Maternal & Child Nutrition

DOI: 10.1111/mcn.12171

Original Article

Relationship of newborn weight loss to milk supply concern and anxiety: the impact on breastfeeding duration

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Abstract

Milk supply concern is the most common reason for breastfeeding discontinuation and maternal anxiety is also associated with reduced breastfeeding duration. Newborn excess weight loss (EWL) could trigger milk supply concern and anxiety and might be amenable to modification. Our objective was to determine the relationship between EWL and the development of milk supply concern and anxiety and the effect of such development on breastfeeding duration. We conducted a cohort analysis using data previously obtained from a randomised controlled trial comparing two post-hospital discharge follow-up strategies. For 1107 well, singleton infants born at ≥34 weeks, we extracted data on all inpatient infant weights. EWL was defined as the loss of ≥10% of birthweight. We surveyed mothers to obtain data on state anxiety and milk supply concern at birth and at 2 weeks. Our final outcome was breastfeeding at 6 months. Seventy (6.3%) infants developed EWL during the birth hospitalisation. At 2 weeks, milk supply concern and positive anxiety screen were more common (42% and 18%, respectively) among mothers whose infants had had EWL than among mothers whose infants had not had EWL (20% and 6%, respectively) ($P < 0.001$ for each comparison). Mothers with milk supply concern at 2 weeks were much less likely to be breastfeeding at 6 months, with odds ratio of 0.47 (0.30, 0.74) in multivariate analysis. EWL may increase milk supply concern and anxiety and these may reduce breastfeeding duration. Ameliorating EWL might alleviate milk supply concern and anxiety and improve breastfeeding duration.

Keywords: lactation, breastfeeding, jaundice, epidemiology, public health.

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Introduction

Breastfeeding reduces the risk of many infectious and allergic diseases in infancy (Ip *et al*. 2007; Kramer & Kakuma 2012) and current national and international guidelines recommend breastfeeding for at least the first 12 months after birth (UNICEF/WHO 2006; US Department of Health and Human Services 2010; Section on Breastfeeding 2012). These recommendations are met in some countries such as Norway, where 98.5% of babies initiate breastfeeding and 82% are still breastfeeding at 6 months of age (Kristiansen *et al*. 2010). However, in countries such as the United States and United Kingdom, many infants initiate breastfeeding at birth, but few continue for the recommended duration. In the Untied States, 75–80% of infants initiate breastfeeding but only 40% breastfeed through 6 months (Centers for Disease Control 2010); in the United Kingdom, 81% of infants initiate breastfeeding but only 34% still breastfeed at 6 months (McAndrew *et al*. 2012).

Although many factors contribute to breastfeeding cessation, including social and cultural pressures and maternal employment, studies have consistently shown that the most frequent reason given by mothers for early discontinuation is maternal concern about inadequate milk supply (Forman *et al*. 1992; Evans *et al*. 1995, 2004; Williams *et al*. 1999; Chan *et al*. 2000; Blyth *et al*. 2002; Colin & Scott 2002; Schwartz *et al*. 2002; Kirkland & Fein 2003; Rempel 2004; Yang *et al*. 2004; Amir & Cwikel 2005; Lewallen *et al*. 2006). Such milk supply concern can often start in the newborn period, when it can be triggered by maternal perception of inadequate growth (Hill 1991). Kools *et al.* reported that mothers who had doubt about infant growth were much more likely to discontinue breastfeeding before 3 months than mothers who did not have doubt about growth (Kools *et al*. 2006) and qualitative research has shown that infant weight changes in the newborn period can trigger maternal milk supply concern (Flaherman *et al*. 2012). Support from peer counsellors, lactation consultants, physicians and post-partum nurses can be helpful in ameliorating milk supply concern (Dennis 2002; Dennis *et al*. 2002; Taveras *et al*. 2003), but milk supply concern can also be resistant to standard provider reassurance (Bunik *et al*. 2010).

While early weight loss is nearly universal for both breastfed and formula-fed newborns, the relationship between newborn weight loss and milk supply concern is important because on average, breastfed newborns lose about 5–7% of their birthweight prior to beginning weight gain (Macdonald *et al*. 2003; van Dommelen *et al*. 2007). Moreover, approximately 10–18% of breastfed newborns develop excess weight loss (EWL) of ≥10% of their birthweight in the days following delivery and providers vary in their practices related to EWL (Macdonald *et al*. 2003; van Dommelen *et al*. 2007; Chantry *et al*. 2011). Factors contributing to weight loss have been well documented and the administration of large volumes of intravenous fluid may be an independent risk factor for newborn weight loss (Noel-Weiss *et al*. 2006; Watson *et al*. 2012). In part because of the complexity of factors related to weight loss, provider practices in the setting of EWL vary by baby, provider and institution and may include supplementation with formula, referral to lactation support and/or earlier scheduled newborn follow-up (Academy of Breastfeeding Medicine Protocol Committee 2009). The effect of EWL on maternal milk supply concern has not been previously examined.

To investigate the relationship between EWL and milk supply concern and the relationship between milk supply concern and eventual breastfeeding outcomes, we took advantage of existing data from the Nurses for Infants Through Teaching and Assessment After the Nursery (NITTANY) randomised controlled trial, which compared the effect of two different strategies for post-hospital discharge care of healthy mothers and newborns and had previously reported that in-home nurse visits increased rates of breastfeeding at 2 weeks and 2 months, but not 6 months (Paul *et al*. 2012). Because the data from this trial and other work show an association between maternal state anxiety and breastfeeding discontinuation (Paul *et al*. 2012; Adedinsewo *et al*. 2014) and because milk supply concern may be associated with maternal anxiety (Huang *et al*. 2009; Flaherman *et al*. 2012), we also examined the relationships between EWL, maternal state anxiety and milk supply concern.

Key messages

- Excess newborn weight loss (≥10% of birth weight) during the birth hospitalization is a strong predictor of maternal anxiety and milk supply concern at two weeks after birth.
- Mothers with either milk supply concern or a positive anxiety score at 2 weeks were much more likely to stop breastfeeding before 2 months.
- Excess weight loss during the birth hospitalization may be an important risk factor for breastfeeding discontinuation.

Methods

We conducted a cohort analysis using the data obtained from a previously published randomised controlled trial comparing two post-hospital discharge care models for mothers attempting to breastfeed during the birth hospitalisation and intending to continue after discharge (Paul *et al*. 2013). For 1107 well, singleton breastfeeding infants born at ≥34 weeks in 2006–2009 at Penn State Hershey Medical Center, we extracted data on all inpatient infant weights. Study infants had been weighed in the course of routine clinical care and were not weighed for study purposes; in general, weights were obtained daily around midnight. Study mothers and infants received usual clinical care, with variable practice patterns regarding clinical management depending on provider. Weight change was defined as the difference between birthweight and each weight recorded subsequently, calculated as a percentage of birthweight. Weight nadir was defined as the difference between birthweight and the lowest recorded inpatient weight subsequent to birthweight, calculated as a percentage of birthweight. EWL was defined as a weight nadir of ≥10% below birthweight. This analysis was approved by the University of California San Francisco Committee on Human Research following study approval by the Penn State Hershey Medical Center Institutional Review Board.

Data on maternal milk supply concern were collected by study investigators during the post-partum hospitalisation and at 2 weeks post-partum using the following methodology. During the post-partum hospitalisation, mothers were asked 'Are you or your baby having any problem feeding now?' If a mother answered yes, she was then asked, 'What is the most important problem you or your baby are having with feeding?' and was given a choice of responses. Mothers who chose, 'Baby still hungry/not enough milk' were scored as having milk supply concern. At 2 weeks post-partum, mothers were asked, 'Did you have any of the following problems breastfeeding your baby during the first 2 weeks of breastfeeding?' and were instructed to answer all that applied. If a mother then answered 'yes' to the item 'I didn't have enough milk', she was scored as having milk supply concern.

Data on maternal state anxiety were collected by investigators during the course of the post-partum hospitalisation and at 2 weeks post-partum using the state anxiety subscale of the validated State Trait Anxiety Inventory (STAI; Tluczek *et al*. 2009). Importantly, there are different components of anxiety (Spielberger 1983). 'Trait anxiety' describes an individual's proneness to anxiety, while 'state anxiety' is a more acute phenomenon in response to a perceived stressful, dangerous or threatening situation. As previously used in the literature, a STAI score of 40 on the state subscale is considered a positive state anxiety screen (Britton 2005).

Breastfeeding and formula use were measured during the birth hospitalisation and at 2 weeks, 2 months and 6 months using questions adapted from the Infant Feeding Practices Study II Neonatal Questionnaire and Infant Month 2 Questionnaire (Centers for Disease Control 2013). As maternal perception of time to onset of mature milk production has been validated as an indicator of lactogenesis II (Chapman & Perez-Escamilla 2000), time until onset of mature milk production was measured by asking mothers at 2 weeks, 'How long did it take for your milk to come in, after you delivered your baby?' This method of measurement, which used a metric of days, is consistent with the Centers for Disease Control and Prevention Infant Feeding Practices II survey which also simply relied on maternal subjective reporting of days until onset of milk production (Centers for Disease Control 2013). All outcome assessments after discharge from the birth hospitalisation were conducted by phone by NITTANY investigators.

We used chi-square analysis to examine the relationship between EWL and dichotomous variables including milk supply concern and positive anxiety screen. We used Student's *t*-test to examine the relationship between EWL and continuous variables including total STAI score and days to onset of mature milk production. We used multivariate logistic regression to examine the relationship between milk supply concern and subsequent breastfeeding status while adjusting for clinical and demographic predictors including maternal age, race/ethnicity and parity.

Results

From the entire study cohort of 1154 mothers, 15 were excluded from this analysis because they delivered twins and 32 were excluded because maximum weight change during the birth hospitalisation was missing ($n = 19$) or nonsensical because of suspected documentation error (≥20% change), leaving 1107 mother-infant pairs for further analysis. (Table 1). Among these 1107 mothers, mean age was 29.0 ± 5.4, 47% were primiparous, 84% were white non-Hispanic and 31.2% gave birth by Cesarean section. Their singleton infants had a mean birthweight of 3.4 ± 0.4 kg, with a range of 1.8 to 5.0 kg. In this cohort, 99% of infants breastfed at least once in the first 24 h and 69% were breastfeeding exclusively at hospital discharge. Median length of stay [interquartile range (IQR)] was 48.7 (40.3–62.9) and differed by method of delivery; mothers who delivered vaginally had a median length of stay (IQR) of 43.4 h (37.6, 50.5) and mothers who delivered by Cesarean had a median length of stay (IQR) of 69.9 (61.75, 74.9), $P < 0.004$.

Mean infant weight loss during the birth hospitalisation was 6.3 ± 2.5%. Seventy (6.3%) infants lost ≥10% of their birthweight during the birth hospitalisation and were defined as having EWL. Among these 70 infants with EWL, mean weight loss at inpatient recorded nadir was 11.3 ± 1.5% and occurred at 34 ± 12 h of age, whereas among infants who did not experience EWL while inpatients, mean weight loss at inpatient recorded nadir was 5.9 ± 2.2% and occurred at 53 ± 14. Mothers whose infants developed EWL were somewhat older, more likely to be primiparous and more likely to have delivered by Cesarean section than mothers whose infants did not develop EWL. At baseline post-partum measurement, mean STAI scores, prevalence of a positive anxiety screen and prevalence of milk supply concern did not differ

Table 1. Baseline clinical and demographic characteristics

Characteristics	EWL during birth hospitalisation ($n = 70$)	No EWL during birth hospitalisation ($n = 1037$)	*P*-value
Maternal age, mean ± SD	30.2 ± 5.3	28.9 ± 5.4	0.05
Maternal race/ethnicity, *n* (%)			
White, not Hispanic or Latino	63 (90)	866 (84)	
White, Hispanic or Latino	4 (5.7)	52 (5.0)	
Black, not Hispanic or Latino	2 (2.9)	60 (5.8)	
Asian	0 (0)	49 (4.7)	
Other	1 (1.4)	9 (0.9)	0.30
Education, *n* (%)			
Some high school	0 (0)	29 (2.8)	
High school graduate	6 (8.6)	158 (15)	
Some college/technical school	18 (26)	258 (25)	
College graduate	34 (49)	379 (37)	
Postgraduate training/degree	12 (17)	209 (20)	0.15
Income, *n* (%)			
<$25 000	2 (2.9)	91 (8.8)	
$25 000–$49 999	14 (20)	192 (19)	
$50 000–$74 999	19 (27)	222 (21)	
$75 000–$99 999	15 (21)	201 (19)	
≥$100 000	17 (24)	212 (20)	
Missing/Refused/Don't know	3 (4.3)	119 (11)	0.19
Primiparous, *n* (%)	42 (60)	482 (46)	0.03
Prematurity <37 weeks, *n* (%)	3 (4)	47 (4)	0.92
Vaginal delivery, *n* (%)	15 (21)	747 (72)	<0.001
STAI score at birth, mean ± SD	32.2 ± 9.2	30.9 ± 8.6	0.24
Positive anxiety screen at birth (STAI ≥ 40), *n* (%)	12 (17)	177 (17)	0.99
Milk supply concern at birth	0 (0)	24 (2.3)	0.20

EWL, excess weight loss; SD, standard deviation; STAI, State Trait Anxiety Inventory.

between mothers whose infants eventually experienced EWL and those whose infants did not.

At 2 weeks follow-up, milk supply concern was present among 20% of mothers including 42% of mothers whose infants had had EWL during the birth hospitalisation and 18% of mothers whose infants had not had EWL ($P < 0.001$) (Table 2). A positive anxiety screen was much more common (18.2%) among mothers whose infants had had EWL than among mothers whose infants had not had EWL (6.3%) ($P < 0.001$); mean STAI scores were 26.6 ± 7.3 among mothers whose infants had not had EWL and 29.5 ± 8.9 among mothers whose infants had had EWL ($P < 0.005$). Mothers with milk supply concern at 2 weeks had higher STAI scores at 2 weeks (28.8 ± 8.1) than did mothers without milk supply concern at 2 weeks (26.3 ± 7.2) ($P < 0.001$). Among mothers with milk supply concern at 2 weeks, 10.2% had a positive state anxiety screen at 2 weeks, while the prevalence of a positive screen was 6.1% among mothers without milk supply concern at 2 weeks ($P = 0.037$). In sensitivity analysis, we repeated the earlier analyses using the subgroup of infants born vaginally and found results consistent with the analysis of the entire cohort.

Mothers of newborns who experienced EWL during the birth hospitalisation had later onset of mature milk production (3.8 ± 1.0 days) than mothers of newborns who did not experience EWL during the birth hospitalisation (3.3 ± 1.0 days) ($P < 0.001$). Mothers with a later onset of mature milk production were much more likely to have milk supply concern and anxiety at 2 weeks post-partum. In multivariate logistic regression, each additional day until mature milk production had an odds ratio (OR) of 2.29 (1.93, 2.72) for the outcome of milk supply concern at 2 weeks after adjusting for maternal age, race/ethnicity and method of delivery; each additional day until the onset of mature milk production had an OR of 1.33 (1.05, 1.70) for the outcome of a positive anxiety screen after adjusting for the same variables. In multivariate linear regression, mean STAI score increased by 0.5 ± 0.2 for each additional day until onset of mature milk production after the same adjustment.

Milk supply concern and anxiety levels at 2 weeks strongly predicted future breastfeeding and formula use. Mothers who had milk supply concern at 2 weeks had an ORs of 7.66 (5.18, 11.3), 5.96 (3.08, 11.5) and 3.56 (1.66, 7.64) for using formula at 2 weeks and 2 and 6 months, respectively, after adjusting for maternal age, race/ethnicity, income, parity and method of delivery (Table 3). Similarly, mothers who had milk supply concern at 2 weeks were much less likely to be breastfeeding at 2 and at 6 months, with ORs of 0.24 (0.17, 0.35) and 0.47 (0.30, 0.74), respectively, after adjusting for the same factors. Higher anxiety levels at 2 weeks were also associated with decreased breastfeeding prevalence at 2 months and increased formula use at 2 weeks and 2 months, with ORs of 0.78 (0.63, 0.96), 1.25 (1.05, 1.49) and 1.30 (1.02, 1.66), respectively, for each 10-point increase in STAI score after adjusting for the same variables. In sensitivity analysis adjusting for time to onset of mature milk production, results were similar to the ones mentioned earlier. Time to onset of mature milk production did not predict breastfeeding rates at 2 weeks, 2 months or 6 months but did predict formula use at these time points, with ORs of 1.37 (1.20, 1.57), 1.43 (1.19, 1.71) and 1.25 (1.01, 1.54), respectively, per

Table 2. Clinical characteristics during follow-up, by weight loss status

Characteristics	EWL during birth hospitalisation ($n = 70$)	No EWL during birth hospitalisation ($n = 1037$)	*P*-value
Time to onset of mature milk production	3.8 ± 1.0	3.3 ± 1.0	<0.001
Weight loss at recorded nadir (% of birthweight)	11.3 ± 1.5	5.9 ± 2.2	<0.001
State Trait Anxiety Inventory score at 2 weeks, mean ± SD	29.5 ± 8.9	26.6 ± 7.3	0.002
Positive anxiety screen at 2 weeks, *n* (%)	12 (18)	60 (6)	<0.001
Milk supply concern at 2 weeks, *n* (%)	29 (41)	187 (18)	<0.001

EWL, excess weight loss; SD, standard deviation.

Table 3. Odds ratios and 95% confidence intervals for the association between variables on infant feeding outcomes in multivariate analysis

Variable	Formula at 2 weeks	Breastfeeding at 2 months	Formula at 2 months	Breastfeeding at 6 months	Formula at 6 months
Milk supply concern	7.68 (5.20, 11.3)	0.24 (0.16, 0.35)	5.93 (3.07, 11.4)	0.46 (0.29, 0.72)	3.49 (1.66, 7.37)
Maternal age (each year)	0.96 (0.93, 0.99)	1.09 (1.05, 1.13)	0.96 (0.92, 1.0)	1.07 (1.03, 1.12)	1.00 (0.95, 1.05)
Race/ethnicity					
White, not Hispanic/Latino	Reference	Reference	Reference	Reference	Reference
White, Hispanic/Latino	1.42 (0.76, 2.62)	0.72 (0.35, 1.47)	0.73 (0.35, 1.50)	0.98 (0.44, 2.23)	1.92 (0.68, 5.41)
Black, not Hispanic/Latino	1.32 (0.70, 2.52)	0.72 (0.35, 1.47)	3.72 (1.06, 13.1)	0.80 (0.35, 1.80)	1.11 (0.36, 3.39)
Asian	0.92 (0.44, 1.90)	4.01 (1.31, 12.2)	1.12 (0.41, 3.09)	2.18 (0.88, 5.4)	1.38 (0.48, 3.98)
Income					
<$25 000	2.02 (1.15, 3.56)	0.72 (0.38, 1.36)	1.34 (0.60, 3.01)	0.67 (0.33, 1.36)	0.69 (0.28, 1.70)
$25 000–$49 999	0.89 (0.57, 1.38)	0.97 (0.58, 1.61)	1.21 (0.69, 2.11)	0.95 (0.57, 1.57)	0.83 (0.44, 1.56)
$50 000–$74 999	Reference	Reference	Reference	Reference	Reference
$75 000–$99 999	1.11 (0.73, 1.69)	1.02 (0.61, 1.69)	1.05 (0.62, 1.80)	1.06 (0.64, 1.75)	1.21 (0.66, 2.24)
≥$100 000	0.85 (0.55, 1.31)	1.30 (0.75, 2.24)	0.76 (0.46, 1.28)	0.91 (0.55, 1.49)	0.64 (0.36, 1.14)
Multiparity	0.88 (0.66, 1.18)	1.15 (0.81, 1.64)	0.76 (0.52, 1.11)	0.97 (0.68, 1.38)	1.00 (0.65, 1.55)
Cesarean section	1.37 (1.01, 1.85)	0.80 (0.56, 1.15)	1.56 (1.05, 2.31)	0.62 (0.43, 0.88)	1.86 (1.16, 2.98)

additional day until onset of mature milk production, adjusting for maternal age, race/ethnicity, income, parity and method of delivery.

Among 1010 mothers who were still breastfeeding at 2 weeks, breastfeeding without formula at 2 weeks was highly associated with increased breastfeeding rates at 2 and 6 months, with ORs of 8.33 (5.56, 12.5) and 6.25 (4.17, 9.09), respectively, in multivariate models adjusting for maternal age, race/ethnicity and income. In this model adjusting for maternal age, race/ethnicity, income and breastfeeding without formula at 2 weeks, the variables method of delivery, time to onset of mature milk production and maternal anxiety level were not significantly associated with the outcomes of breastfeeding at 2 and 6 months.

Discussion

Excess weight loss was a strong predictor of both maternal anxiety and maternal milk supply concern in this study. In combination with the existing literature, which shows that milk supply concern is the most common reason given by mothers for discontinuing breastfeeding in early infancy (Williams *et al*. 1999; Colin & Scott 2002; Schwartz *et al*. 2002; Evans *et al*. 2004; Rempel 2004; Yang *et al*. 2004; Lewallen *et al*. 2006), these associations suggest that strategies which reduce milk supply concern and/or maternal anxiety might make a substantial contribution to improving breastfeeding rates at 2 and 6 months. These results also suggest that milk supply concern may often be caused by EWL, rather than being a justification for cessation used by mothers who did not wish to continue breastfeeding. The generalisability of our findings is supported by the similarity between the prevalence of anxiety and milk supply concern in our post-partum cohort and those prevalences reported in other cohorts (Dennis *et al*. 2013); higher levels of maternal anxiety and milk supply concern were strong predictors of breastfeeding rates at 2 and at 6 months. Therefore, we believe that preventing EWL could benefit breastfeeding outcomes by reducing maternal anxiety and milk supply concern and thereby improving breastfeeding duration at 2 and 6 months.

Maternal education and reassurance about normal milk supply patterns can ameliorate milk supply concern, especially when health professionals focus on normalising newborn weight patterns. However, milk supply concern is not always responsive to clinician reassurance (Flaherman *et al*. 2012). Specific techniques such as intensive inpatient and outpatient lactation support, peer support groups or professional home visits may be useful to alleviate anxiety and

improve breastfeeding (Lieu *et al*. 2000; Porteous *et al*. 2000; Escobar *et al*. 2001; Dennis *et al*. 2002; Chapman *et al*. 2004; Graffy *et al*. 2004; Bonuck *et al*. 2005; Coutinho *et al*. 2005; Anderson *et al*. 2007). It might also be possible to weigh newborns less frequently or to teach physicians to put less emphasis on newborn weight assessment. However, because EWL is a major risk factor for hypernatremic dehydration, practitioners might have important reservations about avoiding the measurement of infant weight. Furthermore, on a long-term basis, weight measurement is important to screen for failure to thrive. As increased volume of antepartum fluid administration is associated with more pronounced newborn weight loss, some authors have suggested that baseline weights should be collected at 12 h of age (Chantry *et al*. 2011; Noel-Weiss *et al*. 2011; Watson *et al*. 2012). It is possible that this would help to ameliorate milk supply concern, but the effectiveness of this approach has not yet been studied. Improved maternal education regarding normal newborn weight loss patterns could also be potentially effective, but educational interventions have shown mixed results for breastfeeding outcomes. Further research is needed to determine whether any of these specific interventions has the potential to prevent EWL and milk supply concern.

Of note in this study, breastfeeding without formula at 2 weeks was the single strongest predictor of breastfeeding duration. In multivariate analysis using breastfeeding without formula at 2 weeks as a predictor of future breastfeeding outcomes, only milk supply concern at 2 weeks remained a significant predictor of breastfeeding duration; other factors associated with breastfeeding duration such as race, ethnicity, income, parity and method of delivery were not significant predictors of breastfeeding duration once breastfeeding without formula at 2 weeks and milk supply concern at 2 weeks were included in the model. These results suggest that if mothers have used formula during the post-partum period and wish to breastfeed through 6 months, efforts should be made to discontinue formula use before 2 weeks post-partum. In addition, it is possible that an intervention that reduced both formula use and milk supply concern at 2 weeks might be very effective at improving breastfeeding duration (Flaherman *et al*. 2013).

This analysis has several important limitations. First, newborn weights were available for the birth hospitalisation only. We did not have data on outpatient weights and therefore we did not capture weight nadir for all infants. Infants with EWL were older at the time of the lowest recorded weight than were infants without EWL. This likely explains why the prevalence of EWL described in this analysis is lower than has been previously described (Macdonald *et al*. 2003; van Dommelen *et al*. 2007; Chantry *et al*. 2011). As infants born by Cesarean section had a longer length of stay (Paul *et al*. 2013), we were more likely to capture weight nadir on those infants, who are therefore overrepresented among the group of newborns with EWL. However, the results of the subgroup analyses of infants born vaginally were consistent with the main results and in multivariate analysis, we were able to adjust for method of delivery. Second, our cohort was drawn from a single centre with a relatively high duration of breastfeeding, with 65% breastfeeding at 6 months. Therefore, our results could be dependent on local feeding management, which might also vary from clinician to clinician. Furthermore, our results do not necessarily apply to populations with a lower prevalence or duration of breastfeeding. Third, our study did not assess trait anxiety or prenatal levels of anxiety and we are therefore unable to report on the effect these important factors might have on postnatal anxiety, milk supply concern and EWL. It is possible that mothers with higher levels of trait anxiety might be more likely to experience milk supply concern in the setting of EWL. In addition, we used a single item question to assess milk supply concern, which can be a complex emotion. Our study design therefore did not allow us to report a causal relationship between anxiety, milk supply concern, EWL and breastfeeding duration. Fourth, mothers in our study were largely white, non-Hispanic, so our results do not necessarily apply to mothers of other racial or ethnic groups. Fifth, we did not capture data on physician recommendations regarding formula supplementation in the setting of EWL and so we are unable to determine the role of

physician recommendations on the relationship between EWL and the development of maternal milk supply concern. Further study is needed in this important area, with special attention to how these factors may vary by type of delivery.

Conclusion

This analysis has identified EWL and maternal milk supply concern as key factors associated with breastfeeding duration, independent of multiple demographic factors. In addition, this analysis suggests a critical window of opportunity for clinicians to address these factors. At 2 weeks after birth, milk supply concern and maternal anxiety are higher among mothers of newborns who have had EWL and increase an infant's risk of breastfeeding discontinuation. Preventing EWL or reducing milk supply concern and anxiety could potentially improve breastfeeding duration. Because formula use at 2 weeks is a very strong predictor of breastfeeding cessation at 2 and at 6 months, providers should discuss strategies for discontinuing formula before 2 weeks with mothers who have used formula in the postpartum period and would like to breastfeed for 6 months.

Acknowledgement

This project is/was supported by the Health Resources and Services Administration (HRSA) of the U.S. Department of Health and Human Services (HHS) under grant R40 MC 06630. This information or content and conclusions are those of the authors and should not be construed as the official position or policy of, nor should any endorsements be inferred by HRSA, HHS or the U.S. Government.

Source of funding

Grant number R40 MC 06630 from the Maternal Child Health Bureau, HRSA, supported data collection and analysis for this study. Grant number K23HD059818 from the National Institute of Children Health and Human Development supported study design, data analysis and manuscript preparation for this study.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Contributions

VF and IP developed the protocol with the support of JB and MC. All authors contributed to the development of the analytic plan. JB and IP collected data with the support of the research nurses and research assistants at the study site. VF conducted the main analyses. All authors contributed to the manuscript, and have read and approved the final manuscript.

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