Breast-feeding During Pregnancy and the Risk of Miscarriage

CONTEXT: *Breast-feeding rates and durations have been increasing among U.S. women in recent decades. As a result, women may be more likely to practice breast-feeding during pregnancy (BDP), which has been hypothesized to increase the risk of miscarriage, yet there has been little research into the issue.*

METHODS: *Data on 10,661 pregnancies from several waves of the National Survey of Family Growth, covering the years 2002–2015, were used to calculate unadjusted miscarriage rates according to BDP status. Multivariate Cox proportional hazards models were employed to investigate the association between BDP and the risk of miscarriage.*

RESULTS: *BDP was practiced for 6% of the total time at risk of miscarriage. The miscarriage rate was higher when mothers exclusively breast-fed during pregnancy (35%) than when they practiced either complementary BDP (i.e., the child also consumed other food) or did not breast-feed (14% and 15%, respectively). After adjustment for maternal and pregnancy characteristics, the risk of miscarriage was greater when mothers exclusively breast-fed than when mothers did not breast-feed (hazard ratio, 3.9), but no increased risk was found with complementary BDP. The miscarriage risk during exclusive BDP was similar to that for women who conceived when they were 40 or older (3.2).*

CONCLUSIONS: *Exclusive BDP is associated with an elevated risk of miscarriage, but it remains unclear whether and how the practice is associated with health outcomes for the mother and breast-fed child. Research is needed to further explore these outcomes to inform recommendations regarding BDP.*

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Breast-feeding offers a variety of health and psychological benefits to mothers and children.[1–6] It even can serve as an effective natural form of contraception when exclusively practiced for up to six months after a baby's birth.[7] As a result, the promotion of breast-feeding is a cornerstone of international efforts to improve family planning and maternal and child health;[8,9] in the United States, it is a core objective for improving infant health in the Federal Interagency Workgroup's Healthy People 2020 initiative.[10] Historically, the United States has had one of the lowest rates of breast-feeding among high-income countries,[11] but it has been increasing over the past two decades—from 70% in 2000[12] to 83% in 2015.[13] Furthermore, U.S. mothers have been increasing their duration of breast-feeding: More children are being breast-fed for up to 12 months and beyond. The latest national estimates show that 57% of U.S. children breast-feed until they are at least six months old, and more than one-third continue to do so up to 12 months.[13]

A consequence of longer breast-feeding duration is that it may increase the prevalence of mothers' breast-feeding during subsequent pregnancies, particularly following shorter interpregnancy intervals. There has been little research into the associations between breast-feeding during pregnancy (BDP) and maternal, child or pregnancy outcomes; the research that has been done exclusively focused on less-developed countries, and none used nationally representative data.[14,15]

Breast-feeding during pregnancy is a relatively common practice in many parts of the world. Estimates based on nationally representative data from low- and middle-income countries show that, on average, 35% of the latest born children who had ever been breast-fed and whose mother had subsequently become pregnant continued to breast-feed during their mother's next pregnancy.[16] Estimates from other low-income countries suggest that the prevalence of BDP is anywhere between 15% and 50%.[17–20] In wealthier populations, statistics are more difficult to come by. The most recent evidence from the United States shows that between 1988 and 1994, some 5% of breast-feeding women were pregnant.[21]

There are two mechanisms that may link BDP to adverse pregnancy outcomes: nutritional stress and hormone release. Pregnancy and lactation are both nutritionally demanding physiological processes. During pregnancy, a well-nourished woman's basal metabolic rate increases by about 5%, 10% and 25% in the first, second and third trimesters, respectively.[22–24] Lactation has even greater energy requirements. From a child's birth until age six months, it is recommended that women consume an additional 500 kcal/day. Those who continue to breast-feed beyond six months are recommended to consume an additional 400 kcal/day.[25] Furthermore, pregnancy and lactation increase not only energy demands, but also nutritional demands. For optimal health, women who are pregnant or lactating also have significantly higher requirements for most vitamins and minerals.

The limited research on the effects of BDP and maternal nutrition comes from low- and middle-income countries and has consistently found that BDP is associated with

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compromised maternal nutrition. Studies in Guatemala, Egypt and Turkey have found that BDP was associated with lower maternal fat reserves, lower weight gain during pregnancy and higher risk of maternal anemia.[18,26–28] Whether this translates to adverse pregnancy outcomes, however, has not been determined. Several studies have investigated the relationship between BDP and the risk of miscarriage and have generally found no statistically significant relationship.[27–32] As a result, two recent reviews of the literature on BDP have concluded that it does not increase the risk of miscarriage, although both acknowledged the need for further research.[14,15]

It has also been suggested that a hormonal mechanism may link BDP and miscarriage.[32] When infants stimulate the nipple and areola, they trigger the release of oxytocin in the mother, which causes a series of reactions that force milk toward the nipple.[33] Oxytocin is also known to cause uterine contractions, which, if occurring in a pregnant woman, may result in either preterm birth or miscarriage. Of the aforementioned mechanisms, virtually all studies have focused on the former.[27–30,32] There is currently no evidence that the release of oxytocin caused by breast-feeding is sufficient to cause miscarriage.

The current literature suffers from several shortcomings. First, all of these studies were conducted using small, clinical or local samples, and it is therefore unclear whether the findings apply to general populations. In several of these studies, positive correlations were found between BDP and the risk of miscarriage, but none were statistically significant.[27,29,30] Because this research question involves a relatively uncommon exposure (i.e., BDP), and therefore a low conditional probability of observing a miscarriage, it is difficult to determine if the lack of significant findings is simply due to low statistical power. Most of these studies could identify only a handful of cases in which a miscarriage occurred, irrespective of breast-feeding status.

A second shortcoming is that none of the studies accounted for changes or variation in exposure to BDP and the censoring of pregnancies that occurs when analyzing miscarriages. When mothers practice BDP, breast-feeding generally does not last for the duration of a pregnancy; instead, it is more likely to overlap with only part of a subsequent pregnancy. In fact, having a subsequent pregnancy is often the reason why a woman discontinues breast-feeding.[31,34] Most studies of the association between BDP and the risk of miscarriage have simply compared women who had ever breast-fed during pregnancy with those who had not.[28–30,32] If women who practice BDP generally do so for only a part of their next pregnancy, the methods employed in the previous studies can exaggerate the amount of time pregnancies are exposed to concurrent breast-feeding. Analytic methods must account for this to avoid misattributing miscarriages to BDP that occurred when women were no longer breast-feeding.

A third shortcoming is that no study of BDP has differentiated between complementary and exclusive breast-feeding; in the former, the child also consumes other food, and in the latter, breastmilk is the child's only source of nutrition. Given the theoretical mechanisms linking BDP to miscarriage, this is an important distinction, as one would expect that exclusive breast-feeding would be far more demanding on a mother in terms of nutrition and stress than complementary breast-feeding. Furthermore, treating both kinds of BDP as having similar risks would obscure any potential association between exclusive BDP and miscarriage, because exclusive breast-feeding, especially for extended periods, tends to be much less common than complementary breast-feeding.[11]

Finally, existing studies have not accounted for the fact that induced abortions and ectopic pregnancies are competing risks to miscarriages. That is, if a woman had become pregnant but the pregnancy ended for reasons other than miscarriage, she should contribute to the population at risk until the end of the pregnancy. It is important to adequately account for these forms of censoring to properly identify who is at risk of experiencing a miscarriage throughout observation—and for how long.

This study used data from the National Survey of Family Growth (NSFG) to investigate whether breast-feeding during pregnancy is associated with the risk of miscarriage in the first 20 weeks of pregnancy. It is the first study to investigate this topic in the United States, and one of the few to make use of nationally representative data. The NSFG is well suited to this research question, as it collects detailed data on the gestation, pregnancy outcomes and breast-feeding durations of all children born to respondents.

METHODS

Data

The data come from the four latest waves of the NSFG and cover the periods 2002, 2006–2010, 2011–2013 and 2013–2015. The NSFG is a cross-sectional, nationally representative survey of American men and women that collects data on relationships, fertility, contraceptive use, socioeconomic characteristics and health. The present study used retrospective pregnancy histories reported by female respondents aged 15–44. The histories include information on dates of conception and pregnancy termination, outcomes of pregnancies (i.e., induced abortion, miscarriage, stillbirth, ectopic pregnancy, currently pregnant, live birth), birth weights, durations of breast-feeding and age when foods other than breast milk were introduced for live births. The four waves recorded data on a total of 52,986 pregnancies.

Several data restrictions were required to arrive at the analytic sample (see Appendix Table 1—Supporting Information—for numbers of cases excluded). First, only women with singleton births were included in the analysis, as twins or higher-order multiple births who breast-feed may place an unusually large strain on maternal nutrition. Second, pregnancies to nulliparous women were omitted. Third, all pregnancies to women who never breast-fed any of their children were omitted. Fourth, pregnancies were excluded if the preceding pregnancy did not end in a live

birth because of miscarriage, induced abortion, ectopic pregnancy or stillbirth. Fifth, pregnancies were excluded if the most recently born child died before the subsequent conception. The three preceding criteria were intended to ensure that BDP was actually possible. Finally, if the most recently born child never breast-fed, the pregnancy was omitted from the analysis to ensure that the comparison between BDP and its absence was not merely capturing differences in the initiation of breast-feeding. Across the four waves of the NSFG, 11,189 pregnancies met all of the inclusion and exclusion criteria (2,533 from 2002; 4,462 from 2006–2010; 2,117 from 2011–2013; and 2,077 from 2013–2015). After dropping outliers and cases that had inconsistent or incomplete information on various characteristics, the final analytic sample consisted of 10,661 pregnancies that were at risk of miscarriage for 46,222 person-months.

Measures

To examine the association between BDP and the risk of miscarriage, event-history models were employed. A pregnancy entered into the population at risk when gestation began; it exited the population at risk when the pregnancy reached 20 weeks' gestation, when the pregnancy was terminated for any reason (i.e., miscarriage, abortion, ectopic pregnancy) or when the end of observation was reached (i.e., the interview date). If a pregnancy ended with an induced abortion or ectopic pregnancy, it contributed to the total time at risk until the loss occurred.

The dependent variable is the incidence of a miscarriage, defined as the involuntary loss of a pregnancy within 20 weeks after the start of gestation. After this point, pregnancies that end in an involuntary loss are generally classified as stillbirths. It is important to note that definitions of miscarriage vary; the definition adopted in this paper is the same as that used by the Centers for Disease Control and Prevention.[35]

The main independent variable is categorical and indicates whether breast-feeding occurred concurrently with pregnancy and, if so, whether it was practiced complementarily (i.e., the child also consumed other food) or exclusively (i.e., breastmilk was the child's only source of nutrition). It was treated as a time-varying covariate, meaning that an individual pregnancy could be exposed to concurrent breast-feeding for only part of the gestational period if breast-feeding ended before the pregnancy exited the population at risk. This also means that a pregnancy could first be exposed to exclusive breast-feeding followed by partial breast-feeding or no breast-feeding throughout the time at risk. For mothers who breast-fed their previously born child either complementarily or exclusively for the entire duration of the pregnancy, or for those who never breast-fed their child during the subsequent pregnancy, this measure does not vary over the duration of the pregnancy.

The model included several control variables to account for observable differences between mothers who did and did not breast-feed during pregnancy. First, the model controlled for variables that were meant to account for differences in both reporting and trends in the incidence of miscarriage over time.[36,37] To this end, categorical variables representing the wave of the NSFG in which the data were recorded and the calendar year of the pregnancy (1980–1989, 1990–1999, 2000–2009 and 2010–2015) were included.

Second, the model controlled for maternal characteristics that may be associated with miscarriage and breast-feeding. These are the mother's marital status (single, married, widowed, divorced, separated or remarried),[38] a binary indicator of whether she had previously experienced a miscarriage,[39] highest completed level of education (less than high school, high school, some college, associate's degree, bachelor's degree or graduate degree),[36] race and Hispanic origin (Hispanic, white, black or other),[36] nativity (foreign-born or U.S.-born)[40] and age at the start of the pregnancy.[39] Marital status was allowed to vary over time, as some relationships started or ended during the course of a pregnancy. The NSFG also collects information on cohabiting relationships, but these were not included as a separate category because many periods of cohabitation had missing or incomplete dates. Nevertheless, it should be kept in mind that the "single" category includes women who were never married, but may or may not have had a cohabiting relationship.

Finally, the model also controlled for characteristics specific to the pregnancy itself that may be associated with breast-feeding and the risk of miscarriage. These include the duration of the interpregnancy interval preceding the current pregnancy (i.e., the amount of time between the last live birth and the start of the current pregnancy),[41] the pregnancy order of the current pregnancy, the birth order of the most recently born child,[42] the intendedness of the pregnancy (later than wanted, at the right time, earlier than wanted, indifferent, unwanted entirely, unsure)[36,43] and the birth weight of the most recently born child. Pregnancy and birth order were included to capture the cumulative physiological burden of pregnancies for the woman, and birth weight of the preceding child was meant to serve as a proxy for the correlation in infant and maternal health across pregnancies. All possible interactions between the indicator for BDP and the control variables were tested, but none were statistically significant.

Analysis

Unadjusted miscarriage rates were calculated as one minus the Kaplan-Meier estimate of the probability of not experiencing a miscarriage by 20 weeks' gestation multiplied by 100. The resulting figures therefore represent the percentage of pregnancies ending in miscarriage according to BDP status and maternal and pregnancy characteristics.

The association between BDP and the risk of miscarriage was estimated using Cox proportional hazards models. Because these models allow for censoring from other forms of pregnancy termination (i.e., induced abortion and ectopic pregnancies), the estimates can be interpreted

as cause-specific hazards. That is, the estimates will represent the instantaneous risk of miscarriage for all pregnancies that have not yet ended because of other reasons. Three models were estimated to explore the association between BDP and miscarriage. The first model included only the main independent variable, and controlled for the period of the pregnancy and the survey wave to account for changes in reporting or incidence over time and across surveys. The second model introduced additional controls for maternal characteristics. The final model also controlled for pregnancy-specific characteristics. To allow for comparison with previous research, the final model was then reestimated with breast-feeding status treated as a time-invariant characteristic. Nearly all previous studies on this topic have divided women into two categories: those who were breast-feeding while pregnant and those who were not. This specification is therefore meant to demonstrate the importance of accurately measuring the time exposed to BDP.

Supplementary analyses were conducted to check the sensitivity of the results to two potential sources of bias. The first sensitivity analysis restricted the sample to examine only the outcomes of pregnancies that were conceived within 24 months of the last child's birth, as most cases of BDP occur when pregnancies are closely spaced. The second sensitivity analysis was designed to address the misreporting of breast-feeding duration. Some women may not remember precisely how long they breast-fed a specific child and may report an approximate duration at a convenient threshold, such as three or six months. When examining the distribution of breast-feeding durations in the sample, there were clear signs of duration heaping, particularly for multiples of six months. Calculation of Myers' blended index,[44] which is indicative of the extent of heaping, suggested that almost 25% of the reported durations may have been misclassified. Hence, this analysis restricted the final sample into two subsamples by omitting any pregnancy for which the previous child's breast-feeding duration was a multiple of either three or six months.

The proportional hazards assumption was tested for all models using scaled Schoenfeld residuals.[45] The results of the test indicated that there was no violation of the proportional hazards assumption for the main independent variable, suggesting that the relationship between BDP and the risk of miscarriage did not vary over time, that is, between the first and second trimesters.

RESULTS

Descriptive Findings

Breast-feeding overlapped with pregnancy for 6% of the total time at risk (Table 1; for brevity, only the weighted findings are presented here). When women reported BDP, most practiced complementary breast-feeding (5.7%) rather than exclusive breast-feeding (0.4%). The miscarriage rate for the entire sample was 15%, and the rate varied across maternal and pregnancy characteristics, as well as BDP status. Miscarriage rates were similar for pregnancies during which the mother was not concurrently breast-feeding (15%) and those during which the mother was complementary breast-feeding (14%). Pregnancies during which the mother exclusively breast-fed her child, however, had more than double the rate of miscarriage for the full sample (35%).

With respect to maternal characteristics, the miscarriage rate was higher among women who had become pregnant in more recent periods (17% in 2010–2015 vs. 12% in 1980–1989), had only a high school diploma (21% vs. 14% for those without one), were white (19% vs. 12% for black women) and had had a previous miscarriage (16% vs. 12%). Regarding pregnancy-specific characteristics, higher miscarriage rates were found following interpregnancy intervals of 60 months or longer (19% vs. 13% for intervals of 12–23 months), among women aged 35–39 and 40 or older (25% and 39%, respectively, vs. 12–16% for younger age-groups), for high pregnancy order (19% for seventh or higher vs. 13% for second pregnancies), for pregnancies that were later than wanted (22% vs. 13% for those that occurred at the right time) and when the birth weight of the last child was 4.5 kg or more (24% vs. 14% for 3.0–3.4 kg).

In the 2002 wave, 6% of the total person-months at risk occurred when a mother was practicing any form of breast-feeding (complementary or exclusive), and this percentage increased to 8% in the 2013–2015 wave (Table 2). The percentage of time at risk did not vary much across most maternal characteristics. There were differences, however, between complementary and exclusive BDP. Among women practicing exclusive BDP, 51% of the time at risk was reported by single mothers, whereas among women who were not concurrently breast-feeding or were complementary breast-feeding, the time at risk reported by single mothers was only 35% and 37%, respectively. The distribution across race and ethnicity was similar for nonconcurrent breast-feeding and complementary breast-feeding, but Hispanics were disproportionately represented among women practicing exclusive BDP, compared with whites (43% vs. 29%).

The clearest differences between women who breast-fed while they were pregnant and those who did not was related to pregnancy-specific characteristics. BDP was practiced 21% of the time during interpregnancy intervals less than 12 months. When mothers practiced complementary BDP, 78% of the time at risk involved this shortest interpregnancy interval, while this figure was 94% for exclusive BDP. The corresponding figure for mothers who were not breast-feeding was 22%. BDP was most common among women who became pregnant before turning 20 (13% vs. 5–8% for older age-groups). Among women practicing complementary or exclusive BDP, 15% and 21%, respectively, of the time at risk was reported by mothers who were younger than 20 when they got pregnant; in contrast, the corresponding figure among mothers who did not report BDP was only 7%. In light of these differences, it is unsurprising that BDP was more common during pregnancies that were perceived as occurring earlier than wanted (11%) or that were entirely unwanted (8%), compared with those viewed as occurring at the right time (5%).

TABLE 1. Percentage distribution of person-months at risk of miscarriage, among U.S. women aged 15–44 whose last child had ever been breast-fed and had survived until her next conception, and miscarriage rate, all by selected characteristics, National Survey of Family Growth, 2002–2015

Characteristic	Unweighted		Weighted	
	% (N=46,222)	Miscarriage rate	% (N=384,548)	Miscarriage rate
Breast-feeding during pregnancy				
Not concurrently	93.3	13.8	93.9	15.0
Complementary	6.2	13.5	5.7	14.4
Exclusive	0.5	38.7	0.4	34.8
NSFG wave				
2002	22.6	13.1	23.0	15.5
2006–2010	40.2	13.3	26.5	13.4
2011–2013	18.8	15.4	25.7	17.2
2013–2015	18.4	14.7	24.8	14.4
Period				
1980–1989	2.5	10.2	4.0	12.0
1990–1999	30.3	12.2	28.8	14.9
2000–2009	56.0	14.4	53.2	15.0
2010–2015	11.1	16.7	14.0	16.7
Marital status				
Single	35.4	13.9	28.8	15.3
Married	55.7	13.5	62.0	14.5
Widowed	0.1	26.0	0.1	15.4
Divorced	3.2	16.4	2.8	14.5
Separated	1.0	13.2	0.6	10.6
Remarried	4.6	16.5	5.7	21.3
Educational attainment				
<high school	23.1	12.9	17.9	13.9
High school	25.9	18.9	24.2	20.6
Some college	20.2	12.3	20.2	11.8
Associate's degree	9.0	13.0	9.1	14.6
Bachelor's degree	15.3	14.4	19.5	16.2
Graduate degree	6.6	15.3	9.2	14.9
Race/ethnicity				
Hispanic	35.6	14.9	26.5	15.9
White	43.9	17.2	57.2	19.0
Black	14.3	11.3	9.0	11.7
Other	6.2	16.3	7.2	17.5
Nativity				
Foreign-born	29.9	13.2	24.7	12.2
U.S.-born	70.1	12.4	75.3	11.7
Previously miscarried				
No	83.4	11.1	82.1	11.5
Yes	16.6	15.1	17.9	16.3
Interpregnancy interval (mos.)				
0–11	25.4	13.6	24.0	14.6
12–23	29.6	13.5	30.7	13.0
24–35	18.1	13.6	18.5	16.4
36–47	10.4	15.1	9.9	16.1
48–59	7.1	11.9	7.1	15.2
≥60	9.5	16.7	9.7	19.1
Age at pregnancy				
15–19	7.6	13.7	5.3	16.1
20–24	29.8	12.1	26.1	12.2
25–29	32.5	12.6	34.2	13.4
30–34	23.0	14.6	26.1	16.1
35–39	6.7	23.0	7.9	25.3
≥40	0.4	44.9	0.5	38.6
Pregnancy order				
Second	46.4	12.8	45.4	12.9
Third	28.5	13.8	29.1	15.8
Fourth	14.1	15.4	14.2	18.3
Fifth	6.5	14.8	6.3	19.7
Sixth	2.6	18.6	2.8	12.7
≥seventh	1.9	19.9	2.2	18.6
Birth order of last child				
First	59.0	13.8	58.8	14.3
Second	26.9	14.1	27.4	17.3
Third	9.5	14.0	9.0	15.2
Fourth	2.9	14.3	2.9	12.9
≥fifth	1.6	13.7	1.9	11.5
Pregnancy intendedness				
Later than wanted	5.8	18.3	6.5	21.9
Right time	54.0	12.2	58.3	12.8
Earlier than wanted	22.0	15.7	19.1	18.6
Indifferent	0.9	19.6	0.9	21.1
Unwanted entirely	16.9	14.8	14.9	15.6
Unsure	0.3	16.8	0.3	17.9
Birth weight of last child (kg)				
<2.5	6.9	15.6	6.2	15.9
2.5–2.9	18.4	14.2	18.0	15.9
3.0–3.4	37.6	14.1	37.4	14.1
3.5–3.9	27.0	13.0	28.0	15.9
4.0–4.4	7.9	12.9	8.2	12.3
≥4.5	2.1	16.1	2.2	23.8
Total or average	100.0	13.9	100.0	15.1

Notes: Ns refer to the number of person-months at risk of miscarriage. Weighted data were generated using the sampling weights for each woman from the respective surveys. The miscarriage rate was calculated as one minus the Kaplan-Meier estimate of the probability of not experiencing a miscarriage by 20 weeks' gestation multiplied by 100. Percentages may not add to 100.0 because of rounding. NSFG=National Survey of Family Growth.

Multivariate Findings

In model 1 of the Cox proportional hazards analysis, there was no difference in the miscarriage risk between women not concurrently breast-feeding and those practicing complementary BDP (Table 3; Appendix Table 2—Supporting Information). Women who practiced exclusive BDP, however, had an elevated risk of miscarriage (hazard ratio, 3.6). The incidence of miscarriage did not vary significantly by survey wave, but did by calendar year: Compared with pregnancies in 2000–2009, those in 1980–1989 and 1990–1999 had a reduced risk of miscarriage (0.6–0.8), whereas those in 2010–2015 had an elevated risk (1.2).

In model 2, which introduced controls for maternal characteristics, the risk of miscarriage was still elevated when exclusive breast-feeding overlapped with pregnancy (hazard ratio, 3.9). Several maternal characteristics were also associated with miscarriage. The risk was higher among whites than Hispanics (1.3), among the U.S.-born than

TABLE 2. Percentage distribution of person-months at risk of miscarriage, by breast-feeding status during pregnancy, and percentage exposed to any breast-feeding during pregnancy

Characteristic	Not concurrently breast-feeding (N=43,122)	Complementary breast-feeding (N=2,876)	Exclusive breast-feeding (N=224)	% breast-feeding during pregnancy
NSFG wave				
2002	22.9	18.1	22.8	5.5
2006–2010	40.1	41.9	35.7	6.9
2011–2013	18.8	19.0	23.9	6.9
2013–2015	18.2	21.0	17.7	7.6
Period				
1980–1989	2.5	3.1	7.2	9.1
1990–1999	30.2	31.5	31.5	7.0
2000–2009	56.0	56.8	52.5	6.8
2010–2015	11.3	8.6	8.8	5.2
Marital status				
Single	35.2	36.6	50.8	7.1
Married	55.7	56.8	43.4	6.7
Widowed	0.1	0.3	0.0	12.6
Divorced	3.3	1.7	0.9	3.5
Separated	1.0	0.8	0.0	5.4
Remarried	4.7	3.8	4.9	5.6
Educational attainment				
<high school	22.9	25.7	25.9	7.5
High school	25.9	26.2	22.8	6.7
Some college	20.1	20.7	29.5	7.1
Associate's degree	9.1	7.3	9.3	5.5
Bachelor's degree	15.5	12.8	10.3	5.5
Graduate degree	6.6	7.3	2.2	7.0
Race/ethnicity				
Hispanic	35.3	39.0	43.2	7.4
White	44.3	38.3	29.3	5.8
Black	14.2	15.5	20.1	7.4
Other	6.1	7.2	7.4	7.8
Nativity				
Foreign-born	29.5	36.1	33.9	8.1
U.S.-born	70.5	63.9	66.1	6.1
Previously miscarried				
No	83.5	82.0	85.0	6.6
Yes	16.5	18.0	15.0	7.2
Interpregnancy interval (mos.)				
0–11	21.5	77.7	94.2	20.9
12–23	30.2	21.3	5.8	4.6
24–35	19.3	1.0	0.0	0.3
36–47	11.2	0.0	0.0	0.0
48–59	7.6	0.0	0.0	0.0
≥60	10.2	0.0	0.0	0.0
Age at pregnancy				
15–19	7.1	14.8	20.6	13.4
20–24	29.6	32.5	43.7	7.5
25–29	32.7	30.1	21.6	6.1
30–34	23.5	16.6	10.0	4.7
35–39	6.8	5.7	4.0	5.6
≥40	0.4	0.3	0.0	4.7
Pregnancy order				
Second	46.6	43.5	45.3	6.3
Third	28.6	26.7	31.2	6.4
Fourth	14.0	15.4	10.7	7.2
Fifth	6.4	7.7	2.9	7.6
Sixth	2.6	2.8	4.0	7.6
≥seventh	1.8	3.8	5.8	13.6
Birth order of last child				
First	59.2	56.3	55.4	6.4
Second	27.0	25.7	33.0	6.5
Third	9.4	11.6	5.4	7.9
Fourth	2.8	4.2	3.6	9.6
≥fifth	1.6	2.2	2.6	9.1
Pregnancy intendedness				
Later than wanted	6.1	2.1	2.7	2.5
Right time	55.0	41.0	29.2	5.0
Earlier than wanted	20.9	36.5	42.5	11.2
Indifferent	0.9	0.9	0.0	6.2
Unwanted entirely	16.7	19.2	25.6	7.8
Unsure	0.3	0.4	0.0	8.3
Birth weight of last child (kg)				
<2.5	6.9	7.3	8.1	7.1
2.5–2.9	18.3	18.5	27.6	7.0
3.0–3.4	37.6	37.3	39.5	6.7
3.5–3.9	27.0	28.0	21.6	6.8
4.0–4.4	8.1	6.6	2.2	5.3
≥4.5	2.1	2.3	0.9	6.9
Total or average	100.0	100.0	100.0	6.7

Notes: Ns refer to the number of person-months at risk of miscarriage. Percentage breast-feeding during pregnancy is the percentage of all person-months at risk within a category when pregnancy overlapped with either complementary or exclusive breast-feeding. Percentages may not add to 100.0 because of rounding. NSFG=National Survey of Family Growth.

the foreign-born (1.2), among those who had gotten pregnant at age 35–39 or at 40 or older than at 15–19 (1.6 and 3.3, respectively) and among those who had had a miscarriage (1.4). Finally, model 3 introduced control variables for characteristics specific to the pregnancy itself. Most of the model 2 associations remained significant in this model and were of similar magnitude. In addition, the risk of miscarriage was higher for interpregnancy intervals of 60 months or longer than for intervals of less than 12 months (1.3), and it was lower for birth orders at parities of five or greater than for a parity of one (0.5), as well as for pregnancies that were perceived as occurring at the right time rather than later than wanted (0.7).

In the model in which breast-feeding status was treated as a time-constant covariate, exclusive breast-feeding was positively associated with the risk of miscarriage (hazard ratio, 2.7). The decline in the hazard ratio from that of models 2 and 3 is likely due to the fact that classifying individuals as whether they had ever breast-fed during pregnancy greatly overestimates the exposure to BDP. Categorizing the exposure variable in this way increased the total person-months at risk in which a woman breast-fed concurrently with pregnancy by nearly 60% (not shown).

Across the first three models, exclusive BDP was strongly associated with the risk of miscarriage. It is notable, however, that the confidence intervals of the hazard ratios

largely overlapped, suggesting that they were not statistically different. The association between exclusive BDP and miscarriage was also substantively meaningful when compared with the size of the estimates for the control variables. In model 3, this association was slightly greater than those for women who had a history of miscarriage and for those who conceived when they were 40 or older, both of which are well-known correlates of miscarriage.[39]

Sensitivity Analyses

After reestimating the analysis using the restricted sample, which included pregnancies conceived within 24 months of the last birth to account for the fact that BDP is primarily practiced following short interbirth intervals, the associations between BDP and miscarriage were similar to those found in the unrestricted models (Table 4; Appendix Table 3—Supporting Information). Complementary BDP remained nonsignificant, and exclusive BDP was associated with an increased risk of miscarriage (hazard ratio, 3.8). The only exception was for a history of miscarriage, which lost significance.

When the sample was restricted to exclude durations of breast-feeding that were multiples of three or six months, the new estimates supported the earlier findings. The magnitude of the hazard ratios increased, but their confidence intervals became much wider and overlapped with those of the Table 3 models. After excluding durations that were a multiple of three months, exclusive BDP was associated with an elevated risk of miscarriage (hazard ratio, 6.7); the exclusion of durations that were a multiple of six months yielded a hazard ratio of 4.9.

DISCUSSION

This study used retrospective pregnancy histories reported by women aged 15–44 in four NSFG waves conducted over the period 2002–2015. In doing so, this represents the first analysis using U.S. nationally representative data to investigate the association between breast-feeding during pregnancy and the risk of miscarriage.

The descriptive results showed that the prevalence of BDP has increased in recent cohorts, and that BDP has a higher prevalence among teenage mothers and following short interpregnancy intervals. The multivariate results demonstrated that mothers' exclusive BDP was associated with a dramatically greater risk of miscarriage than when mothers did not concurrently breast-feed. Pregnancies that overlapped with complementary breast-feeding, however, were not at an elevated risk of miscarriage, suggesting that the intense physical and nutritional demands of both exclusive breast-feeding and being pregnant may explain the increased miscarriage risk.

These associations provide new evidence that questions the safety of practicing exclusive BDP. Because there has been limited research on the topic and a reliance on small, clinical samples, the current scientific consensus holds that BDP is not a risk factor for miscarriage or other adverse outcomes, at least not in well-nourished populations,[14,15]

TABLE 3. Hazard ratios (and 95% confidence intervals) from Cox proportional hazards models assessing associations between breast-feeding during pregnancy and risk of miscarriage

Characteristic	Model 1	Model 2	Model 3	Ever breast-fed during pregnancy
Breast-feeding during pregnancy				
Not concurrently (ref)	1.00	1.00	1.00	1.00
Complementary	1.01 (0.81–1.26)	1.03 (0.83–1.29)	1.07 (0.85–1.36)	1.09 (0.90–1.33)
Exclusive	3.58 (2.39–5.37)***	3.87 (2.58–5.82)***	3.87 (2.55–5.88)***	2.71 (1.78–4.12)***
Period				
1980–1989	0.61 (0.40–0.92)*	0.72 (0.47–1.09)	0.75 (0.49–1.14)	0.75 (0.49–1.15)
1990–1999	0.80 (0.69–0.92)**	0.86 (0.75–1.00)*	0.88 (0.77–1.02)	0.88 (0.77–1.02)
2000–2009 (ref)	1.00	1.00	1.00	1.00
2010–2015	1.20 (1.00–1.43)*	1.11 (0.93–1.33)	1.11 (0.93–1.33)	1.11 (0.93–1.33)
Race/ethnicity				
Hispanic (ref)		1.00	1.00	1.00
White		1.31 (1.12–1.54)***	1.32 (1.12–1.55)***	1.31 (1.12–1.54)***
Black		1.07 (0.89–1.29)	1.03 (0.86–1.25)	1.03 (0.86–1.25)
Other		1.02 (0.80–1.31)	1.02 (0.80–1.31)	1.02 (0.80–1.31)
Nativity				
Foreign-born (ref)		1.00	1.00	1.00
U.S.–born		1.18 (1.01–1.38)*	1.18 (1.01–1.38)*	1.18 (1.01–1.38)*
Age at pregnancy				
15–19 (ref)		1.00	1.00	1.00
20–24		0.85 (0.68–1.05)	0.87 (0.69–1.09)	0.87 (0.69–1.08)
25–29		0.91 (0.72–1.14)	0.95 (0.74–1.21)	0.94 (0.74–1.20)
30–34		1.03 (0.81–1.31)	1.08 (0.83–1.40)	1.07 (0.82–1.40)
35–39		1.59 (1.21–2.08)***	1.64 (1.21–2.20)***	1.63 (1.21–2.20)***
≥40		3.32 (2.07–5.33)***	3.17 (1.93–5.20)***	3.15 (1.92–5.18)***
Previously miscarried				
No (ref)		1.00	1.00	1.00
Yes		1.40 (1.24–1.59)***	1.28 (1.07–1.53)**	1.27 (1.07–1.52)**
Interpregnancy interval (mos.)				
0–11 (ref)			1.00	1.00
12–23			1.11 (0.95–1.29)	1.11 (0.95–1.30)
24–35			1.12 (0.94–1.34)	1.13 (0.94–1.35)
36–47			1.28 (1.04–1.57)*	1.29 (1.05–1.59)*
48–59			0.94 (0.73–1.22)	0.95 (0.73–1.23)
≥60			1.27 (1.02–1.57)*	1.28 (1.03–1.59)*
Birth order of last child				
First (ref)			1.00	1.00
Second			0.88 (0.73–1.07)	0.89 (0.74–1.07)
Third			0.76 (0.57–1.01)	0.76 (0.57–1.02)
Fourth			0.72 (0.47–1.11)	0.73 (0.48–1.12)
≥fifth			0.51 (0.29–0.91)*	0.52 (0.29–0.92)*
Pregnancy intendedness				
Later than wanted (ref)			1.00	1.00
Right time			0.70 (0.57–0.86)***	0.70 (0.57–0.85)***
Earlier than wanted			0.99 (0.79–1.24)	0.98 (0.79–1.23)
Indifferent			1.23 (0.75–2.01)	1.22 (0.75–2.00)
Unwanted entirely			0.89 (0.71–1.13)	0.89 (0.71–1.13)
Unsure			0.95 (0.38–2.33)	0.93 (0.38–2.30)
Pregnancies	*10,661*	*10,661*	*10,661*	*10,661*
Person-months at risk	*46,222.1*	*46,222.1*	*46,222.1*	*46,222.1*
Miscarriages	*1,416*	*1,416*	*1,416*	*1,416*
Chi-squared	*49.9*	*202.3*	*258.8*	*247.4*

*p<.05. **p<.01. ***p<.001. *Notes:* Variables for which coefficients were not statistically significant in the full model are not presented, but were controlled for in the respective models. Model 1 controlled for survey and period-fixed effects. Model 2 included the same controls as model 1, plus marital status, educational attainment, race and ethnicity, age at pregnancy, nativity and history of previous miscarriage. Model 3 included the same controls as model 2, plus duration of interpregnancy interval, pregnancy order, birth order of preceding child, intendedness of current pregnancy and birth weight of preceding child. The model in the rightmost column did not allow breast-feeding during pregnancy status to vary over time. ref=reference group.

TABLE 4. Hazard ratios (and 95% confidence intervals) from Cox proportional hazards models assessing associations between breast-feeding during pregnancy and risk of miscarriage for pregnancies conceived within 24 months of the last birth, and for those whose older sibling's breast-feeding duration was not a multiple of three or six months

Characteristic	Interpregnancy interval <24 mos.	Duration of last breast-feeding not a multiple of 3	Duration of last breast-feeding not a multiple of 6
Breast-feeding during pregnancy			
Not concurrently (ref)	1.00	1.00	1.00
Complementary	1.09 (0.86–1.39)	1.12 (0.77–1.63)	1.19 (0.86–1.65)
Exclusive	3.78 (2.48–5.76)***	6.74 (3.52–12.89)***	4.90 (2.66–9.02)***
Race/ethnicity			
Hispanic (ref)	1.00	1.00	1.00
White	1.42 (1.14–1.77)**	1.30 (1.06–1.60)*	1.35 (1.12–1.62)**
Black	1.00 (0.77–1.31)	1.05 (0.82–1.34)	1.03 (0.83–1.28)
Other	1.07 (0.75–1.52)	1.00 (0.71–1.40)	1.02 (0.76–1.38)
Nativity			
Foreign-born (ref)	1.00	1.00	1.00
U.S.-born	1.29 (1.03–1.61)*	1.20 (0.96–1.48)	1.14 (0.95–1.38)
Age at pregnancy			
15–19 (ref)	1.00	1.00	1.00
20–24	0.94 (0.73–1.22)	0.80 (0.61–1.06)	0.79 (0.61–1.02)
25–29	0.95 (0.71–1.27)	0.81 (0.60–1.11)	0.86 (0.65–1.13)
30–34	1.03 (0.74–1.44)	0.86 (0.62–1.21)	0.92 (0.68–1.24)
35–39	1.82 (1.24–2.67)**	1.51 (1.03–2.22)*	1.48 (1.05–2.09)*
≥40	3.18 (1.40–7.23)**	2.94 (1.57–5.50)***	2.84 (1.59–5.07)***
Previously miscarried			
No (ref)	1.00	1.00	1.00
Yes	1.26 (0.99–1.62)	1.23 (0.97–1.54)	1.27 (1.03–1.56)*
Interpregnancy interval (mos.)			
0–11 (ref)	1.00	1.00	1.00
12–23	1.10 (0.94–1.28)	1.17 (0.96–1.42)	1.16 (0.97–1.39)
24–35	na	1.06 (0.84–1.33)	1.12 (0.91–1.37)
36–47	na	1.27 (0.98–1.65)	1.35 (1.07–1.71)*
48–59	na	0.91 (0.65–1.27)	1.10 (0.83–1.47)
≥60	na	1.31 (1.00–1.73)	1.43 (1.12–1.82)**
Pregnancy intendedness			
Later than wanted (ref)	1.00	1.00	1.00
Right time	0.56 (0.39–0.81)**	0.76 (0.58–0.99)*	0.72 (0.57–0.92)**
Earlier than wanted	0.76 (0.52–1.10)	1.06 (0.79–1.43)	1.01 (0.78–1.31)
Indifferent	1.22 (0.61–2.43)	1.20 (0.63–2.30)	0.96 (0.51–1.81)
Unwanted entirely	0.71 (0.48–1.06)	0.93 (0.69–1.27)	0.92 (0.70–1.20)
Unsure	0.98 (0.34–2.80)	1.68 (0.61–4.66)	1.11 (0.40–3.04)
Pregnancies	*5,837*	*6,099*	*7,817*
Person-months at risk	*25,392.8*	*26,178.0*	*33,565.4*
Miscarriages	*756*	*838*	*1,054*
Chi-squared	*159.0*	*167.9*	*179.8*

*p<.05. **p<.01. ***p<.001. *Notes:* The model controlled for survey and period-fixed effects, marital status, educational attainment, race and ethnicity, age at pregnancy, nativity, previous miscarriage, duration of interpregnancy interval, pregnancy order, birth order of preceding child, pregnancy intendedness and birth weight of preceding child. Variables for which coefficients were not statistically significant in any model are not presented, but were controlled for in the respective models. ref=reference group. na=not applicable.

and leading public health organizations have been silent on this issue. Yet this study shows that exclusive BDP may be more strongly correlated with miscarriage risk than a woman's history of pregnancy loss or becoming pregnant at age 40 or older, both of which are known to be associated with miscarriage.[39,42,46–48]

If the results of the present study are supported by future research, it may be possible to reduce women's risk of miscarriage by updating best-practice guidelines for breast-feeding. Other risk factors for miscarriage, like advanced maternal age,[49,50] remain a fixed characteristic of a pregnancy once it has begun. Thereafter, there is no way for a mother to remove herself from this risk pool. If a woman becomes pregnant while she is still exclusively breast-feeding her previous child, however, behavioral adjustments may reduce her risk of miscarriage. For example, she could decide to wean her child or continue to breast-feed but introduce supplementary foods to the baby's diet; alternatively, she could, if appropriate, supplement her own nutrition. These findings are particularly relevant for women who conceive at a young age or following a short interpregnancy interval, both of which may be risk factors for miscarriage[51,52] and may therefore serve to compound the risk of pregnancy loss in these groups.

Strengths and Limitations

This study has several important strengths. It was the first to utilize nationally representative data for the United States, and the first to distinguish between complementary and exclusive BDP, an important distinction in light of the theoretical mechanisms linking BDP to the risk of miscarriage. The study was also the first to adjust for the fact that breast-feeding generally occurs for only a portion of a subsequent pregnancy and to demonstrate that treating BDP as a time-constant covariate substantially overestimates the total time that pregnancies are exposed to BDP, which consequently influences the estimated association with the risk of miscarriage. Finally, it attempts to account for a variety of competing risks, which allows for the more accurate identification of the population exposed to both BDP and miscarriage.

The present study also has some important limitations. First, the data came from retrospective pregnancy histories, the details of which may sometimes be difficult for respondents to recall accurately, especially for individuals who had completed childbearing many years earlier. Information on dates of conception and pregnancy loss or durations of breast-feeding can be particularly prone to misreporting. Still, recent work has shown that many women are able to accurately recall their breast-feeding durations to within one month, sometimes after as long as 20 years.[53,54] Nevertheless, other forms of misreporting may have gone unidentified. For example, many cultures have taboos against BDP,[28,32] and if this applies in the U.S. context, it may cause respondents to understate breast-feeding durations if it continued during pregnancy, particularly if a miscarriage occurred. This form of misreporting, however, should only serve to underestimate the effects of BDP on the risk of miscarriage.

Second, this study could not consider the intensity of breast-feeding, which is likely an important moderating variable in the association between BDP and miscarriage risk. Just as not all women will breast-feed for the same duration of a subsequent pregnancy, there will also be variation in the frequency of feeding and quantity of milk expressed. Although this study distinguished between complementary and exclusive breast-feeding, these are admittedly crude measures of intensity, particularly for women who practice complementary feeding. Unfortunately, the data simply do

not allow for controlling for breast-feeding intensity in a more refined manner.

A third limitation is that data on miscarriages have well-known problems. Among these is the tendency to underreport, whether unintentionally or intentionally, early pregnancy losses. Unintentional underreporting can arise when women simply mistake an early-term miscarriage for delayed menstruation, or if they simply forget the loss. Intentional underreporting, on the other hand, can occur for several reasons, including emotional distress, feelings of guilt or shame for losing a pregnancy,[55] or to avoid social stigma regarding a woman's decision to obtain an induced abortion, which may lead a respondent to report an aborted pregnancy as a miscarriage or to omit it entirely from her pregnancy history.[37] Unfortunately, little can be done to remedy this shortcoming using the current data.

A final limitation is that this study was unable to control for many unobserved factors that may be correlated with BDP and the risk of miscarriage. That is, mothers who practice BDP may differ from those who do not for unobserved reasons. For example, they may have systematically different views on infant feeding or care, different nutritional statuses or perhaps their endocrine systems may respond differently to pregnancy and breast-feeding. Furthermore, the NSFG data included limited information on maternal health behaviors and characteristics that have been shown to be related to the risk of miscarriage, such as maternal depression,[56–58] maternal body mass index at pregnancy,[59,60] smoking behavior[61] or drug abuse.[62] If these kinds of unobserved characteristics are correlated with both BDP and miscarriage, findings may be biased.

There are opportunities to address the first three limitations in future research. Perhaps the best way to reduce recall bias, improve information on infant feeding and maternal health, and reduce the misreporting of miscarriages is to make use of nationally representative, prospective, longitudinal data. A strength of the clinical studies on the association between BDP and miscarriage is that they generally did not rely on respondents' recall, but instead made use of information recorded during the course of a given pregnancy. Yet this advantage must be weighed against the loss of generalizability inherent to a clinical study. Following a representative cohort of women over time would allow researchers to identify at least some inconsistencies in reported histories relating to omitted pregnancies and their outcomes. It would also allow for a detailed, accurate recording of breast-feeding and maternal health that is unrealistic for retrospective surveys. Furthermore, a prospective approach would largely ameliorate problems relating to the misreporting of pregnancy durations.

Addressing the final limitation would be more difficult. Theoretically, one could estimate models that compare pregnancies from the same woman that were and were not exposed to breast-feeding to control for time-invariant unobserved factors that may be related to both breast-feeding and miscarriage. Given the data requirements for inclusion in the analysis population, however, one would likely need a very large sample of women and pregnancies and it may nevertheless be unfeasible. If BDP and miscarriage are instead related to time-varying unobservable characteristics, it would be even more difficult to address this limitation.

Conclusions

Breast-feeding undoubtedly offers numerous benefits to both mothers and their children, but under certain conditions it may be associated with undesirable outcomes. The present study has shown that when a mother continued exclusive breast-feeding during a subsequent pregnancy, she had a heightened risk of miscarriage—and that this risk was relatively large compared with that attributed to other characteristics with known associations. This topic certainly requires much more research, ideally with nationally representative prospective data.

Future work should also consider how BDP may be simultaneously associated with the outcomes of the mother, the breast-feeding child and the pregnancy. The current study was concerned only with pregnancy outcomes, primarily because of data limitations. But if future work supports the association between BDP and miscarriage, it will be important to weigh this risk against any potential benefits for mothers or breast-fed children before any recommendations are made. After all, it was evident that BDP was also correlated with short interpregnancy intervals and young maternal age, both of which are themselves correlated with poor child outcomes.[63,64] It is possible that BDP may simultaneously increase the risk of pregnancy loss, but improve the health of the most recent child. These uncertainties underline the need for more research on the associations of breast-feeding during pregnancy with maternal, child and fetal outcomes.

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