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Original article

Short interpregnancy intervals and adverse pregnancy outcomes by maternal age in the United States

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ABSTRACT

Purpose: The purpose of the article was to examine the association between short interpregnancy intervals and adverse outcomes by maternal age among U.S. women.
Methods: Using publicly available natality files for 2013–2016 singleton births, we compared the risks of preterm birth, gestational diabetes, gestational hypertension, and maternal morbidity (delivery-related complications) for less than 6-month, 6 to 11-month, and 12 to 17-month to 18- to 23-month interpregnancy intervals, overall and by maternal age. Models adjusted for maternal demographics, conditions, and behaviors.
Results: Among 2,365,219 births, adjusted risk ratios (aRR) for preterm birth overall for intervals less than 6, 6–11, and 12–17 months were 1.62 (95% confidence interval: 1.60, 1.65), 1.16 (1.15, 1.18), and 1.03 (1.02, 1.05), respectively, compared with 18–23 months. Intervals less than 6, 6–11, and 12–17 months were significantly protective overall for gestational diabetes (aRR range: 0.89–0.98), gestational hypertension (aRR range: 0.93–0.95), and maternal morbidity (aRR range: 0.93–1.08). All aRRs attenuated or remained flat with increasing maternal age.
Conclusion: Interpregnancy intervals less than 18 months showed different patterns of association for preterm birth compared with maternal outcomes, overall and across age. This suggests that increasing maternal age may have discordant effects on associations between short interpregnancy interval and adverse perinatal and maternal outcomes.

Introduction

The World Health Organization recommends waiting at least 18–24 months after a live birth before conceiving again to reduce the risk of adverse maternal, perinatal, and infant outcomes[1]. This recommendation stems from a wealth of studies focused on interpregnancy intervals (IPI) and adverse pregnancy outcomes [1–5], and a few studies focused on IPIs and maternal morbidity [2–5].

Average age at first childbirth is increasing in the United States [6], raising concerns that meeting the World Health Organization recommendation may lead to increased maternal morbidity and even adverse pregnancy outcomes, such as preterm birth, as mothers give birth to subsequent children at older ages [7,8]. Indeed, two recent studies have found that IPI and older maternal age were independent risk factors for adverse perinatal outcomes [9,10].

Similar analyses using data from the United States recently became possible when IPI information was released nationally as part of the 2003 revision of the standard birth certificate. In this study, we aimed to estimate the associations between short IPIs and select adverse pregnancy outcomes, including preterm birth, gestational diabetes, gestational hypertension, and maternal morbidity—all causes of infant mortality and morbidity.

Materials and methods

Data source and study population

We used publically available birth certificate data from states and the District of Columbia that had implemented the U.S. 2003 Standard Certificate of Live Birth by 2013 (41 states), 2014 (47

Disclaimer: The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the US Office of Population Affairs.

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states), 2015 (48 states), or 2016 (50 states) [11–14]. These states represented at least 90% of all live births in the United States during 2013–2016. U.S. natality files include information on maternal demographics, maternal and infant clinical characteristics, and pregnancy outcomes. This study was exempt from institutional review board approval as it used secondary analysis of pre-existing publicly available deidentified data.

We examined four main outcomes: preterm birth, gestational diabetes, gestational hypertension, and maternal morbidity. Our main exposure of interest was IPI. For the purpose of this analysis, the "subsequent" birth or pregnancy refers to the birth associated with the birth certificate record, and the "index birth" refers to the mother's previous live birth.

Outcome: preterm birth at the subsequent delivery

Consistent with the *International Classification of Diseases, Ninth Revision and International Classification of Diseases, 10th Revision,* definitions, we defined preterm birth as delivery before the 37th completed week of pregnancy [15], using the obstetric estimate of gestational age [16]. In 2014, the National Center for Health Statistics (NCHS) transitioned to using this as the standard, primary measure of gestational age; this estimate was also available in national data before 2014 (e.g., available for 90% of 2013 births) [16]. The prevalence of preterm birth by maternal age can be found in Appendix Table 1A.

Outcome: maternal morbidity in the subsequent pregnancy

From information available on the birth certificate, we examined three separate maternal outcomes: (1) gestational diabetes (diagnosis during pregnancy of glucose intolerance requiring treatment); (2) gestational hypertension (diagnosis during pregnancy of elevation of blood pressure above normal for age, sex, and physiological condition); and (3) maternal morbidity at the time of delivery hospitalization. The birth attendant entered information on these maternal morbidity outcomes using the delivery record, physician delivery or operative notes, and hospital intake and output forms. Our measure of maternal morbidity included at least one of the following documented events: maternal transfusion (infusion of whole blood or packed red blood cells associated with labor and delivery), perineal laceration (laceration through the perineal skin, vaginal mucosa, perineal body, and partially or completely through the anal sphincter, and/or through the rectal mucosa), ruptured uterus (tearing of the uterine wall), unplanned hysterectomy (surgical removal of the uterus that was not planned before admission), or admission to intensive care (any admission, planned or unplanned of the mother to an intensive care facility) [17]. For 2013 births, we used individual checkbox items from the birth certificate to create a composite maternal morbidity variable indicating whether at least one of these five events was recorded. For 2014–2016 births, we used a composite maternal morbidity variable created by the NCHS based on those five items [11–13]. The prevalence of each outcome by maternal age can be found in Appendix Table 1A.

Exposure: IPI

We examined the IPI, defined as the time between the index live birth and conception of the pregnancy leading to the subsequent live birth. IPI was determined by subtracting gestational age from months since last live birth, a recoded variable calculated by the NCHS.

Covariates

We defined maternal age as the mother's age at the index birth because this is when interventions regarding birth spacing would ideally be administered. To calculate maternal age at the index birth, we converted single-year maternal age from the birth certificate to months, added a random number of weeks to account for variability within year of age (0–52, uniform distribution) and subtracted the months since last live birth. We then converted her age into years and rounded down to the nearest whole integer.

We included factors that represented conditions and behaviors during the IPI (such as prepregnancy smoking [at least one cigarette a day on average for the 3 months before pregnancy] and body mass index [kg/m^2]) as potential confounders because they might have influenced the length of IPI [18]. Although Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) use and month of entry into prenatal care were factors measured in the subsequent pregnancy, we considered them to be proxies for socioeconomic status preceding the IPI and included them as potential confounders. Other potential confounders reflect information available at the time of the subsequent birth: race and ethnicity, highest level or degree of school completed, marital status, total number of live births (including the subsequent birth), month of entry into prenatal care, and previous preterm birth [17].

Generally, we did not consider clinical conditions, characteristics, and outcomes of the subsequent pregnancy as potential confounders because they could have been caused by the length of the preceding IPI, and adjusting for them could have introduced bias [19]. Examples of these factors include smoking during pregnancy, infections during pregnancy, birthweight, infant sex, and cesarean delivery.

Study restrictions

We sought to minimize residual and unknown confounding by including only singleton live births of at least 21 weeks' gestation to U.S. resident women whose last pregnancy ended in a live birth (Fig. 1). First-order births or those missing IPI data were excluded because they do not provide information on IPI. Observations with implausible gestational age and/or IPI were also excluded (e.g., a live birth of less than 21 weeks' gestation or an interval between deliveries that was shorter than the gestational age of the subsequent pregnancy). As we were interested in the association between IPIs shorter than the recommended 18–24 months and adverse pregnancy outcomes, we excluded IPIs longer than 24 months. As a result, the distribution of IPI across age represents the women in our analytic sample, not all women with second-order and higher births in the United States.

Descriptive analysis methods

We examined demographic and clinical characteristics of births, stratifying by quartile of maternal age at the time of last birth. Short IPI was categorized as less than 6, 6–11, 12–17, whereas 18–23 months served as the reference level, based on literature indicating that births among women with this IPI have the lowest risk of adverse pregnancy outcomes [2,8,20].

Modeling methods

We used modified Poisson regression modeling to estimate risk ratios because odds ratios derived from more commonly used logistic regression models could have overestimated the risk ratios, given that preterm birth was not a rare event [21]. Unadjusted modified Poisson regressions estimated the overall association

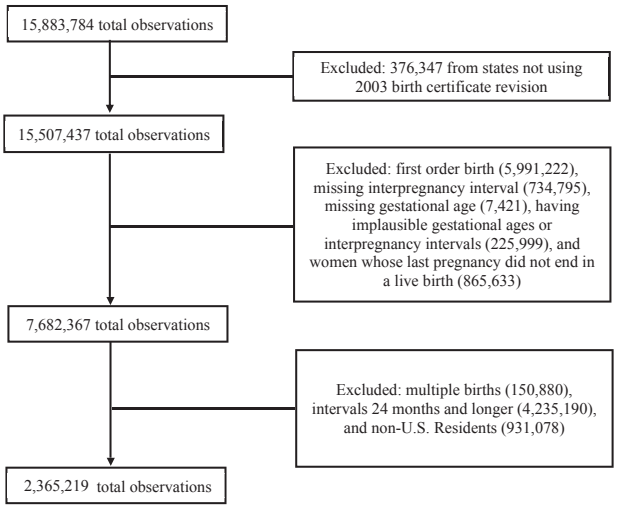

Fig. 1. Exclusion criteria for sample.

between IPI and the adverse pregnancy outcomes of preterm birth, gestational diabetes, gestational hypertension, and maternal morbidity separately, as well as these associations after stratifying by single year of maternal age. All adjusted models included the following maternal covariates: race, education, marital status, receipt of food from WIC for herself during pregnancy, prepregnancy smoking status, live birth order, month of entry into prenatal care, and prepregnancy body mass index category. Preterm birth-adjusted models also included history of preterm birth, as this could affect both length of IPI and outcome of preterm birth. Overall adjusted models also included the terms age and age-squared to account for nonlinear (i.e., J-shaped or U-shaped) associations between age and adverse outcomes.

To estimate trends across maternal age, we added an interaction term between IPI and age to the overall adjusted Poisson models and obtained linear trend *P* values. Predicted adjusted risk ratios (aRR) for preterm birth and maternal outcomes were also estimated from these models, separately. Nonlinear trends across age were assessed by adding an interaction term between IPI and age-squared. We compared the results of these overall adjusted models with a generalized additive model with age as a spline variable [22].

Software

We used SAS statistical software to conduct all analyses (Version 9.4. Cary, NC: SAS Institute Inc; 2014).

Results

This analysis included 2,365,219 nonfirstborn singleton live births during 2013–2016 to U.S. resident women whose IPI was less than 24 months.

Demographic and clinical characteristics of births were associated with maternal age group. The youngest mothers at index birth had the largest proportions of non-Hispanic black and Hispanic women and higher proportions of women who were unmarried, had less than a high school education, received food from WIC, smoked prepregnancy, and were delivering their second live birth (Table 1). The proportion of women with these characteristics decreased with increasing maternal age at index birth.

The distribution of IPI and subsequent preterm birth and maternal morbidity also varied across maternal age. The youngest mothers at the index birth had the shortest IPI, the highest prevalence of preterm birth and the lowest prevalence of gestational diabetes, gestational hypertension, and maternal morbidity (Table 2). Mothers aged 27–30 years at the index birth had the lowest prevalence of preterm birth, whereas those aged 31–49 years at the index birth had the highest prevalence of gestational diabetes, gestational hypertension, and maternal morbidity.

Preterm birth risk varied by IPI in both unadjusted (Appendix Table 2A) and adjusted analyses (Fig. 2; Appendix Table 3A); however, adjusted models resulted in more attenuated estimates. Compared with an IPI of 18–23 months, an IPI less than 6-month aRR of preterm birth was 1.62 (95% confidence interval [CI], 1.60–1.65). For an IPI of 6–11 months, the aRR was 1.16 (95% CI, 1.15–1.18), and an IPI of 12–17 months had an aRR of 1.03 (95% CI, 1.02–1.05; Appendix Tables 2A and 3A). For each level of IPI, there was a decreasing linear trend in preterm birth across maternal age: less than 6 ($P < .01$), 6–11 ($P < .01$), and 12–17 ($P < .01$) compared with 18–23 months (Fig. 2). No significant quadratic trends were found for IPI less than 6 ($P = .10$), 6–11 ($P = .62$), or 12–17 months ($P = .13$).

Gestational diabetes risk varied by IPI in both unadjusted and adjusted analyses (Fig. 3A; Appendix Tables 4A and 5A); as with preterm birth, adjusted models resulted in more attenuated estimates compared with those from unadjusted models. Compared with an IPI of 18–23 months, shorter IPIs showed slight protective associations for the risk of gestational diabetes, less than 6 months' intervals (aRR: 0.89; 95% CI, 0.87–0.90), intervals of 6–11 months (aRR: 0.92; 95% CI, 0.90–0.93), and intervals of 12–17 months (aRR: 0.98; 95% CI, 0.96–0.99). For IPIs less than 6-month ($P < .01$), 6- to 11-month ($P < .01$), and 12- to 17-month ($P < .01$) intervals, there were increasing linear trends in gestational diabetes across maternal age, which led to attenuations of the association (Fig. 3A). No significant quadratic trends were found for IPI less than 6 ($P = .91$), 6–11 ($P = .17$), or 12–17 months ($P = .41$).

Gestational hypertension risk varied by IPI in both unadjusted and adjusted analyses (Fig. 3B; Appendix Tables 6A and 7A). Compared with an IPI of 18–23 months, shorter IPIs showed near-null, but still significant protective associations less than 6 (aRR: 0.95; 95% CI, 0.93–0.98), 6–11 (aRR: 0.93; 95% CI, 0.91–0.95), and 12–17 (aRR: 0.95; 95% CI, 0.94–0.97). Adjusted models resulted in more attenuated estimates compared with those from unadjusted models (Appendix Tables 6A and 7A). For IPIs less than 6 ($P < .01$) and 6–11 ($P < .01$) months, there was an increasing linear trend in maternal morbidity across maternal age, which led to attenuation and even slightly increased risk of gestational hypertension for older ages; no linear trends were found for IPI 12–17 months ($P = .39$; Fig. 3B). No significant quadratic trends were found for IPI less than 6 ($P = .70$), 6–11 ($P = .66$), or 12–17 months ($P = .16$).

Our measure of maternal morbidity risk also varied by IPI in both unadjusted and adjusted analyses (Fig. 3C; Appendix Tables 8A and 9A). Compared with an IPI of 18–23 months, less than 6 months showed an aRR of 1.08 (95% CI, 1.03–1.14); however, IPI of 6–11 months had an aRR of 0.93 (95% CI, 0.89–0.97), and IPI of 12–17 months had an aRR of 0.95 (95% CI, 0.91–0.99). For IPIs 12–17 months ($P < .01$), there was a decreasing linear trend in maternal morbidity across maternal age, which led to more protective estimates in older maternal ages; no linear trends were found for IPI less than 6 ($P = .88$) or 6–11 months ($P = .21$; Fig. 3C). However, a significant quadratic trend was found for IPI 6–11 months ($P = .03$), suggesting an increase in risk of maternal morbidity with IPI 6–11 months for women aged 35 years and older; no quadratic trends were found for IPI less than 6 ($P = .17$) and 12–17 ($P = .99$; Fig. 3C).

In overall adjusted models, maternal age was associated with each outcome and model fit of the generalized additive model

Table 1
Characteristics of the study population by maternal age at index birth, nonfirstborn singleton births in the United States 2013–2016 (N = 2,365,219)

Characteristics	Age 11–22 y (N = 635,156)		Age 23–26 y (N = 566,021)		Age 27–30 y (N = 589,890)		Age 31–49 y (N = 574,152)	
	N	*n* (%)	*N*	*n* (%)	*N*	*n* (%)	*N*	*n* (%)
Maternal race/ethnicity								
Non-Hispanic White	631,928	241,916 (38.3)	562,244	287,882 (51.2)	585,371	352,470 (60.2)	567,769	331,849 (58.5)
Non-Hispanic Black		144,009 (22.8)		91,214 (16.2)		63,666 (10.9)		58,080 (10.2)
Hispanic*		209,135 (33.1)		140,165 (24.9)		114,797 (19.6)		64,587 (11.4)
Other†		36,868 (5.8)		42,983 (7.6)		54,438 (9.3)		113,253 (20.0)
Marital status								
Married	635,156	212,709 (33.5)	566,021	348,642 (61.6)	589,890	465,177 (78.9)	574,152	475,013 (82.7)
Unmarried		422,447 (66.5)		217,379 (38.4)		124,713 (21.1)		99,139 (17.3)
Maternal education								
≤High school	328,949	628,949 (74.1)	559,916	259,186 (46.3)	583,180	583,180 (28.0)	565,464	138,073 (24.4)
Some college		131,297 (20.9)		138,509 (24.7)		101,913 (17.5)		79,451 (14.1)
College degree		30,689 (4.9)		141,980 (25.4)		222,938 (38.2)		209,925 (37.1)
Postgraduate degree		1008 (0.2)		20,241 (3.6)		94,966 (16.3)		138,015 (24.4)
WIC receipt‡								
Yes	625,344	420,665 (67.3)	556,476	272,701 (49.0)	579,837	184,627 (31.8)	564,375	155,088 (27.5)
No		204,679 (32.7)		283,775 (51.0)		395,210 (68.2)		409,287 (72.5)
Prepregnancy body mass index‖								
Underweight	613,940	30,864 (5.0)	548,343	19,705 (3.6)	571,420	17,055 (3.0)	554,152	13,639 (2.5)
Normal		263,259 (42.9)		234,394 (42.8)		273,243 (47.8)		262,603 (47.4)
Overweight		156,770 (25.5)		142,537 (26.0)		146,461 (25.6)		145,827 (26.3)
Obese		135,799 (22.1)		122,799 (22.4)		110,771 (19.4)		109,593 (19.8)
Morbidly obese		27,248 (4.4)		28,908 (5.3)		23,890 (4.2)		22,490 (4.1)
Prepregnancy smoking¶								
Smoker	622,225	90,780 (14.6)	555,354	59,301 (10.7)	579,508	35,293 (6.1)	564,710	24,611 (4.4)
Nonsmoker		531,445 (85.4)		496,053 (89.3)		544,215 (93.9)		540,099 (95.6)
Live birth order								
Second live birth	633,796	404,777 (63.9)	564,797	262,135 (46.4)	588,763	293,100 (49.8)	573,036	257,476 (44.9)
Third live birth		164,162 (25.9)		163,750 (29.0)		143,147 (24.3)		131,035 (22.9)
Fourth live birth		49,419 (7.8)		85,995 (15.2)		80,253 (13.6)		78,295 (13.7)
Fifth live birth or higher		15,438 (2.4)		52,917 (9.4)		72,263 (12.3)		106,230 (18.5)
Month of entry into prenatal care								
First to third	635,156	365,305 (57.5)	566,021	381,243 (67.4)	589,890	443,152 (75.1)	574,152	439,979 (76.6)
Fourth to sixth		175,481 (27.6)		123,177 (21.8)		97,659 (16.6)		89,047 (15.5)
>Sixth		74,035 (11.7)		49,040 (8.7)		39,952 (6.8)		37,029 (6.5)
No prenatal care		20,335 (3.2)		12,561 (2.2)		9127 (1.6)		8097 (1.4)
Previous preterm birth§								
Yes	634,267	28,386 (4.5)	565,351	26,253 (4.6)	589,370	25,257 (4.3)	573,668	26,616 (4.6)
No		605,881 (95.5)		539,098 (95.4)		564,113 (95.7)		547,052 (95.4)

* Includes all persons of Hispanic origin of any race.
† Includes all non-Hispanic Asian, American Indian, Alaskan Native, Native Hawaiian, and Other Pacific Islander.
‡ WIC, the Special Supplemental Nutrition Program for Women, Infants, and Children.
§ Previous preterm birth was defined as a previous infant born at <37 completed gestational weeks.
‖ Prepregnancy body mass index, categories defined by the National Heart, Lung, and Blood Institute.
¶ Mothers who smoked, on average, at least one cigarette daily for the 3 months before pregnancy began.

models with age as a spline variable was comparable to the Poisson models (data not shown).

Comment

We aimed to estimate the associations between short IPIs and select adverse pregnancy outcomes for U.S. women and how these associations varied across maternal age. We found that preterm birth risks were higher with shorter IPI compared with IPI of 18–23 months, but these associations decreased with increasing maternal age. Conversely, short IPIs were associated with slightly lower risks of gestational diabetes and gestational hypertension, and these associations showed, generally, attenuating trends across maternal age. Very short IPIs (<6 months) were associated with a slightly higher risk for our measure of maternal morbidity, and this effect appeared to be constant across maternal age; other IPIs less than 18 months showed slight protective effects, with both increasing and decreasing trends across age. Overall, our findings suggest that family planning interventions may need to take into account maternal age when considering how birth spacing may affect subsequent pregnancy outcomes.

Our findings regarding preterm birth are consistent with previous research that has found short IPIs (<18 months) are associated with a higher risk of preterm birth [20,23]. In contrast, our findings differed from those of Hanley et al., who used a case-crossover analysis of maternally linked births in British Columbia [24]. The authors concluded that previous evidence for increased association between short IPI and preterm birth was the result of residual confounding. However, other case-crossover studies of maternally linked data have reported increased risk of preterm birth for IPIs shorter than 18–23 months [4,25]. In addition, although case-crossover studies allow for better control of characteristics that vary between women, these studies are based on women with at least three births who have discordant outcomes between the second and third birth, which can result in limited generalizability and even induce bias [26,27].

In addition, our findings agree with studies that have found the association between IPI and preterm birth attenuates with maternal age. A recent Canadian cohort study by Schummers et al. found the risk of spontaneous preterm delivery to be increased with IPIs of 3, 6, 9, and 12 versus 18 months for women aged

Table 2
Prevalence of exposure and outcomes for the study population by maternal age at index birth, nonfirstborn singleton births in the United States 2013–2016 ($N = 2,365,219$)

Characteristics	Age 11–22 y ($N = 635,156$)		Age 23–26 y ($N = 566,021$		Age 27–30 y ($N = 589,890$)		Age 31–49 y ($N = 574,152$)	
	N	*n* (%)	*N*	*n* (%)	*N*	*n* (%)	*N*	*n* (%)
Interpregnancy interval (mo)*								
<6	635,156	119,148 (18.8)	566,021	83,875 (14.8)	589,890	61,174 (10.4)	574,152	56,635 (9.9)
6–11		181,520 (28.6)		158,529 (28.0)		151,513 (25.7)		153,996 (26.8)
12–17		180,375 (28.45)		175,926 (31.1)		204,115 (34.6)		202,625 (35.3)
18–23		154,113 (24.3)		147,691 (26.1)		173,088 (29.3)		160,896 (28.0)
Preterm birth†								
Yes	635,156	53,414 (8.4)	566,021	39,575 (7.0)	589,890	34,890 (5.9)	574,152	38,240 (6.7)
No		581,742 (91.6)		526,446 (93.0)		555,000 (94.1)		535,912 (93.3)
Gestational diabetes‡								
Yes	634,267	15,379 (2.4)	565,351	22,492 (4.0)	589,370	30,587 (5.2)	573,668	43,076 (7.5)
No		618,888 (97.6)		542,859 (96.0)		558,783 (94.8)		530,592 (92.5)
Gestational hypertension§								
Yes	634,267	17,122 (2.7)	565,351	18,008 (3.2)	589,370	18,911 (3.2)	573,668	21,129 (3.7)
No		617,145 (97.3)		547,343 (96.8)		570,459 (96.8)		552,539 (96.3)
Maternal morbidity‖								
Yes	634,159	3698 (0.6)	565,246	3839 (0.7)	589,101	4439 (0.8)	573,222	4374 (0.8)
No		630,461 (99.4)		561,407 (99.3)		584 (99.3)		568,848 (99.2)

* Interpregnancy interval was the number of months between index live birth and conception of subsequent pregnancy.
† Preterm birth was defined as infants born at <37 completed gestational weeks. $n = 2,365,219$ observations available for analysis.
‡ Includes pregnancy-induced diabetes. $n = 2,362,656$ observations available for analysis.
§ Includes pregnancy-induced hypertension. $n = 2,362,656$ available for analysis.
‖ Includes any combination of maternal transfusion, perineal lacerations, ruptured uterus, unplanned hysterectomy, and admission to intensive care.

20–34 years and of a smaller magnitude and for women aged 35 years and older (no significant differences were found for indicated preterm delivery [39% of all preterm births in the study] by age) [28]. Another study of births, among Dutch women during 2000–2007, found significant linear decreasing trends for preterm birth with increasing maternal age for IPIs less than 6 and 6–11 versus 18–23 months [9]. However, variation across age was not noted in a study of IPI and preterm birth among three U.S. pregnancy cohorts [20], and a previous study using Missouri maternally linked files from 1978 to 1997 also found that the association between IPI less than 6 months and preterm birth was not significantly different between mothers aged 35 years and older versus younger mothers [10].

The Schummers et al.'s study also assessed the risk of maternal mortality and severe morbidity by IPI and maternal age. They found increased risks of these outcomes for women aged 35 years and older for IPIs of 3, 6, 9, and 12 versus 18 months, but null or protective associations for women aged 20–34 years [28].

These results do not agree with our study, which found IPI less than 6 versus 18–23 months to be associated with a slightly increased risk of maternal morbidity, and this did not vary by age; further for IPI of 12–17 months, we found the association appeared to be decreased for older women. However, we did find that IPI of 6–11 versus 18–23 months showed an increasing quadratic trend across age, showing higher risk of maternal morbidity for women aged 35 years and older. Discrepancies between our study findings be due to differences in how maternal morbidity outcomes were defined and study design between the studies in addition to the relatively small number of these events in each study. Our study used items from the U.S. birth certificate to define maternal morbidity at the time of delivery hospitalization, which has been found to have low sensitivity for individual items when compared with hospital discharge records [29] and would not capture severe outcomes postpartum. Notably, both Schummers et al.'s and our study defined maternal age using the mother's age at her last live birth,

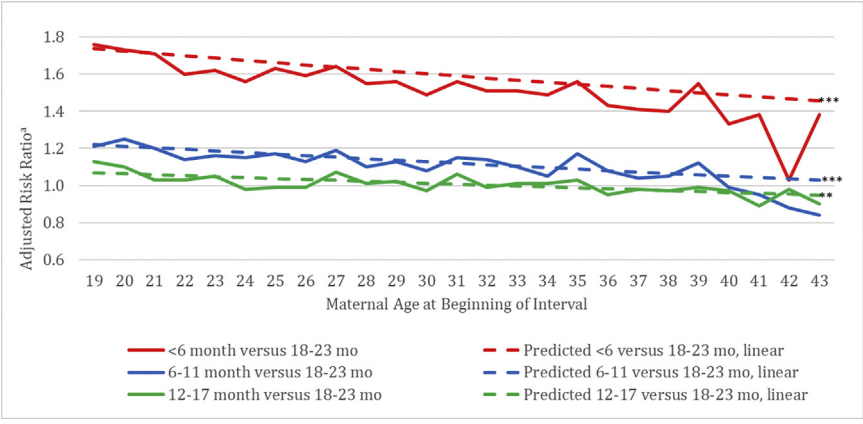

Fig. 2. Preterm birth and interpregnancy interval by maternal age, [a]adjusted risk ratio: a display comparing the adjusted risk ratios for preterm birth for each short interpregnancy interval compared with the reference group, 18–23 months, by single year of maternal age. [a]Adjusted for race, highest level of education, marital status, WIC receipt, previous preterm birth, prepregnancy smoking status, live birth order, month of entry into prenatal care, and prepregnancy body mass index. ***$P < 0.0001$; **$P < 0.01$; *$P < 0.05$.

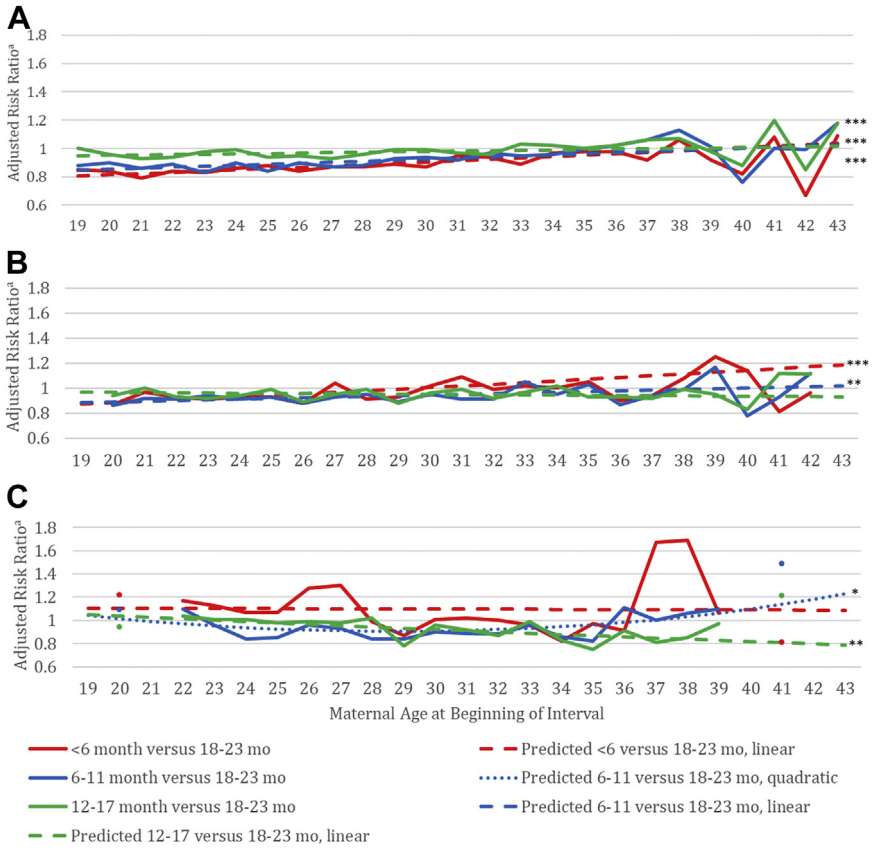

Fig. 3. Maternal morbidity and interpregnancy interval by maternal age, [a]adjusted risk ratio: a display comparing the adjusted risk ratios for (A) gestational diabetes, (B) gestational hypertension, and (C) maternal morbidity for each short interpregnancy interval compared with the reference group, 18–23 months, by single year of maternal age. [a]Adjusted for race, highest level of education, marital status, WIC receipt, prepregnancy smoking status, live birth order, month of entry into prenatal care, and prepregnancy body mass index. ***<0.0001; ** < 0.01; *<0.05.

suggesting increased analytic attention to the sequence of interpregnancy events.

The association of IPI with other maternal morbidity outcomes has not been widely studied, and many published studies are based on small sample sizes and are of suboptimal design [5]. Some studies have found significant adverse associations between long IPI (>59 months) and maternal morbidity (such as preeclampsia and labor dystocia), but little evidence exists for an association, adverse or protective, between short IPIs and maternal morbidity [5,30–32]. The recent study by Hanley et al. found that shorter IPIs were protective against preeclampsia but increased a woman's risk of gestational diabetes [24]. Our study differs from prior work because we examined maternal age at index birth. This could have contributed to the protective effect we found of short IPI on risk of gestational diabetes and gestational hypertension because mothers of the same age at their index delivery who have shorter intervals are younger at their subsequent delivery than are mothers with longer intervals, conferring lower risk for many adverse outcomes [33,34].

Our study is subject to limitations. First, analysis was restricted to the subset of states that had implemented the revised birth certificate; however, this included more than 90% of otherwise study eligible U.S. births in 2013–2016. Second, we could not control for obstetric complications during the previous pregnancy or actions, such as breastfeeding or intention to conceive, which occurred during the IPI. The lack of information on breastfeeding may have biased our findings as breastfeeding is an important determinant of IPI and varies by age [35]; but the association between breastfeeding and subsequent pregnancy outcomes has not been established, suggesting it is not a confounder. We attempted to reduce confounding by controlling for history of preterm birth (in the preterm birth models) and to reduce potential misclassification of interval length by restricting the study to women whose last pregnancy ended in a live birth. These exclusions, therefore, limited the generalizability of our results. Third, there is a potential for residual confounding from variables not available on birth certificate data, such as family income. Fourth, maternal morbidity variables were not reviewed for accuracy, potentially resulting in an underestimate of true maternal morbidity, particularly for our maternal morbidity measures [29,36]. Fifth, we were not able to control for consecutive births to the same gravida, so the observations are not entirely independent. Finally, as with all studies with large sample sizes, some statistically significant results may not necessarily be clinically meaningful.

As the average age of first-time mothers has risen over the past 40 years [6,37] and older mothers' plan for subsequent births, our findings suggest that further research is necessary to develop specific guidelines regarding recommended length of IPI by maternal age. Examining how these associations vary across maternal age can help inform how to tailor counseling on optimal birth spacing given the mother's age at her last birth.

Supplementary Data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.annepidem.2018.12.002.

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