



# Predictors of Breastfeeding Duration in the New Hampshire Birth Cohort Study

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## Abstract

**Introduction** Breastfeeding has significant health benefits for infants and birthing persons, including reduced risk of chronic disease. The American Academy of Pediatrics recommends exclusively breastfeeding infants for 6 months and recently extended its recommendation for continuing to breastfeed with supplementation of solid foods from one to two years. Studies consistently identify lower breastfeeding rates among US infants, with regional and demographic variability. We examined breastfeeding in birthing person-infant pairs among healthy, term pregnancies enrolled in the New Hampshire Birth Cohort Study between 2010 and 2017 (n = 1176).

**Methods** Birthing persons 18–45 years old were enrolled during prenatal care visits at ~24–28 weeks gestation and have been followed since enrollment. Breastfeeding status was obtained from postpartum questionnaires. Birthing person and infant health and sociodemographic information was abstracted from medical records and prenatal and postpartum questionnaires. We evaluated the effects of birthing person age, education, relationship status, pre-pregnancy body mass index, gestational weight gain (GWG), smoking and parity, and infant sex, ponderal index, gestational age and delivery mode on breastfeeding initiation and duration using modified Poisson and multivariable linear regression.

**Results** Among healthy, term pregnancies, 96% of infants were breastfed at least once. Only 29% and 28% were exclusively breastfed at 6-months or received any breastmilk at 12-months, respectively. Higher birthing person age, education, and parity, being married, excessive GWG, and older gestational age at delivery were associated with better breastfeeding outcomes. Smoking, obesity, and cesarean delivery were negatively associated with breastfeeding outcomes.

**Conclusions** Given the public health importance of breastfeeding for infants and birthing persons, interventions are needed to support birthing persons to extend their breastfeeding duration.

## Significance

*What is already known?* The benefits of breastfeeding to child and birthing person health are well-documented, however, rates of breastfeeding initiation and duration continue to fall short of health-based guidelines. Regional differences exist and certain rural New England states tend to have amongst the highest breastfeeding rates in the US.

*What this study adds?* This study of n = 1176 birthing persons-infant pairs enrolled in the New Hampshire Birth Cohort Study, a rural, general population pregnancy cohort, suggests that factors influencing breastfeeding outcomes align closely with studies conducted in urban settings and using nationally-representative surveys.

**Keywords** Breastfeeding initiation · Breastfeeding duration · Predictors · New Hampshire Birth Cohort Study (NHBCS)

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## Introduction

Breastfeeding is recognized by leading pediatric (e.g., American Academy of Pediatrics, AAP) and public health (e.g., World Health Organization, WHO; US Centers for Disease Control and Prevention, CDC) organizations as important to optimize short- and long-term child and birthing persons health (AAP, 2020; CDC, 2020b; UNICEF, 2015; WHO,

2020). Benefits of breastfeeding occur irrespective of socioeconomic status, improving infant and birthing persons health in low-, middle-, and high-income countries, alike (Victora et al., 2016) and have been reviewed previously (Eidelman & Schanler, 2012; Gartner et al., 2005; Salone et al., 2013; Victora et al., 2016). At the time of this study, the AAP and WHO recommended exclusive breastfeeding until infants are six months old, and continued breastfeeding with solid food supplementation until at least 12 months old (“health-based guidelines”) (AAP, 2020; Eidelman & Schanler, 2012; Gartner et al., 2005; WHO, 2020). Current health-based guidelines extend recommendations for supplemental breastfeeding until children are two years old (Meek & Noble, 2022). Breastfeeding rates in many parts of the world, including high-income countries, fall short of these guidelines (CDC, 2020b, 2022). Since breastfeeding guidelines are health-based, low initiation and shorter duration of breastfeeding can pose risks to child and birthing person wellbeing, which may not be replaceable by infant formula and access to high-quality medical care.

Understanding risk factors that predict early cessation is important for developing interventions that promote breastfeeding. Prior studies have identified complex, multifactorial patterns associated with reduced breastfeeding duration in high-income countries (e.g., Cohen et al., 2018; Henninger et al., 2017; Kehler et al., 2009; Scott et al., 2006; Wallwiener et al., 2016). For example, factors such as younger birthing person age, belonging to certain racial/ethnic groups (e.g., Black), lower educational attainment, smoking, higher pre-pregnancy body mass index (ppBMI), cesarean delivery, pregnancy complications, (e.g., pre-term delivery, time in the neonatal intensive care unit), and postpartum work are associated with reduced rates of breastfeeding initiation and/or early cessation (e.g., Amiel Castro et al., 2017; Beauregard et al., 2019; Cohen et al., 2018; Kehler et al., 2009; Lutsiv et al., 2013; Maastrup et al., 2014; Scott et al., 2006; Steurer, 2017). However, this information is compiled from studies conducted in numerous countries and public policy and cultural differences may influence national breastfeeding patterns (Galtry, 2003; Lubold, 2019). Furthermore, regional and local breastfeeding rates vary and studies based on nationally-representative surveys and/or urban populations may not be generalizable to rural settings (e.g., CDC, 2022; Scott et al., 2006; Stough et al., 2019; Wallwiener et al., 2016).

We evaluated predictors of breastfeeding among 1176 birthing person-infant pairs enrolled in the New Hampshire Birth Cohort Study (NHBCS), a rural, general population pregnancy cohort, between 2010 and 2017.

## Methods

### New Hampshire Birth Cohort Study (NHBCS)

The NHBCS is a prospective, rural pregnancy cohort, based in New Hampshire (NH), designed to examine associations of arsenic and other exposures via private drinking water wells with perinatal health and childhood development. An estimated 46% of NH residents receive their drinking water from private water supplies (NHDES, 2018). Birthing persons ages 18–45 years were recruited for enrollment into the NHBCS at prenatal care visits at approximately 24–28 weeks gestation. Eligible birthing persons were receiving prenatal care for a singleton pregnancy at one of the study clinics in either Lebanon or Concord, NH and lived in a household served by a private water system, defined according to state and federal Safe Drinking Water Acts (SDWAs) as systems serving fewer than 15 connections or less than 25 people. Birthing persons needed to plan to live in the same place from their last menstrual period through delivery. NHBCS research was approved by the Dartmouth College Institutional Review Board and all birthing persons provided written, informed consent prior to enrollment.

### Predictors

We selected predictors a priori based on previous research demonstrating their influence on breastfeeding outcomes. Predictor information was obtained through birthing person self-report questionnaires, measurements made by trained study personnel, and abstraction from birthing person and infant medical records. Detailed medical and personal histories were provided by birthing persons at enrollment, including age, race and ethnicity, education, relationship status, smoking history, ppBMI, and parity. Gestational weight gain (GWG), cardiometabolic complications of pregnancy (hypertension/preeclampsia, gestational diabetes), delivery mode, and gestational age at delivery were obtained from birthing person medical records. Pre-pregnancy BMI was categorized as normal, overweight or obese (CDC, 2020a), and GWG was categorized as limited, adequate or excessive (IOM, 2009). Infant sex and birth weight and length were obtained from infant medical records. Infant weight and length were used to calculate ponderal index, a measure of leanness in newborns:  $[\text{birthweight (kg)}]/[\text{birth length (m)}]^3$  (Landmann et al., 2006).

### Breastfeeding Outcomes

Birthing persons completed questionnaires every four months in the first year postpartum, then every six months

up to five years. Birthing persons were asked about the age at which they last breastfed their infant and introduced any non-breastmilk supplementation (infant formula, solid food, juice, water) into their infant's diet. We derived variables of breastfeeding initiation, and "exclusive" and "any" breastfeeding duration based on this information (AAP, 2020; WHO, 2020). Breastfeeding initiation was defined as a birthing person putting their infant to their breast at least one time. "Exclusive" breastfeeding duration was defined as the age (months) when an infant received their first supplementation of non-breastmilk foods or liquids, including water (WHO, 2019). The WHO regards only medically recommended supplementation (oral rehydration solutions, vitamins, minerals, and medicines) as compliant with the definition of exclusive breastfeeding. "Any" breastfeeding duration was defined as the age (months) when an infant last received breastmilk.

### Statistical Analyses

To date, more than 3000 birthing person-infant pairs have been enrolled into the NHBCS. To evaluate predictors of breastfeeding outcomes among this cohort, we restricted to birthing persons enrolled between 2010 and 2017 for whom breastfeeding data were available ( $n = 1337$ ). We excluded birthing persons who had pregnancy-induced hypertension, gestational diabetes mellitus (GDM), preeclampsia, and preterm delivery ( $\leq 37$  weeks gestation) since cardiometabolic pregnancy complications and preterm delivery are strong predictors of adverse breastfeeding outcomes (e.g., Åkerström et al., 2007; Cordero et al., 2012; Demirci et al., 2018; Guelinckx et al., 2012). In total, we evaluated breastfeeding among 1176 birthing person-infant pairs.

We calculated descriptive statistics for all predictors and breastfeeding outcomes. Predictors were selected a priori based on factors previously observed to influence breastfeeding initiation and duration. All models included birthing person age at enrollment (continuous), highest level of education (ordinal categorical), parity (ordinal categorical), marital status (binary), smoking status (categorical), ppBMI (continuous or categorical), GWG (categorical), delivery method (binary), gestational age at delivery (continuous), infant sex (binary), and infant ponderal index (continuous). To assess predictors of breastfeeding initiation, we used modified Poisson regression with robust standard error (Zou, 2004) to estimate the relative risk (RR) of never breastfeeding associated with each predictor, adjusted for other predictors, including ppBMI as a continuous variable, in the multivariable models. When evaluating predictors of breastfeeding duration, we further restricted our analyses to birthing persons who had ever breastfed (96%;  $n = 1124$ ). Using modified Poisson regression, we evaluated predictors of exclusive breastfeeding duration at six months and any

breastfeeding at 12 months, adjusted for other predictors. We evaluated exclusive and any breastfeeding duration as continuous outcomes using multivariable linear regression. All regression models for exclusive and any breastfeeding outcomes included ppBMI as a categorical variable. We did not evaluate race/ethnicity as a predictor of breastfeeding outcomes because  $> 97\%$  of birthing persons participating in the NHBCS identify as non-Hispanic white. Statistical significance was evaluated using 95% confidence intervals (CI) for RR estimates from modified Poisson and beta coefficients from multivariable linear regression models, respectively. All statistical analyses were performed using R version 3.6.1.

## Results

The 1176 birthing persons in the analytic population were predominantly non-Hispanic White (97.1%), educated (70.1% had a Bachelor's degree or higher), and older (mean  $\pm$  SD:  $31.4 \pm 4.8$  years) (Table 1). Most birthing persons were married (85.9%), parous (58.2%), and tended to have good pre-pregnancy health indicators, including no current or prior smoking (87.2%) and relatively healthy ppBMI ( $25.6 \pm 5.6$ ) (Table 1). However, roughly half of birthing persons had excessive GWG (55.9%) (Table 1). Most birthing persons delivered vaginally (71.1%) at full term ( $39.4 \pm 1.1$  weeks gestation) and infants were evenly divided by sex (Table 1). Measures of infant anthropometry also reflected healthy, term pregnancies, weighing  $3.4 \pm 0.6$  kg and measuring  $50.6 \pm 2.9$  cm in length (Table 1).

### Breastfeeding Initiation

Almost all birthing persons (95.6%;  $n = 1124$ ) breastfed their infant at least once (Table 2). Birthing persons with a Bachelor's degree were 1% more likely to breastfeed than those who had attended some college but had not earned a Bachelor's degree (RR; 95% CI: 1.01; 1.01, 1.02) (Table 3). Married birthing persons were 3% more likely to initiate breastfeeding compared to those who were unmarried (1.03; 1.00, 1.06) and for each additional week of gestation, likelihood of breastfeeding initiation increased by 1% (1.01; 1.00, 1.01) (Table 3). Breastfeeding initiation was similar among people delivering by cesarean section and vaginally (0.99; 0.96, 1.01) (Table 3).

### Breastfeeding at Health-Based Guidelines

Among birthing persons who initiated breastfeeding in our study, 28.9% ( $n = 239$ ) exclusively breastfed until their infant was six months old and 28.1% ( $n = 312$ ) were still breastfeeding at least sometimes at 12 months, the health-based

**Table 1** Characteristics of 1176 birthing person-infant pairs enrolled in the New Hampshire Birth Cohort Study (NHBCS) between 2010 and 2017. Our study included healthy (no pregnancy-induced hypertension, preeclampsia, or gestational diabetes mellitus), term ( $\geq 37$  weeks) pregnancies, and for whom information about breastfeeding was available. Breastfeeding initiation (“ever breastfed”) was

defined as a birthing person having put their infant to their breast at least one time. Descriptive statistics are provided for all birthing persons enrolled in the current study, as well as broken out by breastfeeding initiation status. For binary variables, descriptive statistics included herein refer to the category listed in parentheses

Birthing person and infant characteristics		Overall		Ever breastfed		Never breastfed	
Predictors (variable)	n	Mean $\pm$ SD	n	Mean $\pm$ SD	n	Mean $\pm$ SD	
		(%)		(%)		(%)	
Birthing person	All birthing persons	1176	–	1124	(95.6)	52	(4.4)
	Age	1176	31.4 $\pm$ 4.8	1124	31.5 $\pm$ 4.8	52	29.4 $\pm$ 5.3
	ppBMI (kg/m <sup>2</sup> )	1122	25.6 $\pm$ 5.6	1077	25.5 $\pm$ 5.6	45	26.8 $\pm$ 6.1
	Race (Non-Hispanic White)	1142	(97.1)	1091	(97.1)	51	(98.1)
	Relationship status (Married)	939	(85.9)	913	(87.0)	26	(60.5)
	Parity (Nulliparous)	476	(41.8)	464	(42.0)	12	(23.5)
	Gestational weight gain category	1049	–	1010	–	39	–
	Adequate	335	(31.9)	326	(32.3)	9	(23.1)
	Insufficient	128	(12.2)	124	(12.3)	4	(10.3)
	Excessive	586	(55.9)	560	(55.4)	26	(66.7)
	Highest education	1092	–	1049	–	43	–
	High school or less	128	(11.7)	113	(10.8)	15	(34.9)
	Tech school/some college	198	(18.1)	187	(17.8)	11	(25.6)
	Bachelor’s/Graduate/Professional	766	(70.1)	749	(71.4)	17	(39.5)
	Smoking	1093	–	1050	–	43	–
	No	953	(87.2)	923	(87.9)	30	(69.8)
	Current	72	(6.6)	65	(6.2)	7	(16.3)
	Former	68	(6.2)	62	(5.9)	6	(14.0)
	Delivery type (Vaginal)	831	(71.1)	797	(71.4)	34	(65.4)
Infant	Gestational week of delivery	1176	39.4 $\pm$ 1.1	1124	39.4 $\pm$ 1.1	52	39.2 $\pm$ 1.1
	Infant sex (Male)	592	(50.3)	568	(50.5)	24	(46.2)
	Ponderal index (kg/m <sup>3</sup> )	1138	26.5 $\pm$ 3.3	1087	26.5 $\pm$ 3.3	51	26.6 $\pm$ 3.1

**Table 2** Descriptive statistics for breastfeeding outcomes among birthing persons enrolled in the current study who initiated breastfeeding

Breastfeeding Outcomes (variable)	Ever breastfed	
	n	Mean $\pm$ SD (%)
Ever breastfed (Yes)	1124	(95.6)
Exclusive breastfeeding Duration (months)	827	3.9 $\pm$ 2.4
Exclusive breastfeeding, $\geq 6$ months (Yes)	239	(28.9)
Any breastfeeding duration (months)	1110	9.2 $\pm$ 7.5
Any breastfeeding, $\geq 12$ months (Yes)	312	(28.1)

guidelines at this time (Table 2). Positive predictors of breastfeeding at health-based guidelines include education, parity, being married, and excessive GWG, whereas smoking, obesity, and cesarean delivery were negatively associated with breastfeeding. Specifically, for each additional

prior child, a birthing person was 4% (1.04; 1.01, 1.07) more likely to exclusively breastfeed their infant enrolled in the current study at six months, and 3% (1.03; 1.00, 1.05) more likely to continue any breastfeeding to 12 months (Table 3). Married birthing persons were 10% (1.10; 1.02, 1.19) more likely to breastfeed exclusively at six months than those who were unmarried (Table 3). Birthing persons with a Bachelor’s degree were 5% (1.05; 1.02, 1.08) more likely to breastfeed at 12 months than those who had some college education but whom had not earned a Bachelor’s degree and individuals with excessive GWG were 6% (1.06; 1.01, 1.12) more likely to breastfeed at 12 months than those with adequate GWG (Table 3). By contrast, birthing persons who were obese prior to pregnancy (ppBMI  $\geq 30.0$  kg/m<sup>2</sup>) were 12% (0.88; 0.82, 0.94) and 10% (0.90; 0.84, 0.96) less likely to continue exclusive and any breastfeeding until six and 12 months, respectively, than people with normal ppBMI (< 25 kg/m<sup>2</sup>) (Table 3). Birthing persons who currently smoked were 17% (0.83; 0.76, 0.90) less likely to exclusively

**Table 3** Predictors of breastfeeding in accordance with health-based guidelines (ever breastfed; exclusive breastfeeding at six months; any breastfeeding at 12 months). Relative risks (RR) and 95% confidence intervals (CI) are presented, and bold, italicized values indicate variables which significantly predicted breastfeeding outcomes in the respective modified Poisson regression models. BMI—body mass index; ppBMI—pre-pregnancy BMI; GWG—gestational weight gain

Predictors of breastfeeding (variable)	Ever breastfed	Exclusive breastfeeding at 6 months	Any breastfeeding at 12 months
	RR(95% CI)	RR(95% CI)	RR(95% CI)
Birth person age	1.00 (1.00, 1.00)	1.00 (1.00, 1.01)	1.00 (1.00, 1.01)
Education	<b>1.01 (1.00, 1.02)</b>	1.01 (0.98, 1.04)	<b>1.05 (1.02, 1.08)</b>
Parity	1.00 (0.99, 1.00)	<b>1.04 (1.01, 1.07)</b>	<b>1.03 (1.00, 1.05)</b>
Unmarried	Ref	Ref	Ref
Married	1.03 (1.00, 1.06)	<b>1.10 (1.02, 1.19)</b>	1.04 (0.96, 1.11)
Never smoker	Ref	Ref	Ref
Current smoker	0.99 (0.95, 1.04)	<b>0.83 (0.76, 0.90)</b>	1.00 (0.90, 1.11)
Former smoker	0.99 (0.96, 1.03)	0.95 (0.85, 1.07)	0.99 (0.90, 1.08)
BMI (continuous)	1.00 (1.00, 1.00)	–	–
Normal ppBMI	–	Ref	Ref
Overweight ppBMI	–	0.98 (0.92, 1.04)	0.95 (0.86, 1.00)
Obese ppBMI	–	<b>0.88 (0.82, 0.94)</b>	<b>0.90 (0.84, 0.96)</b>
Adequate GWG	Ref	Ref	Ref
Inadequate GWG	1.00 (0.98, 1.02)	1.00 (0.92, 1.09)	1.00 (0.93, 1.08)
Excessive GWG	1.00 (0.98, 1.01)	1.05 (0.99, 1.11)	<b>1.06 (1.01, 1.12)</b>
Vaginal delivery	Ref	Ref	Ref
Cesarean delivery	0.99 (0.96, 1.01)	0.95 (0.90, 1.01)	<b>0.95 (0.90, 1.00)</b>
Gestational age at delivery	<b>1.01 (1.00, 1.01)</b>	0.98 (0.96, 1.00)	1.00 (0.98, 1.02)
Child sex: female	Ref	Ref	Ref
Child sex: male	1.01 (0.99, 1.02)	0.96 (0.92, 1.02)	0.99 (0.95, 1.04)
Child ponderal index	1.00 (1.00, 1.00)	1.00 (1.00, 1.01)	1.01 (1.00, 1.01)

breastfeed at six months versus never smokers, and birthing persons who delivered via cesarean section were 5% (0.95; 0.90, 1.00) less likely to continue breastfeeding until 12 months than those who delivered vaginally (Table 3). Infant characteristics did not predict breastfeeding in accordance with health-based guidelines at six or 12 months.

### Breastfeeding Duration

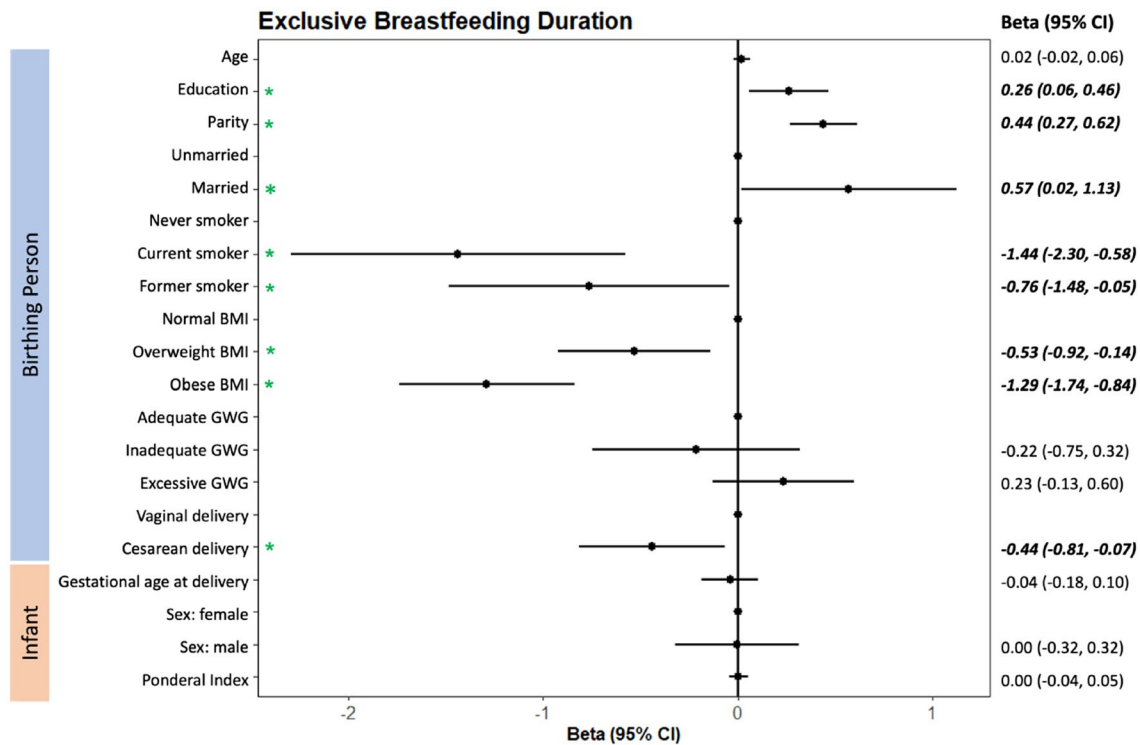
Birthing persons who exclusively breastfed did so for an average of 3.9 months (SD  $\pm$  2.4) (Table 2). Birthing persons continued any breastfeeding for an average of  $9.2 \pm 7.5$  months (Table 2). Several factors were associated with longer exclusive and any breastfeeding duration. For each prior child, parous individuals exclusively and any breastfed for 0.44 (95% CI: 0.27, 0.62; Fig. 1) and 1.15 (0.64, 1.66; Fig. 2) months longer, respectively. Higher education was associated with longer exclusive (Beta: 0.26 months; 95% CI: 0.06, 0.46; Fig. 1) and any (0.83 months; 0.25, 1.42; Fig. 2) breastfeeding. Being married was also associated with longer exclusive breastfeeding (0.57 months; 0.02, 1.13) relative to birthing persons who were unmarried (Fig. 1). For each additional year of age at enrollment, birthing persons continued any breastfeeding for an extra 0.17 (0.05, 0.28) months (Fig. 2). Similarly, a number of factors were associated with shorter exclusive and any

breastfeeding duration. Current and former smokers exclusively breastfed for 1.44 (–2.30, –0.58) and 0.76 (–1.48, –0.05) fewer months, respectively, compared to those who never smoked (Fig. 1). People who were overweight (–0.53 months; –0.92, –0.14) and obese (–1.29 months, 95% CI: –1.74, –0.84) prior to pregnancy exclusively breastfed for less time than those with normal ppBMI (Fig. 1). Similarly, overweight and obese birthing persons continued any breastfeeding for 1.35 (–2.49, –0.21) and 2.37 (–3.70, –1.04) fewer months, respectively, than those with a normal ppBMI (Fig. 2). Birthing persons who delivered via cesarean section breastfed for 1.14 (–2.21, –0.06) fewer months than those who delivered vaginally (Fig. 2). Infant characteristics did not predict duration of exclusive or any breastfeeding in our study.

### Discussion

Because breastfeeding is critical to optimal child and birthing persons health, health-based guidelines recommended exclusively breastfeeding infants until six months of age, followed by continued breastfeeding supplemented with solid foods until 12 months at the time of this study (AAP, 2020; Eidelman & Schanler, 2012; Gartner et al., 2005; WHO, 2020). Breastfeeding rates are generally high in NH





**Fig. 1** Adjusted multivariable linear regression estimates (beta ± 95% CI) of predictors of exclusive breastfeeding duration. Betas (●) and 95% confidence intervals for birthing person and infant characteristics. The vertical line represents the null and points located on this line denote the reference level for categorical variables (e.g., never smoker vs. current smoker). Predictors with betas located to the left of the null are negatively associated with exclusive breastfeeding

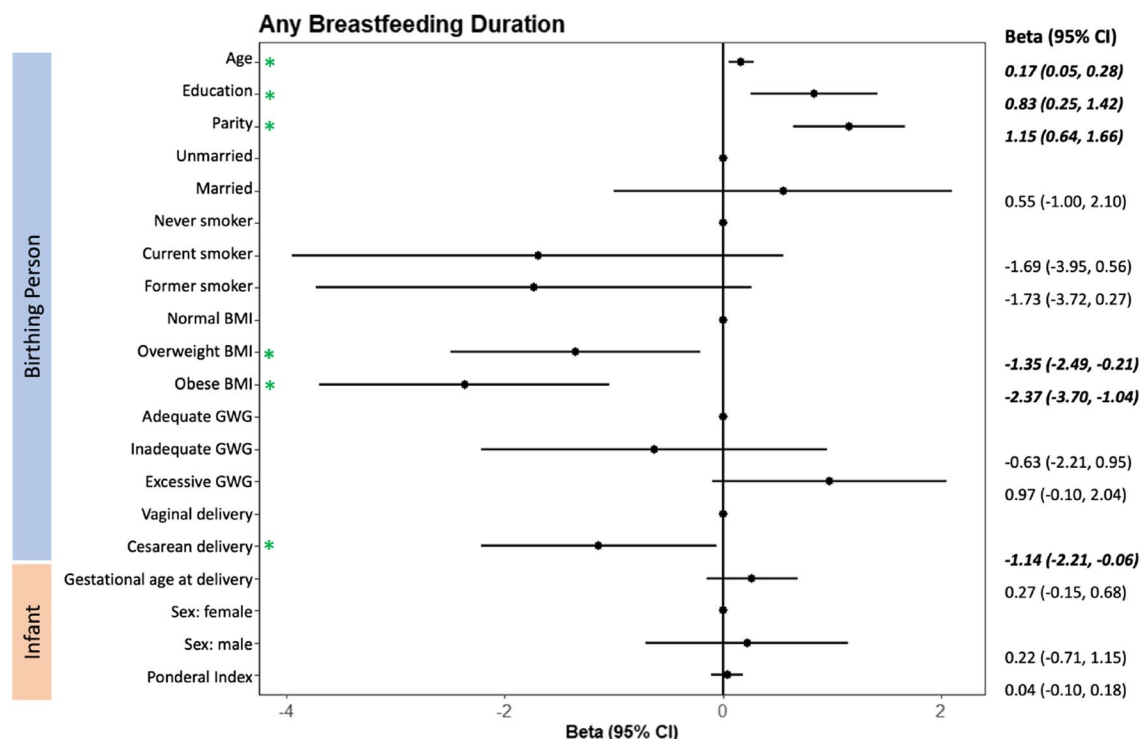
duration, whereas predictors with betas located to the right of the null are positively associated. Green asterisks (\*) and bold, italicized betas and 95% CIs reflect those predictors which are significantly associated with exclusive breastfeeding duration among birthing persons in our study. BMI – pre-pregnancy body mass index; GWG – gestational weight gain

compared to other parts of the US, with 37% of birthing persons exclusively breastfeeding at six months and 40% any breastfeeding at 12 months (CDC, 2022). By contrast, only 25% of infants born in the US in 2019 were exclusively breastfed at six months and only 36% received at least some breastmilk at 12 months (CDC, 2022). Breastfeeding outcomes among birthing persons enrolled in our study tracked closely with national trends and our results corroborate findings from prior studies among US birthing person-infant pairs (CDC, 2020b, 2022; Stough et al., 2019). Notably, among birthing persons enrolled in our study, age, education, parity, being married, excessive GWG, and gestational age at delivery were positively associated with improved breastfeeding outcomes (initiation and longer duration). Conversely, smoking, being overweight or obese, and cesarean delivery were negatively associated with breastfeeding outcomes. These findings provide insight into strategies for improving breastfeeding outcomes in rural settings.

Measures of higher socioeconomic status and a stable family structure, such as higher education and being married, were positive predictors of breastfeeding initiation and duration among NHBCS birthing persons as has been

demonstrated in previous research (Ekstrom et al., 2003; Hackman et al., 2015; Heck, 2006; Kehler et al., 2009; Victora et al., 2016). Although birthing person age tended to be inversely associated with breastfeeding duration in other studies (e.g., Colombo et al., 2018; Kitano et al., 2016), we did not observe this relationship in our study.

We evaluated the role of ppBMI, GWG, and smoking status on breastfeeding initiation and duration to represent measures of overall birthing person health prior to and during pregnancy. Pre-pregnancy obesity was inversely associated with breastfeeding duration in all regression models for exclusive and any breastfeeding. Excessive GWG was associated with longer breastfeeding, whereas inadequate GWG tended to be associated with shorter breastfeeding. Collectively, these findings agree with prior literature suggesting that pre-pregnancy obesity, which is an important metric of overall birthing person health, adversely influences breastfeeding (Huang et al., 2019; Kehler et al., 2009), yet birthing persons who gain excessive weight during pregnancy may be motivated to breastfeed because of the perception that breastfeeding improves postpartum weight loss (Schalla et al., 2017). A history of



**Fig. 2** Adjusted multivariable linear regression estimates (beta  $\pm$  95% CI) of predictors of any breastfeeding duration. Betas (●) and 95% confidence intervals for birthing person and infant characteristics. The vertical line represents the null and points located on this line denote the reference level for categorical variables (e.g., never smoker vs. current smoker). Predictors with betas located to the left of the null are negatively associated with any breastfeeding duration,

whereas predictors with betas located to the right of the null are positively associated. Green asterisks (\*) and bold, italicized betas and 95% CIs reflect those predictors which are significantly associated with any breastfeeding duration among birthing persons in our study. BMI – pre-pregnancy body mass index; GWG – gestational weight gain

smoking was also a risk factor for early breastfeeding cessation in all regression models for exclusive or any breastfeeding among birthing persons enrolled in our study, as has been previously reported (e.g., Mennella et al., 2008; Scott et al., 2006; Wallenborn & Masho, 2016).

Gestational age at delivery and delivery mode predicted breastfeeding initiation and duration in our study as has been reported previously (e.g., Hobbs et al., 2016; Lutsiv et al., 2013). While our analyses were restricted to term pregnancies (> 37 weeks gestation) and did not explore physiological mechanisms underlying breastfeeding initiation, pregnancy and lactation hormones offer possible insights into our findings. Levels of oxytocin and prolactin change in coordinated ways during the perinatal period to support childbirth and breastfeeding, yet may be adversely altered by natural early term delivery (37–39 weeks gestation) or delivery interventions (Buckley, 2015; Hill et al., 2009; Nissen et al., 1996; Parker et al., 1989; Uvnäs-Moberg et al., 2020). Consistent with literature documenting the benefits of vaginal delivery on breastfeeding outcomes (Hobbs et al., 2016; Moore et al., 2016; Prior et al., 2012), cesarean delivery was negatively associated

with breastfeeding initiation and duration in all regression models in our study.

Though not all risk factors for adverse breastfeeding outcomes are modifiable, some identified in this and prior studies offer opportunities for interventions to improve breastfeeding among birthing persons at higher risk of not initiating or maintaining breastfeeding in accordance with health-based guidelines. Characteristics such as obesity, GWG, and smoking adversely impact breastfeeding duration and are already targets for clinical intervention to improve birthing person and child health; related initiatives will benefit breastfeeding outcomes. Hospital practices to connect birthing persons with their newborns as quickly as possible after cesarean delivery may also improve breastfeeding outcomes (e.g., Moore et al., 2016; Rowe-Murray & Fisher, 2002). The WHO and United Nations Children's Fund Baby-Friendly Hospital Initiative outlines best practices to support breastfeeding globally (WHO and UNICEF, 2018) and the Healthy People Initiative includes recommendations to promote higher breastfeeding in the US (Barraza et al., 2020; CDC, 2021). Support programs which focus on compensating for impacts of lower socioeconomic status, such as targeted educational programs, can help address

predictors of breastfeeding outcomes that fall further beyond the control of these birthing persons and their health care providers. Our research supports continued need for such support programs, as the clinical and sociodemographic factors they seek to intervene on are risk factors for poorer breastfeeding outcomes in our study.

Strengths of our study include its large size, prospective design, and extensive breastfeeding outcome data for birthing person–infant pairs living in rural New England, since rural populations are often underrepresented in research settings. This region is well-suited to investigate breastfeeding initiation and duration because breastfeeding rates are relatively high compared to average rates in the US (CDC, 2022). The consistency we observed between important predictors of breastfeeding initiation and duration in our rural cohort compared with previous studies in the general US population (Stough et al., 2019) and a rural Australian cohort (Cox et al., 2015) suggest that factors influencing breastfeeding outcomes are not specific to rural regions, though we did not explicitly test this hypothesis in our study. Our cohort included individuals with private water systems so it tended to over-represent those living in individual homes or small communities and approximately 30% of birthing persons in our study had not earned a college degree. Our findings are potentially limited in their generalizability since our cohort is predominantly comprised of birthing persons identifying as non-Hispanic White, though this is true for the majority of rural America. Further research is needed to expand knowledge of breastfeeding outcomes among birthing persons living in poor, non-White, rural areas of the US. When characterizing exclusive breastfeeding, we used the WHO definition in which supplementation of non-breastmilk foods or liquids, including water, was classified as the end exclusive breastfeeding (WHO, 2019). While this is a strength of our study because it most closely reflects health-based guidelines, our findings may not be directly comparable to other studies which apply a more lenient definition of exclusive breastfeeding. Misclassification of breastfeeding outcomes may have occurred if a birthing person in our study exclusively fed their infant manually-expressed breastmilk and did not consider this to be a form of breastfeeding when providing information about infant feeding via the first postpartum study questionnaire. Because breastfeeding initiation is high (96%) in our cohort and follow-up postpartum questionnaires specifically ask about breastfeeding defined as either direct feeding or using expressed milk, we believe that such misclassification is rare in our study.

## Conclusions

In a rural pregnancy cohort from northern New England, like in many regions of the US, we found breastfeeding initiation was high, but the percentages of birthing

persons meeting health-based guidelines for exclusive and any breastfeeding duration were low. Metrics of higher socioeconomic status and good birthing person health were positively associated with breastfeeding initiation and duration, whereas measures of poor health and cesarean delivery negatively predicted breastfeeding outcomes. Collectively, this and prior research inform interventions such as support programs targeted at individuals at risk of poorer breastfeeding outcomes, to improve breastfeeding and, thus, birthing person and child health across the life course.

**Author Contributions** All authors provided critical review and feedback of the manuscript. KAC conducted all analyses and drafted the manuscript. LGG assisted with data management and provided technical expertise to inform the statistical analyses. ERB provided technical review on pregnancy and breastfeeding concepts. MRK developed and oversees the NHBCS, contributed to study design and provided technical review of the analysis and manuscript. MER was responsible for study design, provided technical review of all analyses, and contributed to manuscript preparation.

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**Data Availability** Investigators interested in additional information about this study are referred to the New Hampshire Birth Cohort Study website. For other questions, investigators should contact Margaret Karagas, PhD (margaret.r.karagas@dartmouth.edu).

**Code Availability** Not applicable.

## Declarations

**Conflicts of interest** The authors have no conflicts of interest or relevant financial or non-financial interests to disclose.

**Ethics Approval** Approval for this study was granted by the Institutional Review Board (IRB) at Dartmouth College. Participants provided written, informed consent via IRB-approved consent protocols.

**Consent to Participate** Not applicable.

**Consent for Publication** Not applicable.

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