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Breastfeeding during Pregnancy and the Risk of Miscarriage in the United States

Joseph Molitoris[1]

Abstract

Context

In recent decades, breastfeeding rates and the duration of breastfeeding among American women have been increasing. A consequence of longer breastfeeding, however, is that it is more likely to overlap with subsequent pregnancies, and the implications of this arrangement for pregnancy outcomes is not well understood.

Methods

Cox proportional hazards models were used to investigate the association between breastfeeding during pregnancy and the risk of miscarriage using data on 10,661 pregnancies from four waves of the National Survey of Family Growth spanning 2002-2015.

Results

Women were more likely to breastfeed during pregnancy when conception occurred after short interpregnancy intervals and at younger ages. When breastfeeding occurred concurrently with a subsequent pregnancy, women had a 29% increase in the risk of miscarriage when controlling for maternal and pregnancy characteristics. The magnitude of the increase in risk was similar to that of a woman who had a history of previous miscarriage, which is a well-known predictor of subsequent pregnancy loss. Furthermore, these results were robust to sensitivity analyses that account for misreporting of breastfeeding durations and differences in pregnancy spacing between women who did and did not breastfeed during pregnancy.

Conclusion

Breastfeeding during pregnancy is associated with a heightened risk of miscarriage, but it remains unclear how the practice is associated with outcomes of the mother and breastfed child. More research is therefore needed to understand all of these potential relationships before any firm recommendations on the safety of the practice should be made.

Keywords: Miscarriage; Breastfeeding; Spontaneous Abortion; United States

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Introduction

Breastfeeding 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 breastfeeding is a cornerstone of international efforts to improve family planning and maternal and child health [8, 9], and in the United States it is currently a core objective for improving infant health in the Federal Interagency Workgroup's Healthy People 2020 initiative. From an international perspective, the United States has had some of the lowest rates of ever breastfeeding in recent years [10], but these have been rapidly increasing over the past two decades [11]. Furthermore, American mothers have also been increasing their duration of breastfeeding, with more and more children being breastfed for up to twelve months and beyond. The latest national estimates show that about 55% of children continue to breastfed until they are at least six months old and more than one-third continue to do so at twelve months [11].

A consequence of longer breastfeeding durations is that it may increase the incidence of breastfeeding overlapping with subsequent pregnancies, particularly following shorter interpregnancy intervals (i.e. the time between the birth of a child and the next conception). As of 2018, there has been very little research into the associations between breastfeeding during pregnancy (BDP) and maternal, child, or pregnancy outcomes, and the little that has been done has been almost exclusively focused on less-developed contexts and has used site-specific data [12]. To date there has only been one study that has used nationally representative data, but it was only focused on low- and middle-income countries [13]. Recent reviews of the literature on BDP's associations with maternal, child, or pregnancy outcomes have concluded that there is no evidence to support that BDP is associated with the risk of miscarriage [12, 14], yet no studies have analyzed nationally representative data from Western countries.

The present study will use data on over 10,000 pregnancies from four waves of the National Survey of Family Growth (NSFG) between 2002 and 2015 to investigate if BDP is associated with the risk of miscarriage in the first 150 days of pregnancy. This is the first study to investigate the association between BDP and miscarriage in the United States, and one of the few to make use of nationally representative data. The NSFG is well-suited to this particular research question, as it includes detailed data on the gestation and breastfeeding durations of all children born to female respondents. To analyze the association between BDP and the risk of miscarriage, I employ event-history models to adequately account for differences in the exposure to BDP and in the exposure to miscarriage.

Background

Breastfeeding during pregnancy is a relatively common practice in many parts of the world. Recent estimates based on nationally representative data from low- and middle-income countries have shown that, on average, 35% of most recently born children who had ever been breastfed and whose mother had subsequently become pregnant continued to breastfeed during their mother's next pregnancy [13]. Estimates from other low-income populations have also reported the prevalence of BDP anywhere between 15-50% [15-18]. In wealthier populations, recent statistics are more difficult to come by. The most recent evidence from the United States reports that between 1988 and 1994, 5% of breastfeeding women were currently pregnant [19].

There are two possible 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 [20-22]. Lactation has even greater energy requirements. From a child's birth until age six months, women are recommended to consume an additional 500 kcal/day. Women continuing to breastfeed beyond six months are currently recommended to consume an additional 400 kcal/day [23]. Furthermore, pregnancy and lactation do not simply increase the body's energy demands, but also its 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 come from low-income populations and have been consistent in finding that BDP is associated with compromised maternal nutrition. Studies of women from 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. [16, 24-26]. Whether or not this translates to adverse pregnancy outcomes, however, has not been resolved. Several studies have investigated the relationship between BDP and the risk of miscarriage and have generally found no statistically significant relationship between the two [25-30]. As a result, two recent reviews of the literature on BDP have concluded that BDP does not increase the risk of miscarriage, although both acknowledged the need for further research on the topic [12, 31].

It has also been suggested that a hormonal mechanism may link BDP and miscarriage [30]. When an infant stimulates the nipple and areola, it triggers the release of oxytocin in the mother, which causes a series of reactions that force milk towards the nipple [32]. Oxytocin is also known to cause uterine contractions, which, if occurring in a pregnant woman, may result in either pre-term birth or miscarriage. Of the aforementioned mechanisms, virtually all studies have focused on the former. There is currently no evidence that the release of oxytocin caused by breastfeeding is sufficient to cause miscarriage.

The current body of literature suffers from several shortcomings. First, all of these studies were comprised of small, clinical or local samples. It is therefore unclear how their findings generalize to the general population. In several of these studies, positive associations were found between BDP and the risk of miscarriage, but none were statistically significant [25, 27, 28]. Because this research question involves a relatively uncommon outcome (i.e. miscarriage), as a response to a relatively uncommon exposure (i.e. BDP), it is difficult to distinguish if the lack of statistical significance was simply due to low statistical power. Most of these studies could only identify a handful of cases in which a miscarriage occurred.

A second shortcoming is that none of the studies have appropriately dealt with the changes in exposure to BDP and the censoring of pregnancies that occurs when analyzing miscarriages. In cases of BDP, breastfeeding generally will not last the entire duration of a pregnancy. Instead, it will more likely overlap with only a part of a subsequent pregnancy. In fact, a subsequent pregnancy is often a reason why a woman discontinues breastfeeding her child [29, 33]. Yet most studies of the association between BDP and the risk of miscarriage have simply compared women who ever breastfed during pregnancy to those who had not [26-28, 30]. If most women who practice BDP only do so for a fraction of their next pregnancy, this dichotomization can greatly exaggerate the amount of time pregnancies are actually exposed to concurrent breastfeeding. Analytical methods therefore must appropriately account for the time-varying nature of BDP in order to avoid attributing miscarriages to women who were no longer breastfeeding.

Additionally, it is necessary to account for the fact that induced abortions and ectopic pregnancies serve as competing risks to miscarriages. That is, if a woman had become pregnant but lost the pregnancy for reasons other than miscarriage, she should contribute to the population at-risk until she terminated the pregnancy. The existing studies on this topic have not addressed this issue. Similar to the issue raised above, it is important to adequately account for these forms of censoring in order to properly identify who is at risk of experiencing a miscarriage throughout observation and for how long.

The present study addresses these shortcomings by using nationally representative data for the United States. In addition, I use event history models to properly account for changes in exposure to BDP over time as well as to account for censoring as a result of other kinds of pregnancy terminations.

Methods

Data

The data come from the four latest waves of the National Survey of Family Growth (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 records data on relationships, fertility, contraceptive use, socioeconomic characteristics, and health. The present study specifically makes use of retrospective pregnancy histories reported by female respondents. They include information on dates of conception and pregnancy termination, outcomes of pregnancies (i.e. live birth, induced abortion, miscarriage, stillbirth, ectopic pregnancy, and currently pregnant), as well as the birth weights and the durations of breastfeeding for live births. The four waves together recorded data on a total of 52,986 pregnancies, the main unit of analysis in this study.

Several data restrictions were required to arrive at the analytical sample used in this study (Table 1). First, only women without a multiple birth were included in the analysis, as twins or higher-order multiple births who breastfeed may place an unusually large strain on maternal nutrition compared to single births. Second, pregnancies were omitted if they were not preceded by a live birth. This criterion therefore excludes all first pregnancies. Third, all pregnancies from women who never breastfed any of their children were not included in the sample. Fourth, pregnancies were excluded if the preceding pregnancy did not end in a live birth. The two preceding criteria are therefore meant to ensure that BDP was actually possible. Fifth, if the most recently born child never breastfed for any duration, the pregnancy was omitted from the analysis. This restriction is necessary to ensure that the comparison between BDP and not BDP is not merely capturing differences in the initiation of breastfeeding. Finally, if the most recently born child had died before the subsequent conception, the pregnancy was not included, as there would have been no opportunity for an overlap between breastfeeding and pregnancy. Based on the above criteria, 11,189 pregnancies were included in the analysis. After dropping outliers and cases which had inconsistent or incomplete information on various characteristics, the final analytical sample was 10,661 pregnancies.

Analysis

To study the association between BDP and the risk of miscarriage, Cox proportional hazards models are employed. A pregnancy entered into the population at-risk when gestation began. It exited the population at-risk when either the pregnancy reached 150 days of gestation, when the pregnancy was terminated for any reason (i.e. miscarriage, abortion, or 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. Thereafter, that pregnancy was censored from the population at-risk. Thus, the estimates from the Cox models can be interpreted as a cause-specific hazard. That is, they will represent the instantaneous risk of miscarriage for all pregnancies that have not yet ended due to other reasons.

The dependent variable in this study is the incidence of a miscarriage, defined as the involuntary loss of a pregnancy within 150 days after the start of gestation. After this point, pregnancies that end in an involuntary loss are generally classified as stillbirths.

The main independent variable of interest is binary and indicates if breastfeeding occurred concurrently with pregnancy. It is treated as a time-varying covariate, meaning that an individual pregnancy is allowed to be exposed to concurrent breastfeeding for only part of the gestational period if breastfeeding ends before the pregnancy exits the population at-risk. For mothers who breastfed their previously born child for the entire duration of the pregnancy or for those who never breastfed their child during the subsequent pregnancy, the variable does not vary over the duration of the pregnancy.

The model includes several control variables in order to account for observable differences between mothers who do and do not breastfeed during pregnancy. First, it controls for variables that are meant to account for differences in both reporting and trends in the incidence of miscarriage over time. To this end, I included a categorical variable representing the wave of the NSFG in which the data were recorded and a categorical variable for the calendar year of the pregnancy (1980-1989, 1990-1999, 2000-2009, and 2010-2015).

Second, the model controls for maternal characteristics that may be associated with miscarriage. These are the mother's marital status (single, married, widowed, divorced, separated, and remarried), a binary indicator if she had previously experienced a miscarriage, highest completed level of education (less than high school, high school, some college, associate's degree, bachelor's degree, and graduate degree), race and Hispanic origin (Hispanic, non-Hispanic white, non-Hispanic black, non-Hispanic other), nativity (foreign-born and US-born), and her age at the start of the pregnancy. 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 spells 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 models also controlled for characteristics specific to the pregnancy itself which may be associated with 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), the pregnancy order of the current pregnancy, the birth order of the most recently born child, the intendedness of the pregnancy (occurred later than wanted, occurred at the right time, occurred earlier than wanted, indifferent, unwanted entirely, and unsure), and the birth weight of the most recently born child. All possible interactions between the indicator for BDP and the control variables were tested, but none were statistically significant.

Results

Descriptive Findings

An overlap of breastfeeding and pregnancy accounted for about 6% of the total time at-risk for pregnancies that were preceded by a live birth that had ever been breastfed. When breastfeeding overlapped with pregnancy, the rate of miscarriage was 34.9 per 1,000 woman-months at-risk, compared to 30.4 when there was no concurrent breastfeeding (Table 2).

TABLE 2 HERE

The rate of miscarriage also varied according to maternal and pregnancy characteristics. With respect to maternal characteristics, becoming pregnant in more recent periods, being divorced or remarried, having had a previous miscarriage, having high educational attainment, being non-Hispanic white, being US-born, and high age at pregnancy (especially beyond age 35) were all associated with higher rates of miscarriage. Regarding pregnancy-specific characteristics, long interpregnancy intervals (i.e. greater than 60 months), high pregnancy order, having a pregnancy later than intended, and having a previous child with a very high or low birth weight were all associated with the rate of miscarriage.

Pregnancies that experienced an overlap with breastfeeding generally only differed from those which did not along a few dimensions (Table 3). The distributions of most maternal characteristics, such as marital status, period of birth, or experiencing a previous miscarriage, were similar between the two groups. When pregnancy overlapped with breastfeeding, mothers tended to be to lower-educated, non-white, and foreign-born, although the differences in the distributions were not large. The most significant differences in characteristics between pregnancies that overlapped with breastfeeding and those that did not was that the former almost exclusively began after a short interpregnancy interval, typically less than twelve months. Furthermore, women who became pregnant before reaching age 20 were also more likely to breastfeed while pregnant. Pregnancies that overlapped with breastfeeding were also more likely to be perceived as occurring earlier than wanted or as entirely wanted.

The *prevalence* of BDP also varied across characteristics. Between the 2002 and 2013-2015 surveys, the rate of BDP increased by 40% from 5.5% to 7.6% of pregnancies included in the sample. It was more common among women who had never been married, had less than high school education, were not white, were foreign-born, and whose previously born child had a birth weight below 2.5 kg. The prevalence was highest, however, among women who had conceived following an interpregnancy interval that was less than 12 months. Among all interpregnancy intervals shorter than 12 months in duration, about 20% of pregnancies overlapped with breastfeeding. Furthermore, breastfeeding concurrent with pregnancy was more common among mothers below the age of 20. About 13% of teenage mothers who had conceived a second child continued breastfeeding during their subsequent pregnancy. Finally, there was a correlation between the prevalence of BDP and the intendedness of the pregnancy. For pregnancies that were perceived as occurring earlier than wanted, 11% overlapped with the breastfeeding of the previous child. This is consistent with the disproportionate prevalence of BDP after short interpregnancy intervals and at young ages.

TABLE 3 HERE

Multivariate Findings

Cox proportional hazards models were used to examine whether or not the association between BDP and miscarriage persists when controlling for survey, maternal, and pregnancy characteristics. Three models were estimated to explore the association. First, I estimate a baseline model which only includes the main independent variable and controls for the period of the pregnancy and the wave of the survey in order to account for changes in reporting or incidence over time and across surveys. The second model then introduces additional controls for maternal characteristics, which include marital status, history of previous miscarriage, highest achieved level of education, race and Hispanic status, nativity, and age at the start of the pregnancy. The final specification adds controls for pregnancy characteristics, including the duration of the previous interpregnancy interval, the order and intendedness of the pregnancy, and the birth order and weight of the most recently born child.

TABLE 4 HERE

In model 1, risk of miscarriage was about 22% higher (hazard ratio=1.22) when breastfeeding overlapped with pregnancy compared to when it did not (Table 4). The incidence of miscarriage did not depend on the wave of the survey in which the data were collected, but increased with calendar year, with the lowest risk of miscarriage being found for pregnancies occurring in the 1980s and the highest risk in the most recent period, 2010-2015.

Model 2 introduced controls for maternal characteristics that may be correlated with miscarriage and breastfeeding practices. In this model, the risk of miscarriage was again higher when breastfeeding overlapped with pregnancy. The point estimate suggests that BDP was associated with an increase in miscarriage rates of about 25%. Several maternal characteristics were also associated with the incidence of miscarriage. In particular, women who had previously experienced a miscarriage, were non-Hispanic white, were US-born, and those who became pregnant after age 35 had elevated risks of miscarriage.

Model 3 introduced control variables for characteristics specific to the pregnancy itself. Once again, pregnancies that overlapped with breastfeeding had higher risks of miscarriage by about 29%. Even after introducing the additional controls, a previous miscarriage, maternal age, being born in the US, and being non-Hispanic white continued to significantly predict the risk of miscarriage. Pregnancy loss was also associated with long interpregnancy intervals (i.e. longer than 36 months) and high pregnancy order.

To allow for comparison with previous research, the full model was then re-estimated, but did not allow breastfeeding during pregnancy to vary over time. Virtually all previous studies on this topic have only classified women as breastfeeding while pregnant or not. This specification is therefore meant to demonstrate the importance of accurately measuring the time exposed to BDP. In this model, breastfeeding was positively associated with the risk of miscarriage, but the point estimate had become slightly smaller. Furthermore, it is the only model in which the association between concurrent breastfeeding and miscarriage was statistically insignificant. The reason is likely due to the fact that crudely classifying individuals as ever breastfeeding during pregnancy or not greatly overestimates the exposure to BDP. Categorizing the exposure variable in this way increases the total woman-months at-risk in which a woman breastfed concurrently with pregnancy by nearly 60%.

Across all three models, the BDP was significantly associated with the risk of miscarriage. Although the point estimates increased as more controls were added, their confidence intervals largely overlapped, suggesting that there are likely no statistical differences in the estimates. The association between BDP and miscarriage was also substantively meaningful when compared to the size of the estimates for the control variables. In model 3, the estimated association was even larger than that for women who had a history of pregnancy loss. The only characteristics associated with larger increases in the risk of miscarriage were high age at pregnancy and high pregnancy order, both of which are correlated with one another.

Sensitivity Analyses

Supplementary analyses were conducted in order to check the sensitivity of the results to two potential sources of bias. Table 3 revealed clear differences in the distribution of interbirth intervals between pregnancies that overlapped with breastfeeding and those that did not. Among pregnancies which had been conceived during breastfeeding, 99% had been preceded by an interpregnancy interval less than 24 months in duration. In contrast, only 51% of pregnancies which did not overlap with breastfeeding were preceded by such short intervals. The first sensitivity analysis therefore restricted the sample to only examine the outcomes of pregnancies that were conceived within 24 months of the last child’s birth in order to draw an adequate comparison between the groups.

Another source of potential bias is the misreporting of durations of breastfeeding, specifically misreporting due to heaping durations on multiples of three and six. In other words, some women may not precisely remember how long they breastfed a specific child, and may simply report an approximate duration at a convenient threshold, like three, six, nine, or twelve months. When examining the distribution of breastfeeding durations in the sample, there were clear signs of duration heaping, particularly for multiples of six months. Calculating Myers' blended index, which is indicative of the extent of heaping, suggested that almost 25% of the reported durations may be misclassified. The second sensitivity analysis therefore restricted the final sample into two subsamples by omitting any pregnancy for which the previous child's breastfeeding duration was a multiple of either three or six.

TABLE 5 HERE

After re-estimating the models on the restricted the sample that only included pregnancies conceived within 24 months of the last birth, the association between BDP and miscarriage was similar to the unrestricted models. BDP was associated with a 31% increase in the risk of miscarriage. Furthermore, the previously identified associations with maternal characteristics were robust to the new specification as well.

When the sample was then restricted to exclude durations of breastfeeding that were a multiple of three or six, the new estimates supported the earlier findings. In fact, the magnitude of the point estimates increased. When excluding durations that were a multiple of three, BDP was associated with an increase in the risk of miscarriage by 40%; when excluding those that were a multiple of six, the point estimate indicated an increase in risk of 43%. Again, all associations between the models' covariates and the risk of miscarriage were similar to the main analysis.

Discussion

This study used retrospective pregnancy histories reported by women aged 15-44 in the NSFG waves 2002-2015 to investigate whether or not BDP was associated with the risk of miscarriage.

It doing so, it is the first study to investigate this association in a Western population and using nationally-representative data. It is also the first to identify a statistically significant association between BDP and the risk of miscarriage.

The descriptive results showed that the prevalence of BDP has increased in recent cohorts, and that it is disproportionately prevalent among teenage mothers and following short interpregnancy intervals. The multivariate results showed that, when pregnancy overlapped with the breastfeeding of the most recently born child, the risk of miscarriage was 20-30% higher than for pregnancies in which the most recently born child was weaned prior to conception. Furthermore, the results showed the importance of properly accounting for the time-varying nature of BDP. The only model which found no statistically significant association between BDP and the risk of miscarriage was that which only differentiated between pregnancies that ever overlapped with breastfeeding and those that did not.

The associations presented here provide new evidence that calls into question the safety of BDP. Because there has been limited research on the topic and an exclusive 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 [12, 31], and leading public health organizations have been silent on this issue. Yet this study shows that BDP is as good a predictor as a woman's history of previous pregnancy loss. This is an important finding, as a large body of research has previously identified a strong association between having a history of previous miscarriage and the risk of subsequent miscarriage [34-37]. It is also consistent with recent findings from low- and middle-income countries, where BDP was also found to be positively associated with the risk of miscarriage [13].

If the results of this study are supported by future research, there may be great potential to reduce the risk of miscarriage by updating best-practice guidelines for breastfeeding. Other well-known predictors of miscarriage, like advanced maternal age at pregnancy [38, 39], 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 breastfeeding her previous child, however, there may be interventions available to reduce her risk of miscarriage. For example, she can still decide to wean the previous child, or, if appropriate, additional nutrition supplementation may be considered. These findings are particularly relevant for women who conceive at a young age or following a short interpregnancy interval, as BDP was much more prevalent among women with these characteristics. Furthermore, because both short interpregnancy intervals and low maternal age are themselves well-known risk factors for miscarriage [40, 41], BDP may serve to compound the risk of pregnancy loss in these groups.

Strengths and Limitations

This study has important strengths compared to previous work on the topic. First, it was the first to make use of nationally-representative data for a Western industrialized country. Most previous work on the association between BDP and miscarriage was restricted so small, clinical or local samples, making generalizability difficult to assess. Second, it is also the first to adjust for the fact that breastfeeding will generally only occur for a portion of the subsequent pregnancy. In doing so, I demonstrated that categorizing women into groups which ever breastfed during pregnancy and those which did not substantially overestimates the total time pregnancies are exposed to BDP, which in turn greatly influences its estimated association with the risk of miscarriage. Finally, it is currently the only study to address the issue of competing risks when analyzing the association between BDP and miscarriage. By allowing for pregnancies to remain in the analysis even if they ended due to reasons other than miscarriage, this study has more accurately identified the population exposed to BDP and miscarriage.

These strengths notwithstanding, there are important limitations that must be discussed. First, the data used in this study come from retrospective pregnancy histories, the details of which may sometimes be difficult for respondents to recall accurately. This is a particularly relevant concern for older respondents who had already completed childbearing years earlier. Information on dates of conception and pregnancy loss or durations of breastfeeding can be particularly prone to misreporting. In an additional sensitivity analysis (not shown here), the sample was restricted to only births occurring within the five years preceding the interview. The estimated associations were virtually identical to those from model 3, but the loss of statistical power caused them to become statistically insignificant. Still, a recent Norwegian study comparing recorded and self-reported breastfeeding duration showed that women who had given birth even 20 years earlier were surprisingly accurate in recalling breastfeeding duration. In fact, about two-thirds of mothers could recall the duration of breastfeeding to within one month of the true duration [42]. And a recent prospective study of American women showed that mothers could accurately recall their breastfeeding duration within one month for children born six years earlier [43]. One form of misreporting was identified in the data, namely duration heaping, and the results remained robust even after limiting the sample to exclude potential heaping on multiples of three and six months. Nevertheless, there may be other forms of misreporting that have not been identified. For example, many cultures have taboos against BDP [26, 30], and if this is the case in the American context, it may cause respondents to understate breastfeeding durations if breastfeeding continued during pregnancy, particularly if they suffered a miscarriage. 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 breastfeeding, which is likely an important moderating variable in the association between BDP and the risk of miscarriage. Just as not all women will breastfeed for the same duration of a subsequent pregnancy, there will also be variation in the frequency of feeding and quantity of milk that is expressed. These variables should be important determinants of nutritional demands or hormone production. Unfortunately, the data simply do not allow for such a detailed analysis.

A third limitation is that data on miscarriages have well-known problems. Among these is the tendency to underreport early pregnancy losses both unintentionally and intentionally. 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. Emotional distress or feelings of guilt or shame for losing a pregnancy may make some respondents unwilling to mention the experience during an interview. A recent study on the perceptions of miscarriage in the United States showed that, among both women who had suffered a miscarriage and men whose partner had, nearly half felt guilty, about 40% felt that they had done something wrong, and over one-third felt they had lost a child [44]. Miscarriages may also be misreported due to social stigma against induced abortion. If a respondent feels uncomfortable reporting voluntary pregnancy terminations, she may instead report the pregnancy as ending in a miscarriage or omit it entirely from the pregnancy history. A study of the 2002 NSFG showed that lifetime induced abortions and miscarriages were underreported by about 23% and 25%, respectively [45]. Unfortunately, there is little that can be done to remedy this shortcoming using the current data.

A final limitation is that this study has been unable to control for unobserved factors which 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 breastfeeding. If these kinds of unobservable characteristics are correlated with both BDP and miscarriage, results may be biased.

There are opportunities to address the first three limitations in future research, however. Perhaps the best way to reduce recall bias, improve information on infant feeding, 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 was 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 also 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 of inconsistencies in reported histories relating to omitted pregnancies and their outcomes. It would also allow for a detailed, accurate recording of breastfeeding behavior that is unrealistic for retrospective surveys. Furthermore, a prospective approach would also 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 breastfeeding. This would control for unobserved time-invariant differences across mothers, but the approach has its own challenges. Both BDP and miscarriages are relatively uncommon at the population level, and a model that compares pregnancies to the same woman would require at least three observed pregnancies to be included in a study of this kind. Furthermore, there are likely very few mothers who had one pregnancy which overlapped with breastfeeding and one which did not, and both of which were preceded by the birth of a child who was ever breastfed. Therefore, a within-mother analysis would likely need a very large sample of women and pregnancies and may simply be unfeasible. If BDP and miscarriage are instead related to *time-varying* unobservable characteristics, it would be even more difficult to address this limitation.

Conclusion

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

Future work also needs to consider how BDP is simultaneously associated with the outcomes of the mother, breastfeeding child, and pregnancy. The current study was only concerned with pregnancy outcomes, primarily because of data limitations. But if the association between BDP and miscarriage is supported by future work, it will be important to weigh this risk against any potential risks for mothers or breastfed children as well before any recommendations for behavioral change should be made. After all, it was evident that BDP was also correlated with short interpregnancy intervals and, to a lesser degree, low birth weight for the previously born child, both of which are themselves correlated with poor child outcomes [46]. 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 BDP with maternal, child, and fetal outcomes.

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Table 1. Sample selection process to arrive at the final analytical sample.

	Pooled Waves	2002	2006-2010	2011-2013	2013-2015
Total number of reported pregnancies	52,986	13,593	20,492	9,543	9,358
Omitted cases:					
Pregnancies to women with any multiple birth	1,965	544	710	358	353
Pregnancies with no previous live birth	3,284	960	1,222	520	582
First pregnancies	11,061	2,642	4,256	2,073	2,090
Pregnancies to women who never breastfed	15,670	4,510	6,086	2,668	2,406
Last pregnancy did not end in a live birth	6,492	1,615	2,436	1,224	1,217
Most recent born child did not breastfeed	3,303	783	1,315	578	627
Most recent born child died before next conception	22	6	5	5	6
Remaining pregnancies	11,189	2,533	4,462	2,117	2,077
Inconsistent or incomplete information:					
Missing data on date of conception	23				
Dates of consecutive pregnancies inconsistent	26				
Breastfeeding lasted longer than 36 months	48				
Interpregnancy interval longer than 10 years	193				
Mother had incomplete birthdate information	5				
Missing information on US-born status	11				
Previous live birth had missing birth weight	222				
Final Analytical Sample	10,661				

Table 2. Selected characteristics of pregnancies to US women aged 15-44 whose last birth had ever been breastfed and had survived until her next conception, National Survey of Family Growth, 2002-2015.

	Unweighted				Weighted[a]			
	%	Woman-Months	Miscarriages	Rate[b]	%	Woman-Months	Miscarriages	Rate[b]
Breastfeeding:								
Not concurrently breastfeeding	93.3	43,112.5	1,309	30.4	93.9	360,916.6	12,070	33.4
Concurrently breastfeeding	6.7	3,096.4	108	34.9	6.1	23,514.0	826	35.1
NSFG Wave:								
2002	22.6	10,456.8	301	28.8	23.0	88,569.1	3,065	34.6
2006-2010	40.2	18,556.0	541	29.2	26.5	101,931.0	3,004	29.5
2011-2013	18.8	8,709.8	300	34.4	25.7	98,643.7	3,812	38.6
2013-2015	18.4	8,486.3	275	32.4	24.8	95,286.7	3,015	31.6
Period:								
1980-1989	2.5	1,161.5	25	21.5	4.0	15,545.3	401	25.8
1990-1999	30.3	14,015.2	370	26.4	28.8	110,607.7	3,644	32.9
2000-2009	56.0	25,898.7	827	31.9	53.2	204,551.0	6,807	33.3
2010-2015	11.1	5,133.5	195	38.0	14.0	53,726.6	2,044	38.0
Marital Status:								
Single	35.4	16,353.9	507	31.0	28.8	110,827.0	3,838	34.6
Married	55.7	25,723.0	759	29.5	61.9	238,146.2	7,560	31.7
Widowed	0.1	63.1	4	63.4	0.1	461.7	16	34.7
Divorced	3.2	1,476.2	56	37.9	2.8	10,623.4	358	33.7
Separated	1.0	453.1	13	28.7	0.6	2,363.0	54	22.9
Remarried	4.6	2,139.6	78	36.5	5.7	22,009.3	1,070	48.6
Previously miscarried:								
No	83.4	38,554.5	1,086	28.2	82.1	315,560.5	9,628	30.5
Yes	16.6	7,654.4	331	43.2	17.9	68,870.0	3,268	47.5
Highest level of education:								
Less than high school	23.1	10,667.8	285	26.7	17.9	68,668.4	1,758	25.6

High school	25.9	11,951.5	343	28.7	24.2	92,911.3	3,033	32.6
Some college	20.2	9,313.7	296	31.8	20.2	77,531.3	2,788	36.0
Associate's degree	9.0	4,152.7	141	34.0	9.1	35,112.3	1,162	33.1
Bachelor's degree	15.3	7,065.1	234	33.1	19.5	74,824.1	2,643	35.3
Graduate degree	6.6	3,058.2	118	38.6	9.2	35,383.2	1,512	42.7
Race and ethnicity:								
Hispanic	35.6	16,463.0	404	24.5	26.5	102,012.0	2,572	25.2
Non-hispanic white	43.8	20,250.4	738	36.4	57.2	219,963.5	8,664	39.4
Non-hispanic black	14.3	6,628.9	197	29.7	9.1	34,798.9	954	27.4
Non-hispanic other	6.2	2,866.6	78	27.2	7.2	27,656.2	706	25.5
Nativity:								
Foreign-born	29.9	13,825.7	331	23.9	24.6	94,674.7	2,356	24.9
US-born	70.1	32,383.2	1,086	33.5	75.4	289,755.8	10,540	36.4
Age at pregnancy (years):								
15-19	7.6	3,513.9	107	30.5	5.3	20,340.8	742	36.5
20-24	29.8	13,771.3	363	26.4	26.1	100,437.6	2,677	26.7
25-29	32.5	15,030.1	415	27.6	34.1	131,207.1	3,868	29.5
30-34	23.0	10,613.6	343	32.3	26.1	100,231.8	3,606	36.0
35-39	6.7	3,090.7	166	53.7	7.9	30,465.1	1,823	59.8
40+	0.4	189.3	23	121.5	0.5	1,748.0	180	103.0
Interpregnancy interval (months):								
0-11	25.3	11,713.8	352	30.1	24.0	92,255.4	2,988	32.4
12-23	29.6	13,666.8	405	29.6	30.7	118,144.7	3,360	28.4
24-35	18.1	8,343.4	251	30.1	18.5	71,245.3	2,640	37.1
36-37	10.4	4,820.5	160	33.2	9.9	37,959.1	1,357	35.7
48-59	7.1	3,271.1	84	25.7	7.1	27,368.9	916	33.5
60+	9.5	4,393.3	165	37.6	9.7	37,457.2	1,635	43.6
Pregnancy order:								
2	46.4	21,420.5	601	28.1	45.4	174,390.5	4,945	28.4

3	28.5	13,186.7	401	30.4	29.1	111,930.3	3,917	35.0
4	14.1	6,515.4	224	34.4	14.2	54,587.4	2,255	41.3
5	6.5	2,991.6	98	32.8	6.3	24,272.6	1,107	45.6
6	2.6	1,193.3	51	42.7	2.8	10,914.8	298	27.3
7+	2.0	901.3	42	46.6	2.2	8,334.9	374	44.9
Birth order of last child:								
1	59.0	27,261.0	829	30.4	58.8	225,915.4	7,143	31.6
2	27.0	12,459.9	388	31.1	27.4	105,313.8	4,087	38.8
3	9.5	4,387.0	135	30.8	9.0	34,743.6	1,159	33.4
4	2.9	1,348.1	42	31.2	2.9	11,253.8	320	28.4
5+	1.6	752.9	23	30.5	1.9	7,204.0	187	26.0
Intendedness of pregnancy:								
Later than wanted	5.8	2,681.7	112	41.8	6.5	25,040.0	1,282	51.2
Right time	54.0	24,958.0	656	26.3	58.3	224,123.2	6,210	27.7
Earlier than wanted	22.0	10,178.0	360	35.4	19.1	73,281.6	3,139	42.8
Indifferent	0.9	435.2	19	43.7	0.9	3,635.6	172	47.3
Unwanted entirely	16.9	7,821.6	265	33.9	14.9	57,163.0	2,045	35.8
Unsure	0.3	134.3	5	37.2	0.3	1,187.2	48	40.4
Birthweight of last child (kg):								
<2.5	7.0	3,212.3	112	34.9	6.2	23,686.7	846	35.7
2.5-2.9	18.4	8,496.6	266	31.3	18.0	69,006.7	2,442	35.4
3.0-3.4	37.6	17,378.4	543	31.2	37.4	143,917.4	4,444	30.9
3.5-3.9	27.0	12,470.2	356	28.5	28.0	107,670.2	3,831	35.6
4.0-4.4	8.0	3,677.1	105	28.6	8.2	31,532.0	864	27.4
≥4.5	2.1	974.3	35	35.9	2.2	8,617.6	469	54.4
TOTAL	100.0	46,208.9	1,417	30.7	100.0	384,430.5	12,896	33.5

[a] Using the sampling weights for each woman from the respective surveys

[b]Calculated as the number of miscarriages per 1,000 woman-months at-risk

Table 3. Comparison of selected characteristics for breastfeeding concurrent with pregnancy and not concurrent with pregnancy for US women aged 15-44, National Survey of Family Growth, 2002-2015.

	Not Concurrently Breastfeeding				Concurrently Breastfeeding				
	%	Woman-Months	Miscarriages	Rate[a]	%	Woman-Months	Miscarriages	Rate[a]	Prevalence of Breastfeeding during Pregnancy[b]
NSFG Wave:									
2002	22.9	9,885.1	279	28.2	18.5	571.7	22	38.5	5.5
2006-2010	40.1	17,281.5	501	29.0	41.2	1,276.5	40	31.3	6.9
2011-2013	18.8	8,108.0	278	34.3	19.4	601.9	22	36.6	6.9
2013-2015	18.2	7,845.0	251	32.0	20.9	646.4	24	37.1	7.6
Period:									
1980-1989	2.5	1,058.9	23	21.7	3.3	102.6	2	19.5	8.8
1990-1999	30.2	13,041.6	335	25.7	31.4	973.6	35	35.9	6.9
2000-2009	56.0	24,152.2	764	31.6	56.6	1,753.6	63	35.9	6.8
2010-2015	11.3	4,866.9	187	38.4	8.6	266.7	8	30.0	5.2
Marital Status:									
Single	35.2	15,190.6	471	31.0	37.6	1,163.3	36	30.9	7.1
Married	55.6	23,994.5	696	29.0	55.8	1,728.5	63	36.4	6.7
Widowed	0.1	55.2	4	72.5	0.3	7.9	0	0.0	12.6
Divorced	3.3	1,431.0	53	37.0	1.7	52.3	3	57.4	3.5
Separated	1.0	428.8	13	30.3	0.8	24.3	0	0.0	5.4
Remarried	4.7	2,019.5	72	35.7	3.9	120.2	6	49.9	5.6
Previously miscarried:									
No	83.5	36,008.0	1,010	28.0	82.5	2,553.5	76	29.8	6.6
Yes	16.5	7,111.5	299	42.0	17.5	542.9	32	58.9	7.1
Highest level of education:									
Less than high school	22.9	9,872.9	255	25.8	25.7	794.9	30	37.7	7.5
High school	25.9	11,148.3	315	28.3	26.1	809.3	28	34.6	6.8

Some college	20.1	8,653.4	277	32.0	21.3	660.3	19	28.8	7.1
Associate's degree	9.1	3,923.3	131	33.4	7.4	230.3	10	43.4	5.5
Bachelor's degree	15.5	6,678.7	223	33.4	12.5	386.4	11	28.5	5.5
Graduate degree	6.6	2,842.9	108	38.0	7.0	215.3	10	46.4	7.0
Race and ethnicity:									
Hispanic	35.3	15,240.0	364	23.9	39.5	1,222.9	40	32.7	7.4
Non-Hispanic white	44.3	19,100.5	687	36.0	37.4	1,157.0	51	44.1	5.7
Non-Hispanic black	14.2	6,131.9	188	30.7	16.1	497.1	9	18.1	7.5
Non-Hispanic other	6.1	2,647.1	70	26.4	7.1	219.5	8	36.5	7.7
Nativity:									
Foreign-born	29.5	12,716.4	303	23.8	35.8	1,109.3	28	25.2	8.0
US-born	70.5	30,403.2	1,006	33.1	64.2	1,987.1	80	40.3	6.1
Age at pregnancy (years):									
15-19	7.1	3,046.3	89	29.2	15.2	471.7	18	38.2	13.4
20-24	29.6	12,746.8	332	26.0	33.2	1,026.6	31	30.2	7.5
25-29	32.7	14,116.2	390	27.6	29.5	913.9	25	27.4	6.1
30-34	23.5	10,112.8	324	32.0	16.2	500.8	19	37.9	4.7
35-39	6.8	2,917.1	152	52.1	5.6	174.6	14	80.2	5.6
40+	0.4	180.5	22	121.9	0.3	8.8	1	113.2	4.7
Interpregnancy interval (months):									
0-11	21.5	9,278.4	264	28.5	78.8	2,439.4	88	36.1	20.8
12-13	30.2	13,040.8	386	29.6	20.3	628.1	19	30.3	4.6
24-35	19.3	8,314.4	250	30.1	0.9	28.9	1	34.6	0.3
36-37	11.2	4,820.5	160	33.2	0.0	0.0	0	0.0	0.0
48-59	7.6	3,271.1	84	25.7	0.0	0.0	0	0.0	0.0
60+	10.2	4,394.3	165	37.5	0.0	0.0	0	0.0	0.0
Pregnancy order:									
2	46.6	20,076.4	562	28.0	43.5	1,346.1	39	29.0	6.3
3	28.6	12,344.8	373	30.2	27.3	846.0	28	33.1	6.4

4	14.0	6,043.9	204	33.8	15.2	471.6	20	42.4	7.2
5	6.4	2,770.2	91	32.8	7.2	222.4	7	31.5	7.4
6	2.6	1,106.7	46	41.6	2.8	86.6	5	57.7	7.3
7+	1.8	777.5	33	42.4	4.0	123.8	9	72.7	13.7
Birth order of last child:									
1	59.2	25,528.9	772	30.2	56.0	1,734.1	57	32.9	6.4
2	27.0	11,641.5	353	30.3	26.6	823.5	35	42.5	6.6
3	9.4	4,045.3	125	30.9	11.0	341.7	10	29.3	7.8
4	2.8	1,220.4	38	31.1	4.1	127.7	4	31.3	9.5
5+	1.6	683.5	21	30.7	2.2	69.4	2	28.8	9.2
Intendedness of pregnancy:									
Later than wanted	6.1	2,615.9	109	41.7	2.1	65.8	3	45.6	2.5
Right time	55.0	23,722.0	618	26.1	40.0	1,238.0	38	30.7	5.0
Earlier than wanted	21.0	9,035.6	323	35.7	37.0	1,146.6	37	32.3	11.3
Indifferent	0.9	408.2	18	44.1	0.9	27.0	1	37.1	6.2
Unwanted entirely	16.7	7,214.7	236	32.7	19.6	608.0	29	47.7	7.8
Unsure	0.3	123.2	5	40.6	0.4	11.1	0	0.0	8.3
Birthweight of last child (kg):									
<2.5	6.9	2,982.5	104	34.9	7.4	229.8	8	34.8	7.2
2.5-2.9	18.3	7,906.6	244	30.9	19.1	592.0	22	37.2	7.0
3.0-3.4	37.6	16,217.9	504	31.1	37.6	1,165.6	39	33.5	6.7
3.5-3.9	27.0	11,623.4	335	28.8	27.3	846.8	21	24.8	6.8
4.0-4.4	8.1	3,478.7	94	27.0	6.4	198.5	11	55.4	5.4
≥4.5	2.1	910.5	28	30.8	2.1	63.8	7	109.7	6.5
TOTAL	100.0	43,119.5	1,309	30.4	100.0	3,096.4	108	34.9	6.7

[a] Calculated as the number of miscarriages per 1,000 woman-months at-risk

[b] The percentage of all woman-months at-risk in which pregnancy overlapped with breastfeeding for each respective category in a variable.

Table 4. Hazard ratios from Cox proportional hazards model assessing associations of selected maternal and pregnancy characteristics and an overlap of breastfeeding with pregnancy with the risk of miscarriage.

	Model 1		Model 2		Model 3		Ever Breastfed during Pregnancy[a]	
	HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
Breastfeeding:								
Not concurrently breastfeeding (ref)	1.00		1.00		1.00		1.00	
Concurrently breastfeeding	1.22*	(1.00-1.48)	1.25*	(1.03-1.53)	1.29*	(1.04-1.59)	1.20	(1.00-1.44)
NSFG Wave:								
2002 (ref)	1.00		1.00		1.00		1.00	
2006-2010	0.90	(0.77-1.05)	0.95	(0.81-1.12)	0.96	(0.82-1.13)	0.96	(0.82-1.13)
2011-2013	0.96	(0.80-1.16)	1.05	(0.87-1.27)	1.07	(0.88-1.29)	1.07	(0.88-1.29)
2013-2015	0.87	(0.71-1.06)	0.96	(0.78-1.18)	0.98	(0.79-1.20)	0.98	(0.79-1.21)
Period:								
1980-1989	0.62*	(0.41-0.94)	0.73	(0.48-1.11)	0.76	(0.50-1.16)	0.76	(0.50-1.16)
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*	(1.01-1.43)	1.11	(0.93-1.33)	1.11	(0.93-1.33)	1.11	(0.92-1.32)
Marital Status:								
Single (ref)			1.00		1.00		1.00	
Married			0.85*	(0.74-0.97)	0.90	(0.79-1.03)	0.90	(0.79-1.03)
Widowed			1.78	(0.66-4.79)	1.79	(0.66-4.83)	1.81	(0.67-4.87)
Divorced			0.99	(0.75-1.32)	0.96	(0.72-1.28)	0.96	(0.72-1.28)
Separated			0.83	(0.48-1.44)	0.82	(0.47-1.43)	0.82	(0.47-1.43)
Remarried			0.88	(0.68-1.13)	0.91	(0.71-1.17)	0.91	(0.71-1.17)
Previously miscarried:								
No (ref)			1.00		1.00		1.00	
Yes			1.40***	(1.23-1.58)	1.28**	(1.07-1.53)	1.27**	(1.06-1.52)
Highest level of education:								
Less than high school (ref)			1.00		1.00		1.00	

High school	0.94	(0.80-1.11)	0.92	(0.78-1.09)	0.92	(0.78-1.09)
Some college	0.98	(0.82-1.17)	0.96	(0.80-1.14)	0.95	(0.80-1.14)
Associate's degree	1.07	(0.86-1.34)	1.04	(0.83-1.30)	1.04	(0.83-1.30)
Bachelor's degree	0.95	(0.78-1.17)	0.95	(0.77-1.17)	0.95	(0.76-1.17)
Graduate degree	1.01	(0.79-1.29)	1.01	(0.78-1.30)	1.01	(0.78-1.30)
Race and ethnicity:						
Hispanic (ref)	1.00		1.00		1.00	
Non-hispanic white	1.31**	(1.11-1.53)	1.31***	(1.12-1.54)	1.31***	(1.12-1.54)
Non-hispanic black	1.07	(0.89-1.29)	1.03	(0.85-1.24)	1.03	(0.85-1.24)
Non-hispanic other	1.02	(0.79-1.31)	1.02	(0.79-1.31)	1.02	(0.79-1.31)
Nativity:						
Foreign-born (ref)	1.00		1.00		1.00	
US-born	1.18*	(1.01-1.38)	1.18	(1.01-1.38)	1.18*	(1.01-1.38)
Age at pregnancy (years):						
15-19 (ref)	1.00		1.00		1.00	
20-24	0.84	(0.68-1.05)	0.87	(0.69-1.09)	0.86	(0.69-1.08)
25-29	0.90	(0.71-1.13)	0.94	(0.74-1.20)	0.93	(0.73-1.19)
30-34	1.02	(0.80-1.30)	1.07	(0.82-1.39)	1.06	(0.81-1.38)
35-39	1.57**	(1.20-2.06)	1.62**	(1.20-2.18)	1.62**	(1.20-2.18)
40+	3.26***	(2.03-5.22)	3.10***	(1.89-5.08)	3.10***	(1.89-5.08)
Interpregnancy interval (months):						
0-11 (ref)			1.00		1.00	
12-23			1.09	(0.93-1.27)	1.10	(0.94-1.28)
24-35			1.11	(0.93-1.32)	1.12	(0.93-1.34)
36-37			1.27*	(1.04-1.56)	1.28*	(1.04-1.58)
48-59			0.94	(0.73-1.21)	0.94	(0.73-1.22)
60+			1.26*	(1.02-1.55)	1.27*	(1.02-1.57)
Pregnancy order:						
2 (ref)			1.00		1.00	

3			1.06	(0.88-1.28)	1.06	(0.88-1.28)
4			1.21	(0.93-1.59)	1.21	(0.93-1.59)
5			1.14	(0.80-1.63)	1.15	(0.80-1.63)
6			1.56	(1.00-2.43)	1.57*	(1.01-2.44)
7+			1.69*	(1.01-2.80)	1.69*	(1.02-2.81)
Birth order of last child:						
1 (ref)			1.00		1.00	
2			0.89	(0.74-1.07)	0.89	(0.74-1.07)
3			0.76	(0.57-1.01)	0.76	(0.57-1.01)
4			0.73	(0.47-1.11)	0.73	(0.48-1.11)
5+			0.51	(0.29-0.90)	0.51*	(0.29-0.90)
Intendedness of pregnancy:						
Later than wanted (ref)			1.00		1.00	
Right time			0.69***	(0.56-0.85)	0.69***	(0.56-0.85)
Earlier than wanted			0.98	(0.78-1.23)	0.98	(0.78-1.23)
Indifferent			1.21	(0.74-1.98)	1.21	(0.74-1.97)
Unwanted entirely			0.90	(0.71-1.13)	0.89	(0.71-1.13)
Unsure			0.93	(0.38-2.29)	0.92	(0.37-2.26)
Birthweight of last child (kg):						
<2.5			1.13	(0.92-1.38)	1.13	(0.92-1.39)
2.5-2.9			0.99	(0.86-1.15)	1.00	(0.86-1.15)
3.0-3.4 (ref)			1.00		1.00	
3.5-3.9			0.91	(0.79-1.04)	0.91	(0.79-1.04)
4.0-4.4			0.90	(0.73-1.11)	0.90	(0.73-1.11)
≥4.5			1.17	(0.83-1.64)	1.17	(0.83-1.64)
Pregnancies	10,661	10,661	10,661		10,661	
Woman-Months at-risk	46,208.9	46,208.9	46,208.9		46,208.9	
Miscarriages	1,417	1,417	1,417		1,417	
Chi2	27.3	177.9	235.7		234.1	

*$p<0.05$, **$p<0.01$, ***$p<0.001$ Note: ref=reference group

[a]In this model, women are only classified as having ever breastfed during pregnancy or not. Breastfeeding during pregnancy status is therefore treated as time-invariant.

Table 5. Hazard ratios from Cox proportional hazards model assessing associations of selected maternal and pregnancy characteristics and an overlap of breastfeeding with pregnancy with the risk of miscarriage for pregnancies conceived within 24 months of the last birth and for those whose older sibling's breastfeeding duration was not a multiple of three or six.

	Interpregnancy interval <24 months		Duration of last breastfeeding not a multiple of 3		Duration of last breastfeeding not a multiple of 6	
	HR	95% CI	HR	95% CI	HR	95% CI
Breastfeeding:						
Not concurrently breastfeeding (ref)	1.00					
Concurrently breastfeeding	1.31*	(1.05-1.62)	1.40*	(1.00-1.96)	1.43*	(1.07-1.92)
NSFG Wave:						
2002 (ref)	1.00		1.00		1.00	
2006-2010	0.97	(0.78-1.20)	0.95	(0.78-1.16)	0.92	(0.77-1.10)
2011-2013	1.07	(0.82-1.39)	1.00	(0.77-1.28)	1.01	(0.81-1.26)
2013-2015	1.05	(0.79-1.40)	1.06	(0.80-1.38)	0.99	(0.78-1.27)
Period:						
1980-1989	0.91	(0.57-1.47)	0.82	(0.48-1.41)	0.72	(0.44-1.18)
1990-1999	1.04	(0.86-1.26)	0.93	(0.77-1.12)	0.92	(0.78-1.08)
2000-2009 (ref)	1.00		1.00		1.00	
2010-2015	1.18	(0.91-1.51)	1.16	(0.92-1.46)	1.07	(0.87-1.32)
Marital Status:						
Single	1.00		1.00		1.00	
Married	0.88	(0.73-1.05)	0.92	(0.77-1.10)	0.89	(0.76-1.04)
Widowed (ref)			2.33	(0.57-9.53)	1.78	(0.44-7.22)
Divorced	1.18	(0.76-1.84)	1.14	(0.81-1.61)	0.98	(0.72-1.35)
Separated	0.74	(0.27-2.01)	1.06	(0.54-2.07)	0.93	(0.51-1.70)
Remarried	0.96	(0.68-1.35)	0.96	(0.68-1.34)	0.96	(0.72-1.29)
Previously miscarried:						
No (ref)	1.00		1.00		1.00	
Yes	1.26	(0.98-1.61)	1.23	(0.98-1.55)	1.27*	(1.03-1.56)
Highest level of education:						

Less than high school (ref)	1.00		1.00		1.00	
High school	0.85	(0.68-1.07)	1.00	(0.80-1.24)	0.98	(0.81-1.18)
Some college	0.89	(0.69-1.14)	1.01	(0.80-1.27)	0.94	(0.76-1.16)
Associate's degree	0.98	(0.72-1.34)	1.15	(0.86-1.54)	1.14	(0.88-1.47)
Bachelor's degree	0.95	(0.71-1.26)	1.00	(0.76-1.33)	0.96	(0.75-1.22)
Graduate degree	0.90	(0.64-1.29)	1.08	(0.77-1.51)	1.01	(0.75-1.37)
Race and ethnicity:						
Hispanic (ref)	1.00		1.00		1.00	
Non-hispanic white	1.40**	(1.13-1.75)	1.29*	(1.05-1.58)	1.33**	(1.11-1.59)
Non-hispanic black	0.99	(0.76-1.29)	1.03	(0.81-1.32)	1.01	(0.81-1.26)
Non-hispanic other	1.05	(0.74-1.49)	0.98	(0.69-1.37)	1.01	(0.75-1.37)
Nativity:						
Foreign-born (ref)	1.00		1.00		1.00	
US-born	1.29*	(1.03-1.62)	1.21	(0.97-1.50)	1.15	(0.96-1.39)
Age at pregnancy (years):						
15-19 (ref)	1.00		1.00		1.00	
20-24	0.95	(0.73-1.22)	0.81	(0.61-1.07)	0.80	(0.62-1.03)
25-29	0.94	(0.70-1.26)	0.82	(0.60-1.11)	0.87	(0.66-1.15)
30-34	1.02	(0.73-1.42)	0.87	(0.62-1.21)	0.93	(0.69-1.26)
35-39	1.80**	(1.23-2.64)	1.52*	(1.03-2.23)	1.51*	(1.07-2.13)
40+	2.97**	(1.31-6.74)	2.92***	(1.56-5.46)	2.89***	(1.62-5.16)
Interpregnancy interval (months):						
0-11 (ref)	1.00		1.00		1.00	
12-23	1.08	(0.93-1.27)	1.16	(0.96-1.41)	1.15	(0.96-1.38)
24-35			1.05	(0.84-1.33)	1.11	(0.90-1.37)
36-37			1.27	(0.98-1.65)	1.35*	(1.07-1.70)
48-59			0.91	(0.65-1.27)	1.09	(0.82-1.46)
60+			1.31	(0.99-1.73)	1.41**	(1.11-1.80)
Pregnancy order:						

2 (ref)	1.00		1.00		1.00	
3	1.00	(0.77-1.30)	1.11	(0.87-1.40)	1.05	(0.85-1.30)
4	1.13	(0.77-1.65)	1.28	(0.91-1.81)	1.20	(0.88-1.63)
5	0.92	(0.56-1.52)	1.17	(0.74-1.86)	1.20	(0.80-1.80)
6	1.41	(0.76-2.62)	1.87*	(1.07-3.27)	1.45	(0.86-2.44)
7+	1.75	(0.90-3.38)	1.59	(0.81-3.11)	1.47	(0.81-2.65)
Birth order of last child:						
1 (ref)	1.00		1.00		1.00	
2	1.05	(0.81-1.36)	0.90	(0.71-1.14)	0.92	(0.74-1.13)
3	0.72	(0.48-1.10)	0.73	(0.50-1.06)	0.75	(0.53-1.05)
4	0.89	(0.51-1.56)	0.74	(0.42-1.28)	0.75	(0.45-1.24)
5+	0.62	(0.29-1.31)	0.52	(0.24-1.12)	0.67	(0.35-1.30)
Intendedness of pregnancy:						
Later than wanted (ref)	1.00		1.00		1.00	
Right time	0.55**	(0.38-0.79)	0.74*	(0.57-0.97)	0.72**	(0.56-0.91)
Earlier than wanted	0.74	(0.51-1.08)	1.04	(0.78-1.40)	1.00	(0.77-1.30)
Indifferent	1.17	(0.59-2.33)	1.17	(0.61-2.23)	0.95	(0.50-1.79)
Unwanted entirely	0.71	(0.48-1.06)	0.91	(0.67-1.23)	0.91	(0.70-1.20)
Unsure	0.95	(0.33-2.69)	1.62	(0.59-4.50)	1.08	(0.39-2.98)
Birthweight of last child (kg):						
<2.5	1.12	(0.85-1.48)	1.08	(0.83-1.42)	1.15	(0.91-1.45)
2.5-2.9	0.99	(0.81-1.21)	1.09	(0.90-1.31)	1.06	(0.90-1.26)
3.0-3.4 (ref)	1.00		1.00		1.00	
3.5-3.9	0.83*	(0.69-1.00)	0.89	(0.74-1.06)	0.92	(0.79-1.08)
4.0-4.4	0.94	(0.71-1.25)	1.02	(0.78-1.34)	0.95	(0.75-1.21)
≥4.5	1.18	(0.72-1.93)	1.02	(0.62-1.67)	0.98	(0.64-1.51)
Pregnancies	5,837		6,099		7,817	
Woman-Months at-risk	25,386.7		26,166.9		33,554.4	
Miscarriages	757		838		1,055	

Chi2	137.2	151.20	167.20

*p<0.05, **p<0.01, ***p<0.001 Note: ref=reference group