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Publication Date
2017-02-01

DOI
10.1016/j.jpeds.2016.10.044

Peer reviewed

HHS Public Access
Author manuscript
J Pediatr. Author manuscript; available in PMC 2018 February 01.

Published in final edited form as:
J Pediatr. 2017 February ; 181: 294–297.e3. doi:10.1016/j.jpeds.2016.10.044.

The relation between breast milk sodium to potassium ratio and maternal report of a milk supply concern

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Abstract

We report here that among exclusively breastfeeding mothers at day 7 postpartum, those with milk supply concerns were significantly more likely to exhibit biochemical evidence of less progress toward mature lactation (elevated milk Na:K). Furthermore, elevated milk Na:K was predictive of early weaning.

Keywords

Breastfeeding; lactation; milk supply; insufficient milk; breast milk; Na:K

Low milk supply is one of the most frequently cited reasons for early breastfeeding cessation.[1] A previous analysis of the Early Lactation Success (ELS) cohort revealed that 27% of breastfeeding primiparas reported a low milk supply concern at 7 days postpartum, and this concern was significantly associated with stopping breastfeeding earlier than intended.[2] The extent to which a milk supply concern in the early postpartum is based on maternal *misperception* of normal lactation versus *valid perception* of sub-optimal mammary gland function is unknown.

The ratio of breast milk sodium to potassium (Na:K) dramatically declines in parallel with whole-transcriptome changes in mammary gene expression as lactation progresses through colostral, transitional, and mature milk production stages;[3] thus, declining milk Na:K is an objective biomarker of mammary gland progress toward copious mature milk production over the first week postpartum.[4]

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The authors declare no conflicts of interest.

In this extension of the previous analysis,[2] our primary objective is to determine if elevated breast milk Na:K at day 7, as an objective biomarker of lack of progress toward mature milk production, is significantly more prevalent in mothers reporting a milk supply concern, even in the context of current exclusive breastfeeding. Our secondary objective is to determine if elevated breast milk Na:K at day 7, in the context of exclusive breastfeeding, is independently predictive of stopping breastfeeding before day 60.

Methods

The ELS cohort was recruited from the University of California Davis Medical Center (UCDMC), Sacramento, CA, as described in previous reports.[2, 5–7] Briefly, the ELS study enrolled expectant first-time mothers who were receiving prenatal care at UCDMC, spoke either English or Spanish, and lived within a pre-defined catchment area. Women with a known breastfeeding contraindication, with multiple gestation, or who were < 19 years old and unable to obtain parental consent were excluded from enrollment; and mothers who delivered <37 weeks gestation, were separated from their infant in the immediate postpartum >24 hours, or who did not initiate breastfeeding, were excluded from postnatal interviews.[2] The University of California Davis Institutional Review Board approved the ELS study. Cincinnati Children's Institutional Review Board approved continued analysis.

Data collection details have been previously described.[2, 5–7] Briefly, during a prenatal clinic visit, mothers were interviewed regarding socio-demographic variables and infant feeding attitudes and intentions.[8, 9] At day 7, participants were asked, "Please describe any problems or concerns you have had since our last interview or are currently having about feeding your infant, including breastfeeding problems, concerns or discomforts." The main category of "milk supply concern" is comprised of the following subcategories of maternally reported concerns: (1) inadequate maternal production or milk supply; (2) infant not getting enough milk or unsure if getting enough milk; (3) infant shows signs of hunger; and (4) milk not in.[2]

Participants used an electric breast pump or hand expression to provide a 5 mL spot sample of breast milk from a single breast at d7. Thawed milk samples were centrifuged at 15,000g for 10 minutes. Sodium and potassium concentrations were assayed in the aqueous fraction using flame photometry (Cole-Parmer Dual-Channel Flame Photometer, Vernon Hills, IL). Within each sample, mean milk Na:K was calculated from duplicate runs (mean of [$sodium_1$/$potassium_1$], [$sodium_2$/$potassium_2$]). Expressing sodium as a ratio to potassium adjusts for slight variations in the lipid-free purity of the aqueous fraction.[10]

Infant feeding status was determined at each follow-up interview, including at day 60 postpartum (d60). Exclusive breastfeeding was defined as infant receiving only feedings at mother's breast and/or feedings of mother's expressed breast milk during the 24 hours preceding the interview. Stopped breastfeeding was defined as no breastfeeding or expressed breast milk feeding in the preceding 24 hours.[2]

Data analyses

Formula use, by disrupting regular breast emptying, may inhibit milk production.[7] The temporal relationship between early formula use and elevated milk Na:K could not be determined, and thus, examination of our objectives was restricted to the subset of mothers who were exclusively breastfeeding in the 24 hours prior to the d7 interview. Furthermore, mastitis causes increased breast permeability, leading to elevated milk Na:K.[11], and therefore mothers who reported a mastitis diagnosis at d7 were also excluded. Thus the analytic subset was comprised of those women who were exclusively breastfeeding at d7 and without mastitis. We defined elevated milk Na:K as >75th percentile among the analytic subset. This cut-off was selected because milk Na:K, as a marker of progress toward mature milk production, likely exists along a continuum and this *a priori* definition is an unbiased approach to testing our hypotheses.

In general, we categorized study variables as described previously.[5] Because only a small number of women who were exclusively breastfeeding at d7 had weak feeding intentions, we collapsed feeding intention into two categories representing those without, versus with, strong intention to exclusively breastfeed for at least 3 months.

Within the analytic subset, we examined whether elevated Na:K status was predicted by maternal report of a milk supply concern at d7 (primary objective) and if stopping breastfeeding before d60 was predicted by elevated d7 Na:K (secondary objective) using logistic regression analysis. For each model, we first examined the unadjusted odds ratio, then adjusted for socio-demographic variables associated ($P<0.10$) with the dependent variable. From these models, we report the odds ratio (OR) and 95% confidence interval (95%CI). Analyses were performed with SAS 9.3 or SAS JMP 12 (Cary, NC).

Results

The flow diagram leading to the analytic subset of 196 participants included in the present analysis is shown in the Figure (available at www.jpeds.com). The characteristics of mothers who were interviewed on d7, stratified by the inclusion criteria for the analytic subset, are compared in Table I (available at www.jpeds.com). Among the 196 in the analytic subset, median milk Na:K (quartile range) was 0.62 (0.48–0.80), and median timing of the d7 sample collection (quartile range) was 7.4 (7.2–7.8) days postpartum. Milk Na:K was not correlated with timing of the d7 sample collection and thus we did not adjust for it in subsequent analyses.

D7 milk supply concern as a predictor of elevated d7 milk Na:K

In the analytic subset, neither infant feeding intention nor previous breastfeeding exclusivity was associated with elevated Na:K. However, elevated d7 milk Na:K occurred in 42% of mothers with a d7 milk supply concern, compared with 21% of mothers without a d7 milk supply concern (unadjusted relative risk, 2.0, $P=0.008$) (Table II). The unadjusted odds of elevated Na:K were 2.7 [1.3–5.9] greater with maternal report of milk supply concern (reference=no concern, $P=0.01$) and further increased after adjustment for maternal ethnicity (3.4 [1.5–7.9], $P=0.003$) (Table II).

Risk of stopping breastfeeding by d60 according to d7 milk Na:K status

Of the 192 in the analytic subset for objective two, 18 (9%) had stopped breastfeeding by d60. Socio-demographic variables significantly associated with stopping breastfeeding were younger maternal age (P<0.001), public health insurance (P=0.026), and weaker infant feeding intentions (P=0.048).

In chi-square analysis of the 192 in this analytic subset, 8 of 46 (17%) *with* elevated d7 milk Na:K, as compared with 10 of 146 (7%) *without* elevated d7 milk Na:K, stopped breastfeeding by d60 (unadjusted relative risk, 2.5, P=0.03) (Table III). The unadjusted odds of stopping breastfeeding by d60 were 2.9 [1.1–7.8] with elevated d7 milk Na:K (reference=normal milk Na:K, P=0.04) and further increased after full adjustment for significant socio-demographic variables (3.3 [1.1–9.7], P=0.03) (Table III).

Discussion

If concerns about milk supply among exclusively breastfeeding women were primarily due to lack of knowledge about the signs of abundant milk production, then the expected outcome would be no difference in milk Na:K as compared with exclusively breastfeeding women without milk supply concerns. Given our definition of elevated Na:K, we would expect to observe about 25% prevalence of elevated Na:K in both groups. Instead, the observed prevalence of elevated Na:K was 2-fold greater in the mothers with milk supply concerns (42% versus 21%). This significant difference remained robust in an adjusted model, suggesting less progress toward mature milk production despite exclusive breastfeeding. This result challenges the belief that milk supply concern in the context of exclusive breastfeeding is primarily maternal misperception.[12]

Furthermore, we found that 17% of exclusively breastfeeding mothers with elevated milk Na:K stopped breastfeeding by d60 as compared with only 7% without elevated milk Na:K, a difference that strengthened after adjusting for socio-demographic variables associated with stopping breastfeeding. Although it is notable that elevated milk Na:K at d7 is a significant risk factor for stopping breastfeeding by d60, nonetheless the large majority (83%) with elevated milk Na:K were still breastfeeding at d60.

Mastitis is an acute inflammation of the breast, usually caused by an infectious agent.[11] Breast permeability increases during mastitis.[11] We did not observe a significant difference in d7 milk Na:K according to mastitis status at d14, or non-mastitis infections reported at either d7 or d14 (data not shown), thus only the single case of mastitis on d7 was excluded from our analyses.[13] It has been demonstrated that milk Na markedly declines as the mammary gland progresses toward mature milk production.[3] We analyzed milk sodium as a ratio to potassium because this approach adjusts for variation in the lipid-free purity of the aqueous fraction of the milk sample and thus produces less error in assessing its relation to mammary gland tight junction formation.[10] Corroborating this rationale, we observed weaker associations for both of our primary outcomes when we used a cut-off based on Na concentration alone (Na > 16 mmol/L). We *a priori* defined elevated Na:K at the >75th percentile, and coincidentally, this cut-off aligns well with the definition of elevated milk Na used by Humenick et al[14] and Morton[15] (day 6 milk Na > 16 mmol/L) (Table IV; available at www.jpeds.com). The results by Morton, replicated by Humenick et al, showed that milk Na > 16 mmol/L at day 6 postpartum was a significant risk factor for short breastfeeding duration.[14, 15] Other investigators, using cross-sectional data, observed that day 3 breast milk sodium was negatively associated with infant breast milk intake[16] and with breastfeeding frequency.[17]

Limitations

There are a few limitations to our analysis. First, we focused our analysis on mothers who were exclusively breastfeeding at d7, and as compared with nonexclusively breastfeeding mothers, they had lower milk Na:K, lower prevalence of milk supply concern, and were less likely to stop breastfeeding by d60, which may limit generalizability to all mothers with low milk supply concerns. Second, we did not control for left versus right breast or time of day in obtaining the milk sample, and lack of control for these factors may have introduced additional error in our model. Third, a small proportion of women may have physiologically-driven low milk supply due to insufficient glandular tissue, which is not likely reflected in elevated milk Na:K.

The only other significant predictor of elevated milk Na:K was maternal ethnicity. Most notably, only 1 of 20 Hispanic women who identified as primarily Spanish-speaking and were exclusively breastfeeding at d7 exhibited elevated milk Na:K. There may be a cluster of breastfeeding behaviors that distinguish Spanish-speaking Hispanic women from other mothers. This finding will be explored in a subsequent analysis.

We observed that 42% of exclusively breastfeeding mothers with a milk supply concern at d7 had concurrent biochemical evidence of less progress toward mature milk production. Furthermore, among exclusively breastfeeding mothers with elevated milk Na:K at d7, the adjusted odds of stopping breastfeeding by d60 were significantly greater than for women without elevated milk Na:K, irrespective of perceived milk supply concern at d7. The take home messages from these findings are two-fold. First, milk supply concerns should not be dismissed as misperception of normal lactation, even if the mother is exclusively breastfeeding. Second, the clinical usefulness of milk Na:K as a diagnostic tool in assessing lactation sufficiency deserves further study, especially with regard to informing the care plan for the breastfeeding dyad during the critical window of the first week or two postpartum when lactation problems are most amenable to intervention.

Acknowledgments

Funded by the National Institutes of Health (NIH; MC 04294 [to K.D.], HD 063275-01A1 [to L.N.-R.], ORWH 5 K12 HD051953 [University of Cincinnati to L.N.-R.]). M.M. was supported by a Showa University international study fellowship at Cincinnati Children's Hospital Medical Center. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH.

Abbreviations

ELS	Early Lactation Success
breast milk Na:K	Ratio of breast milk sodium to potassium concentration
d7	Day 7 interview time points
d60	day 60 interview time points

UCDMC	University of California Davis Medical Center
OR	Odds ratio
95%CI	95% confidence interval

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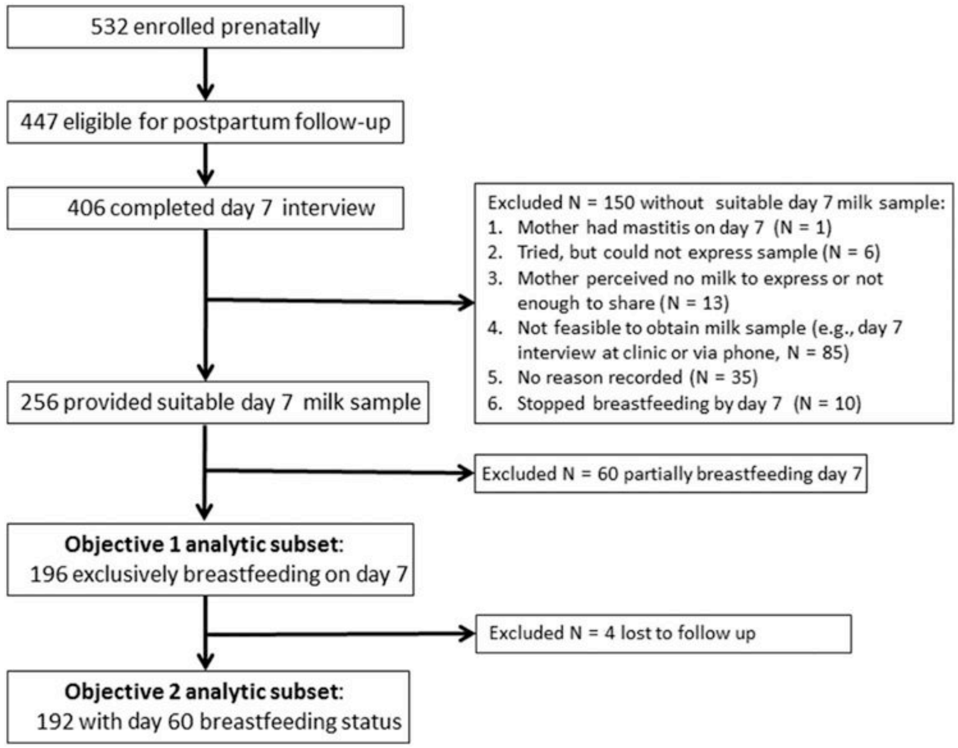

Figure.

Flow diagram describing derivation of analytic subsets

Table 1

Chi-squared analysis comparing subsets of mothers interviewed on day 7 (d7)

	Provided d7 milk sample[a]		Breastfeeding status at d7[b]		Milk Na:K at d7[c]	
	Yes	**No**	**Exclusive**	**Partial**	**≤75th %tile**	**>75th %tile[d]**
	256 (63%)	150 (37%)	196 (77%)	60 (23%)	148 (76%)	48 (24%)
Interview day, median (25th–75th)[e]	7.5 (7.2–7.8)	7.7 (7.2–8.1)	7.4 (7.2–7.8)	7.6 (7.2–7.8)	7.5 (7.2–7.8)	7.5 (7.3–7.8)
	N (%)	**N (%)**	**N (%)**	**N (%)**	**N (%)**	**N (%)**
Ethnic category	256	150	196	60	148	48
Asian	28(11)	20(13)	18(9)	10(17)	15(10)	3(6)
African-American	31(12)	25(17)	21(11)	10(17)	12(8)	9(19)
White, non-Hispanic	118(46)	48(32)	99(50)	19(32)	70(47)	29(60)
Hispanic (English-speaking)	37(14)	22(15)	23(12)	14(23)	19(13)	4(8)
Hispanic (Spanish-speaking)	25(10)	28(19)	20(10)	5(8)	19(13)	1(2)
Identifies with >1 major ethnic category	17(7)	7(5)	15(8)	2(3)	13(9)	2(4)
P-value	0.026		0.026		0.028	
Maternal age, years	256	150	196	60	148	48
<25	106(41)	82(54)	78(40)	28(47)	58(39)	20(42)
25–29.9	72(28)	31(21)	59(30)	13(22)	44(30)	15(31)
> 30	78(30)	37(25)	59(30)	19(32)	46(31)	13(27)
P-value	0.033		0.411		0.869	
Medical Insurance Status	254	148	195	59	147	48
Public	110(43)	87(59)	83(43)	27(46)	60(41)	23(48)
Private	144(57)	61(41)	112(57)	32(54)	87(59)	25(52)
P-value	0.003		0.664		0.389	
Education status	256	150	196	60	148	48
High school or less	89(35)	72(48)	64(33)	25(42)	49(33)	15(31)
At least some college	167(65)	78(52)	132(67)	35(58)	99(67)	33(69)
P-value	0.009		0.204		0.811	
Delivery mode	254	150	195	59	147	48

	Provided d7 milk sample[a]		Breastfeeding status at d7[b]		Milk Na:K at d7[c]	
	Yes	**No**	**Exclusive**	**Partial**	**≤75th %tile**	**>75th %tile[d]**
Vaginal	176(69)	99(66)	143(73)	33(56)	104(71)	39(81)
Cesarean	78(31)	51(34)	52(27)	26(44)	43(29)	9(19)
p-value	0.494		0.013		0.143	
Maternal body mass index at day 7	255	143	195	60	147	48
<30	167(65)	103(72)	134(69)	33(55)	101(69)	33(69)
≥ 30	88(35)	40(28)	61(31)	27(45)	46(31)	15(31)
p-value	0.178		0.054		0.996	
Infant Feeding Intentions category[f]	256	150	196	60	148	48
Weak/Moderate	54(21)	46(31)	32(16)	22(37)	24(16)	8(17)
Strong/Very strong	202(79)	104(69)	164(84)	38(63)	124 (84)	40(83)
P-value	0.032		0.001		0.942	
Delayed lactogenesis	256	150	196	60	148	48
Yes	105(41)	72(48)	74(38)	31(52)	57(39)	17(35)
No	151(59)	78(52)	122(62)	29(48)	91(61)	31(65)
P-value	0.171		0.057		0.700	
Expressed breast milk between days 3 and 7	256	149	196	60	147	48
Yes	186(73)	85(57)	136(69)	50(83)	98(66)	38(79)
No	70(27)	64(43)	60(31)	10(17)	50(34)	10(21)
P-value	0.001		0.028		0.083	
Fed directly at the breast, day 7	256	149	196	60	148	48
Yes	237(93)	126(85)	191(97)	46(77)	145(98)	46(96)
No	19(7)	23(15)	5(3)	14(23)	3(2)	2(4)
P-value	0.012		<0.001		0.439	
Average weight gain, days 3 to 7	242	106	186	56	141	45
<30 grams/day	57(24)	20(19)	48(26)	9(16)	35(25)	13(29)
≥ 30 grams/day	185(76)	86(81)	138(74)	47(84)	106 (75)	32 (71)
P-value	0.328		0.121		0.590	
Exclusively breastfed throughout first 7 days of life	256	150	196	60	148	48

	Provided d7 milk sample[a]		Breastfeeding status at d7[b]		Milk Na:K at d7[c]	
	Yes	**No**	**Exclusive**	**Partial**	**≤75th %tile**	**>75th %tile[d]**
Yes	104(41)	40(27)	104(53)	0(0)	82(55)	22(46)
No	152(59)	110(73)	92(47)	60(100)	66(45)	26(54)
P-value	0.004		<0.001		0.249	
Breastfeeding status, d7	256	149	196	60	148	48
Exclusive	196(77)	85(57)	196 (100)	0(0)	148 (100)	48 (100)
Non-exclusive	60(23)	64(43)	0(0)	60(100)	0(0)	0(0)
P-value	<0.01		<0.01		(–)	
Milk supply concern, d7	256	150	196	60	148	48
Concern	62(24)	45(30)	36(18)	25(42)	21(14)	15(31)
No	194(76)	105(70)	160(82)	35(58)	127(86)	33(69)
p-value	0.204		<0.001		0.011	
Stopped breastfeeding by day 60	249	148	192	57	146	46
Yes	37(15)	42(28)	18(9)	19(33)	10(7)	8(17)
No	212(85)	106 (72)	174 (91)	38(67)	136 (93)	38(83)
P-value	0.001		<0.001		0.044	
Exclusive breastfeeding at day 60	254	148	194	60	146	48
Yes	131(52)	60(40)	126 (65)	5(8)	99(68)	27(56)
No	123(48)	88(60)	68(35)	55(92)	47(32)	21(44)
P-value	0.028		<0.001		0.150	

[a] Among mothers interviewed on day 7;

[b] Among mothers who provided day 7 milk sample

[c] Among mothers who provided day 7 sample and were exclusively breastfeeding d7

[d] Milk sodium to potassium ratio 75th percentile=0.80

[e] P<0.05, using Mann-Whitney U-test.

[f] Infant Feeding Intentions category at prenatal interview (score range: 0–16): weak/moderate, score <11.5; strong, score between 12–15.5; and very strong, score=16.

Table 2

Logistic regression model predicting the odds of elevated milk Na:K according to presence of a milk supply concern among mothers exclusively breastfeeding on day 7[a]

Milk supply concern at day 7[b]		Number (%) with elevated milk Na:K	Elevated milk Na:K, Odds Ratio [95% Confidence Interval]	
Category	Number		Model 1[c]	Model 2[d]
No	160	33 (21)	1.0 (reference)	1.0 (reference)
Yes	36	15 (42)	2.7 [1.3–5.9]	3.4 [1.5–7.9]

[a]Defined as maternal report of exclusive breastfeeding during the 24 hours prior to the day 7 interview;

[b]Defined as milk Na:K > 75th percentile (> 0.80) on day 7 for the analytic subset;

[c]P=0.01;

[d]P=0.003, adjusted for ethnic group

Table 3

Logistic regression model predicting stopped breastfeeding by day 60 according to day 7 milk Na:K status among mothers exclusively breastfeeding at day 7[a]

Milk Na:K at day 7		No. (%) stopped breastfeeding	Stopped breastfeeding by day 60, Odds Ratio [95% confidence interval]			
Category[b]	**No.**		**Model 1[c]**	**Model 2[d]**	**Model 3[e]**	**Model 4[f]**
Not elevated	146	10 (7)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Elevated	46	8 (17)	2.9 [1.1–7.8]	3.0 [1.1–8.6]	3.1 [1.1–8.9]	3.3 [1.1–9.7]

[a]Defined as maternal report of exclusive breastfeeding during the 24 hours prior to the day 7 interview;

[b]Elevated milk Na:K defined as > 75th percentile (> 0.80) for the analytic subset;

[c]P=0.04, unadjusted odds ratio;

[d]P=0.04, adjusted for maternal age;

[e]P=0.04, adjusted for maternal age and health insurance status;

[f]P=0.03, adjusted for Infant Feeding Intentions category, maternal age, and health insurance status, score=16.

Table 4

Agreement between elevated milk Na and elevated milk Na:K at day 7

		Elevated milk Na:K (> 0.80)[b]	
		Yes	**No**
Elevated milk Na (> 16 mmol/L)[a]	Yes	42 (91%)	4 (9%)
	No	6 (4%)	144 (96%)

[a]Morton, 1994;

[b]Milk Na:K > 0.80 is equivalent to milk Na:K >75th percentile among mothers exclusively breastfeeding at day 7 in current studye=16.