)	1.9 (0.9)	2.6 (1.0)	0.241
Total protein (g)	81.0 (19.1)	108.9 (24.8)	0.047
Total carbohydrate (g)	234.7 (97.7)	313.2 (78.8)	0.219
Total vitamin A activity RAE (µg)	662 (237)	1148 (426)	0.015
Vitamin D (calciferol) (µg)	5.8 (3.3)	9.7 (7.1)	0.157
Thiamin (vitamin B1) (mg)	1.7 (0.6)	2.7 (0.6)	0.030
Riboflavin (vitamin B2) (mg)	2.0 (0.8)	3.2 (1.0)	0.043
Vitamin B6 (mg)	1.8 (0.7)	2.3 (0.3)	0.178
Vitamin B-12 (cobalamin) (µg)	4.4 (1.7)	7.4 (2.0)	0.016
Choline (mg)	285.8 (118)	452.6 (141)	0.3527
PUFA 22:6 (docosahexaenoic acid [DHA]) (g)	0.05 (0.03)	0.06 (0.01)	0.498

g, grams; kcal, kilocalorie; mg, milligrams; µg, micrograms; RAE, retinol activity equivalents

Suggested food sources high in selected nutrients for mothers providing breastmilk to premature infants

Table 4

	Vitamin A (µg)	Vitamin D (µg)	DHA (mg)	Choline (mg)
Salmon (sockeye), cooked, 3 oz	Amount / serving	11.18	600.00	96
Egg (omega 3 fortified), 1 large	Amount / serving	1.00	81.00	145
Sweet Potato, baked in skin, 1 whole	Amount / serving	n/a	n/a	26.2
Ready-to-eat cereal, fortified with 10% * of the DV for vitamin A and D, ¾–1 cup	Amount / serving	1.00	n/a	10
Milk, fat-free or skim, with added vitamin A and vitamin D, 1 cup	Amount / serving	2.88	n/a	43
Carrots, raw, 1/2 cup	Amount / serving	n/a	n/a	5.6
Peppers, sweet, red, raw ½ cup	Amount/serving	n/a	n/a	4.2
Mustard Greens, cooked, 1 cup	Amount/serving	n/a	n/a	0.5

* More heavily fortified cereals might provide more of the DV
mg, milligrams; µg, micrograms; oz, ounce