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Risk factors and child outcomes associated with short and long interpregnancy intervals

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Abstract

Previous research assessing consequences of interpregnancy intervals (IPIs) on child development is mixed. Utilizing a population-based US sample (n=5,339), we first estimated the associations between background characteristics (e.g., sociodemographic and maternal characteristics) and short (≤ 1 year) and long (> 3 years) IPI. Then, we estimated associations between IPI and birth outcomes, infant temperament, cognitive ability, and externalizing symptoms. Several background characteristics, such as maternal age at childbearing and previous pregnancy loss, were associated with IPI, indicating research on the putative effects of IPI must account for background characteristics. After covariate adjustment, short IPI was associated with poorer fetal growth and long IPI was associated with lower infant activity level; however, associations between short and long IPI and the other outcomes were neither large nor statistically significant. These findings indicate that rather than intervening to modify IPI, at-risk families may benefit from interventions aimed at other modifiable risk factors.

Keywords

Interpregnancy interval; birth spacing; birth outcomes; infant temperament; childhood cognitive ability; childhood externalizing symptoms

Introduction

Interpregnancy interval (IPI) is the duration between the birth of a previous child and the conception of the focal child. Previous studies have found both short and long IPIs are associated with a range of adverse child outcomes, including adverse birth outcomes (e.g.,

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preterm birth and low birth weight; Class et al., 2018; Conde-Agudelo, Rosas-Bermudez, & Kafury-Goeta, 2006; Janša et al., 2018; Koullali et al., 2017; Schummers et al., 2018; Shachar et al., 2016), psychiatric problems (e.g. autism spectrum disorder and schizophrenia; Cheslack-Postava, Liu, & Bearman, 2011; Cheslack-Postava et al., 2014; Gunawardana et al., 2011; Gunnes et al., 2013; Risch et al., 2014; Smits, Pedersen, Mortensen, & van Os, 2004), and reduced cognitive ability (Class et al., 2018; Crowne, Gonsalves, Burrell, McFarlane, & Duggan, 2012; Hayes, Luchok, Martin, McKeown, & Evans, 2006).

Specific mechanisms of action could explain how short and long IPI could influence child development. Potential mechanisms of actions for short IPI include conditions that could negatively affect the intrauterine environment, such as inadequate maternal physiological recovery from the previous pregnancy (Miller, 1991), maternal folate or nutritional depletion (Conde-Agudelo, Rosas-Bermudez, Castano, & Norton, 2012), changes in composition of a woman's vaginal microbiota that occur after delivery and remain for up to a year that make the vaginal microbiota similar to gut microbiota (Jacob, 2015), and transmission of infections between siblings (Conde-Agudelo et al., 2012). Other potential mechanism specifically for associations between short IPI and longer-term outcomes are adverse birth outcomes (Conde-Agudelo et al., 2006), sibling competition (Conde-Agudelo et al., 2012; Thoma et al., 2019), parental stress, and neglectful parenting practices (El-Kamary et al., 2004; Thoma et al., 2019). In regards to long IPI, failure to benefit from physiological adaptations from prior pregnancies could be mechanisms of action because pregnancy related physiological adaptations, such as increased uterine blood flow, may not carry over from previous pregnancies in multiparous women with long IPIs (Zhu, Rolfs, Nangle, & Horan, 1999). Moreover, more proximal child outcomes, such as adverse birth outcomes, could also explain how long IPI could impact longer-term outcomes (Conde-Agudelo et al., 2006).

Based on the assumption that IPI causes adverse child outcomes researchers and policy groups recommend an IPI longer than 18 months (Conde-Agudelo et al., 2006) or 24 (Marston, 2006) and shorter than 59 months (Conde-Agudelo et al., 2006). In order to promote healthy IPIs and prevent negative outcomes in children, the National Institute of Health also recently released a call for research to identify causal social and behavioral mechanisms for associations with IPI that can be targeted with public health interventions (National Institute of Child Health and Human Development, 2019).

However, associations with IPI may not be due to causal processes. Some researchers have suggested that the associations between IPI and child development may be due to risk factors associated with short and long IPIs rather than a casual effect of IPI itself (Klebanoff, 2017). Several studies have compared risk for adverse outcomes among children born in the same family (e.g., siblings) to account for genetic and environmental risk factors shared by children in the same family (Ball, Pereira, Jacoby, de Klerk, & Stanley, 2014; Class et al., 2018; Class et al., 2017; Hanley, Hutcheon, Kinniburgh, & Lee, 2017). Studies have also tested the influence of familial risk factors by assessing associations with post-birth intervals because similar associations with post-birth intervals as with IPI would be inconsistent with a causal influence of IPI (Class et al., 2018; Class et al., 2017; Erickson & Bjerkedal, 1978).

These studies suggest that IPI, particularly short, IPI may not increase the risk of adverse birth outcomes, such as preterm birth and reduced fetal growth (Ball et al., 2014; Class et al., 2017; Erickson & Bjerkedal, 1978; Hanley et al., 2017), as well as later childhood problems, such as attention deficit/hyperactivity disorder and lower school grades (Class et al., 2018). Nonetheless, given that findings have been mixed, major reviews and funding agencies have recently called for more research on IPI, particularly research that controls for potential confounding factors (Ahrens, Hutcheon, et al., 2019; Ahrens, Nelson, Stidd, Moskosky, & Hutcheon, 2019; Hutcheon et al., 2019).

Therefore, due to the state of the current research, there were two primary purpose of the present study, which reports the results of analyses from a population-based sample of families in the United States with measures of multiple childhood traits. First, because family factors may account for associations between IPI and child outcomes, we assessed associations between several background characteristics and short (≤ 1 year) and long (> 3 years) IPI. Second, we adjusted for these background characteristics when estimating associations between short and long IPI, and a range of child outcomes, including birth outcomes, temperament, cognitive ability, and externalizing problems. A previous study conducted by Buckles and Munnich (2012) used the same dataset as the present study and found that birth spacing was not related to math and reading standardized test scores. However, the present study explored a variety of additional outcomes and accounted for gestational age of the focal child when calculating IPI. Accounting for gestational age is important because gestational age has been consistently linked to child development even after accounting for genetic and environmental risk factors (e.g., D'Onofrio et al., 2013).

Methods

Sample

We used data from the National Longitudinal Survey of Youth 1979 (NLSY79) and the Children of the National Longitudinal Survey of Youth (CNLSY; Bureau of Labor Statistics, 2012). Data collection for the NLSY79 began in 1979. Male and female participants between 14 and 22 years were selected for the NLSY79 sample using a stratified and clustered household probability sampling approach. The NLSY79 sample included a nationally representative sample of 6,111 individuals and an over-sample of 3,652 Hispanic and African American individuals. From 1979 to 1994, NLSY79 assessments occurred annually. Following 1994, assessments occurred biennially. The first NLSY79 assessment had a response rate of 90%, and the retention rates for the first 16 waves were over 90%. Beginning in 1986, children of female NLSY79 participants were recruited to participate in biennial assessments. This sample of children from the female NLSY79 participants is referred to as the children of the NLSY79 (CNLSY). Ninety-five percent of families participated in the first CNLSY assessment; and, on average, 90% participated in subsequent waves.

From the original CNLSY sample of 11,512 children, we sequentially dropped children without siblings in the dataset (1,176); multiples (262); first born children (3,706); sixth- or later-born children (140); children with missing information on gestational age (878); and children with implausible gestational ages (i.e., less than 23 weeks; 1), birth weight (i.e.,

less than 300 grams; 6), and IPI (i.e., negative IPI; 4). Our final sample consisted of 5,339 children born between 1973 and 2008. The sample represents 83% of target second- through fifth-born children. We excluded first-born children because, by definition, IPI cannot be calculated for these children.

Measures

IPI—We defined IPI as the interval between the birth of the previous child and the conception of the focal child with focal children's conception dates defined as their birth dates minus their gestational ages (recorded in weeks and converted to days for the IPI calculation). We calculated IPI in days and then converted it to years represented to the nearest $1/100^{th}$ year. Short IPI was IPI of 1.00 year or less, and long IPI was IPI greater than 3.00 years. Therefore, the reference group included children with IPIs greater than 1.00 year and less than or equal to 3.00 years. We chose these IPI categories in order to have an adequate number of children in each category.

Background characteristics—Measured child characteristics included sex and birth order. Maternal characteristics included race/ethnicity (Hispanic, African American, or non-Hispanic White), age at focal child's birth (in years; categorized into < 20, 20 to 24, 25 to 29, 30 to 34, and 35+), education (years of schooling attained by 2012), IQ (measured with the Armed Forces Qualification Test in 1980; standardized with M=0, SD=1), depression (assessed with the Center for Epidemiological Studies-Depression scale in 1992; Randloff, 1977; standardized with M=0, SD=1), alcohol use and dependence symptoms (maternal-reported number of lifetime alcohol use and dependence symptoms by 1994), and delinquency (participation in 12 delinquent acts assessed with the Self-Reported Delinquency interview between the ages of 15 and 22 years; Elliott & Huizinga, 1983; standardized with M=0, SD=1).

Additional background characteristics included family income (reported by mothers at age 30 years; square root and standardized with M=0, SD=1), whether families included any half-siblings, and whether a miscarriage, stillbirth, or abortion occurred within the focal child's IPI.

Birth outcomes—Mothers reported birth weight (in grams) and gestational age (in weeks). We assessed associations with birth weight alone, as well as birth weight adjusted for gestational age to assess fetal growth. We also estimated associations with gestational age (in weeks) and preterm birth (defined as birth before 37 gestational weeks).

Infant temperament—Mothers reported on the following five dimensions of infant (birth to 23 months) temperament: activity level, predictability, fearfulness, positive affect, and fussiness. The items used to assess temperament were based on a subset of items from the Infant Behavior Questionnaire (IBQ; Rothbart, 1981). Each item was rated on a 5-point scale, ranging from "almost never" to "almost always." Consistent with previous studies (Ellingson, Goodnight, Van Hulle, Waldman, & D'Onofrio, 2014), the infant temperament measures were created by taking the mean of the items for each dimension and then standardizing (M=0, SD=1) the scores. Confirmatory factor analyses have shown

that the infant temperament items support the aforementioned five factors (Lahey et al., 2008). Cronbach's alpha coefficients for the raw temperament scales have been shown to be modest (activity=0.66; predictability=0.59; positive affectivity=0.71; fearfulness=0.61; fussiness=0.60; Lahey et al., 2008). See Lahey et al. (2008) for more details about these measures.

Cognitive ability—The Peabody Picture Vocabulary Test (PPVT; Dunn, 1981) was administered biennially from ages 4 to 12 years. The Digit Span subtest of the Wechsler Intelligence Scales for Children-Revised (WISC-R; Wechsler, 1974) and the Math, Reading, and Reading Recognition subtests of the Peabody Individual Achievement Test-Revised (PIAT-R; Dunn & Markwardt, 1970) were administered biennially from ages 7 to 12 years. For all cognitive ability measures, we created middle childhood cognitive measures (mean of 9 through 12-year scores) and standardized scores (M=0, SD=1).

Adequate psychometric properties have been demonstrated for the PPVT (Costello & Ali, 1971), Digit Span scale of the WISC-R (Irwin, 1966; Rosenthal, Riccio, Gsanger, & Jarratt, 2006), and PIAT-R (Costenbader & Adams, 1991). See Ellingson et al. (2014) for more details about these measures.

Externalizing symptoms—When children were between 4 and 9 years, mothers completed the Behavior Problem Index (BPI; Peterson & Zill, 1986) to assess symptoms of conduct problems (CP), oppositional defiant problems (ODP), and attention/deficit-hyperactivity problems (ADHP). CP items were cheats or lies, breaks things on purpose or deliberately destroys his/her own or another's things, disobedient at home, disobedient at school, has trouble getting along with teachers, does not feel sorry after misbehaving, and bullies other children. ODP items were argues too much, is stubborn, sullen or irritable, and has a very strong temper and loses it easily. ADHP items were has difficulty concentrating, impulsive or acts without thinking, and restless or overly active. Mothers rated behaviors on a three-point scale, where "3" indicated "often true," "2" indicated "sometimes true," and "1" indicated "not true." Consistent with previous studies (e.g., D'Onofrio et al., 2008), to make the CP, ODP, and ADHP measures, we first created an aggregate symptom score for each measurement point by summing the items, then averaged these scores across ages 4 to 9 years, and finally standardized (M=0, SD=1) the measures.

The BPI consists of a subset of items from the Child Behavior Checklist (CBCL; Achenbach, 1978), which have been shown to have the strongest associations with CBCL factor scores (Peterson & Zill, 1986). Confirmatory factor analyses have shown that the 13 externalizing items on the BPI support a three-factor solution (D'Onofrio et al., 2008). See D'Onofrio et al. (2008) for more information about the validity of these measures.

Data Analyses

First, using SAS 9.4, we obtained descriptive statistics of the measures. Second, using Mplus Version 5, we estimated associations between the background characteristics and odds of having a short or long IPI. To do this, we used full information maximum likelihood (FIML) to handle missing data and fit separate multinomial logistic regression models to predict IPI from each background characteristics. Third, also using Mplus Version 5 and FIML, we

estimated associations between IPI and child outcomes. We used linear regression to predict continuous outcomes and logistic regression to predict the dichotomous outcomes (i.e., PTB). We fit three models that successively controlled for more covariates. The *unadjusted* models did not control for any covariates; the *minimally adjusted* models controlled for child characteristics only (i.e., sex and birth order); and, the *fully adjusted* models controlled for all available background characteristics. Because the sample was obtained using a stratified and clustered household probability sampling approach, we incorporated probability weights based on maternal demographic characteristics when estimating all associations.

Results

Table 1 reports descriptive statistics for all variables.

Associations between Background Characteristics and IPI

Tables 2 includes point estimates and confidence intervals (CIs) for associations between background characteristics and short and long IPIs.

Standardized maternal lifetime alcohol problems were the only factor that did not predict either short or long IPI.

Some background characteristics were differentially related to short and long IPI. Being a third- or later-born child compared to a second-born child was associated with increased odds of short IPI but was not associated with long IPI. Teenage maternal childbearing was associated with higher odds of short IPI and lower odds of long IPI, and maternal childbearing after 35 years was associated with higher odds of long IPI but was not associated with short IPI. Maternal depression was associated with increased odds of short IPI but was not associated with long IPI. Having a pregnancy loss during the focal child's IPI was associated with lower odds of short IPI and higher odds of long IPI.

Several factors were associated with higher odds of both short and long IPI. These factors included Hispanic race/ethnicity compared to White race/ethnicity, African American race/ethnicity compared to White race/ethnicity, less than 12 years of maternal education compared to 12 or more years of maternal education, lower maternal IQ, maternal delinquency, lower family income, and child being in a family that includes half siblings compared to families with full siblings only.

Taken together, these results highlight the importance of accounting for background characteristics when evaluating associations with IPI.

Associations between IPI and Child Outcomes

Table 3 includes point estimates and CIs for associations between short and long IPI and child outcomes.

Birth outcomes—Short IPI was associated with lower birth weight (in grams) in the unadjusted and minimally adjusted models. The fully adjusted models showed an attenuated but robust association that indicated that short IPI was associated with a small (i.e., 90

grams [less than a quarter pound]) reduction in birth weight. The associations with long IPI were weaker and had large standard errors, making it difficult to infer whether long IPI was meaningfully related to birth weight.

We also assessed unadjusted, minimally adjusted, and fully adjusted associations between short and long IPI and birth weight while adjusting for gestational age. Associations were commensurate to associations that did not adjust for gestational age, suggesting that IPI also does not have a large impact of fetal growth.

Associations between short IPI and long IPI and gestational age (in weeks) and PTB were also small and not statistically significant across all models.

Infant temperament—Associations between short IPI and activity level, predictability, fearfulness, or positive affect were neither large nor statistically significant in any model; and, the unadjusted and minimally adjusted associations between short IPI and fussiness were completely attenuated in the fully adjusted model. These results indicate that short IPI is not meaningfully related to infant temperament.

Across all models, the associations between long IPI and predictability, fearfulness, positive affect, and fussiness were neither large nor statistically significant. However, we observed a small statistically significant associations between long IPI and activity level in the adjusted model (b=0.21), though the magnitude of this association may not reflect a consequential difference in behavior.

These results indicate that while long IPI may be associated with slightly lower infant activity level, both short and long IPI are not meaningfully associated with several other areas of infant temperament independent of several family factors.

Cognitive ability—Associations between short IPI and digit span score were small and non-significant across all models. The small statistically significant associations between short IPI and PPVT, math, reading recognition, and reading scores in unadjusted and minimally adjusted models were completely attenuated in the fully adjusted models.

Associations between long IPI and PPVT, math, and reading recognition scores were small and not statistically significant across all model. The small statistically significant associations between long IPI and digit span and reading scores observed unadjusted models were completely attenuated in minimally adjusted and fully adjusted models.

These results suggest that short and long IPI are not meaningfully associated with child cognitive development after accounting for background characteristics.

Externalizing symptoms—The associations between short and long IPI and CP, ODP, and ADHP symptoms were small and non-statistically significant across all models, indicating that IPI may not be meaningfully related to externalizing symptoms.

Discussion

In a sample of 5,339 children born in the United States between 1973 and 2008 drawn from a population-based sample of families in the US, we explored background characteristics and child outcomes associated with short (≤ 1 year) and long (> 3 years) IPI. Several background characteristics were associated with short and long IPI, illustrating that IPI is associated with other factors that influence child adjustment. Characteristics that were associated with both short and long IPI included maternal race/ethnicity (i.e., Hispanic and African American), low maternal education, lower maternal IQ, maternal delinquency, lower family income, and families including any half siblings. Additionally, being a later born child, teenage childbearing, maternal depression, and a preceding pregnancy loss was associated with short IPI; and, older (≥ 35 years) maternal age at childbearing was associated with long IPI.

Although we found that after adjusting for background characteristics short IPI was associated with a small reduction in fetal growth (i.e., 90 grams lower birth weight), and long IPI was associated with a small increased risk in less infant activity, our results indicated that short and long IPI were not highly associated with several important child outcomes. Neither short nor long IPI was meaningfully associated with gestational age (and PTB), several dimensions of infant temperament (predictability, fearfulness, positive affect, and fussiness), several areas of cognitive ability (digit span, vocabulary, math, reading recognition, and reading), and symptoms of externalizing problems (CP, ODP, and ADHP symptoms). These findings are consistent with previous studies that also did not find that short and long IPI were associated with increased risk of adverse birth and neurodevelopmental outcomes in children after adjusting for familial confounding (Ball et al., 2014; Class et al., 2018; Class et al., 2017; Erickson & Bjerkedal, 1978; Hanley et al., 2017).

Our results should be considered in light of several limitations. First, our study was only able to account for confounding by measured characteristics. Thus, it is possible that unmeasured genetic and environmental factors confound the independent associations with child outcomes. However, given that effect sizes were already small after accounting for measured factors, accounting for unmeasured factors would be unlikely to change our conclusions. Second, standard errors for associations with some child outcomes (e.g., birth weight) were large. Therefore, it is possible that our study was underpowered to detect associations of interest. A larger sample size may have increased the precision of our estimates and allowed us to draw stronger conclusions. Third, several of our measures were based on maternal reports, which are subject to self-report biases. Inaccurate maternal reports could have led to measurement error, which could have biased our findings. However, we found a similar pattern of findings with standardized cognitive assessments, suggesting that measurement error in the childhood traits cannot fully account for conclusions. Fourth, we may have observed associations with long IPI that were smaller in magnitude than some other studies because we defined long IPI as greater than three years whereas some other studies have used more extreme cut offs for long IPI (e.g., Cheslack-Postava et al., 2011 defined long IPI as greater than 60+ months). Fifth, for some women some of the maternal characteristics

were assessed after IPI occurred, and, therefore, theoretically could have been a result of the IPI rather than a confounder.

Despite these limitations, our results have important public health implications. Our findings, which are based on a sample of children born to a nationally representative sample of women, can help families make informed decisions about birth spacing, particularly because they suggest that short and long IPI may not have a large, direct effect on several important child outcomes. The results also suggest that background characteristics associated with IPI, rather than IPI itself, may explain the increased risk of some adverse outcomes among children with short and long IPIs. Thus, our findings suggest that rather than intervening to modify IPI, at-risk families may benefit more from intervention efforts focused on changing other modifiable risk factors that impact child development.

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Biographical notes

Ayesha C. Sujan received her bachelor's degree in Psychology at Tulane University and her Master's degree in Human Development from Cornell University. She is currently a doctoral student in the Clinical Science Program in the Department of Psychological and Brain Sciences at Indiana University. Her training is primarily in clinical psychology, though she is also receiving training in related fields, including psychopharmacology, epidemiology, and developmental science. Broadly speaking, her research focuses on prenatal risk factors. She is particularly interested in understanding the potential consequences of maternal use of psychiatric medications during pregnancy on child development.

Quetzal A. Class is an Assistant Professor in Obstetrics and Gynecology at the University of Illinois, Chicago. After receiving her doctorate in clinical psychology from Indiana University, she completed post-doctoral training in Public Health Sciences at the University of Chicago. She strives to understand the implications of events and environments experienced in the preconception, prenatal, and immediate postpartum period on the development of the offpsring and mother.

Martin E. Rickert currently works as a research scientist in the Developmental Psychopathology Lab (Psychological and Brain Sciences) and in the Clinical Optics Research Lab (Borish Center) at Indiana University. His PhD and Research Fellowship work involved 'building' and evaluating computational models of sensory processing and decision making in the areas of auditory psychophysics and psychoacoustics. Since returning to Indiana University, his main research interests and contributions have focused on the analysis of large scale, population-based data (i.e., statistical estimation and causal inference in psychiatric epidemiology) and multivariate predictive modeling.

Carol Van Hulle's background training is in psychology with an emphasis on quantitative genetics, an approach she used to study the development of behavior problems in children for over 15 years, until joining the Wisconsin Alzheimer's Disease Research Center in 2018. Currently, she is studying cerebrospinal fluid biomarkers related to Alzheimer's disease and subjectively reported memory impairment. She is still active in the field of child development through collaborations with Drs. Elizabeth Shirtcliff and H. Hill Goldsmith and has most recently been involved in research on pubertal development and suicidal behaviors in adolescence.

Brian M. D'Onofrio is currently a Professor and the Director of Clinical Training in the Department of Psychological and Brain Sciences at Indiana University. He received his undergraduate and graduate degrees in Psychology from the University of Virginia, and he completed his internship at Children's Hospital Boston/Harvard Medical School. His research explores the causes and treatments of behavioral health problems using large-scale datasets, as well as how to implement evidence-based assessments in community settings. Brian's research has been supported by grants from the National Institutes of Health, the National Science Foundation, the American Foundation for Suicide Prevention, the Indiana Clinical and Translational Sciences Institute, and other foundations. Brian's research and service have also been acknowledged by major scientific awards from numerous organizations, including the Association for Psychological Science, Behavior Genetics Association, Brain and Behavior Research Foundation, Federation of Associations in Behavioral and Brain Sciences, and the Society for Research in Child Development.

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Table 1.

Descriptive Statistics

	N	Mean (SD)	Range	Frequency (%)
IPI				
Short IPI (≤ 1 year)	5339	–	–	1171 (22)
IPI reference (>1 year, ≤ 3 years)	5339	–	–	2228 (42)
Long IPI (> 3 years)	5339	–	–	1940 (36)
IPI (in years)	5339	2.99 (2.78)	0.01,26.57	–
Covariates				
Female child	5339	–	–	2599 (49)
Birth order				
Second	5339	–	–	3204 (60)
Third	5339	–	–	1474 (28)
Fourth	5339	–	–	493 (9)
Fifth	5339	–	–	168 (3)
Race				
White	5339	–	–	2736 (51)
Hispanic	5339	–	–	1069 (20)
African American	5339	–	–	1534 (29)
Maternal age at childbearing				
< 20 years	5339	–	–	432 (8)
20 to 24 years	5339	–	–	1732 (32)
25 to 29 years	5339	–	–	1799 (33)
30 to 34 years	5339	–	–	956 (18)
≥ 35 years	5339	–	–	420 (8)
Years of maternal education	5335	12.83 (2.65)	1.00,20.00	–
Maternal IQ	5073	0.00 (1.00)	−1.22,2.43	–
Maternal depression	4413	0.00 (1.00)	−1.11,4.63	–
Maternal lifetime alcohol problems	4392	1.68 (3.30)	0.00,25.00	–
Maternal delinquency	5041	0.00 (1.00)	−1.04,6.20	–
Family income (square root)	4553	0.00 (1.00)	−1.68,9.43	–
Half-siblings in family	5339	–	–	2271 (43)
Miscarriage, stillbirth, or abortion during IPI	5339	–	–	612 (11)
Outcomes				
Birth outcomes				
Birth weight (in grams)	5060	3344.67(615.35)	453.60,7597.80	–
Gestational age (in weeks)	5339	38.56 (2.14)	23.00,49.00	–
Preterm birth	5339	–	–	632 (12)
Infant temperament				

	N	Mean (SD)	Range	Frequency (%)
Activity	1447	0.00 (1.00)	−1.77,1.90	–
Predictability	1442	0.00 (1.00)	−4.10,0.96	–
Fearfulness	3021	0.00 (1.00)	−1.27,2.80	–
Positive affect	3009	0.00 (1.00)	−4.07,0.83	–
Fussiness	3024	0.00 (1.00)	−1.60,4.29	–
Child cognitive ability				
Digit span	3636	0.00 (1.00)	−2.90,3.14	–
PPVS	3270	0.00 (1.00)	−3.49,3.43	–
Math	3768	0.00 (1.00)	−2.50,2.44	–
Reading recognition	3766	0.00 (1.00)	−2.47,2.22	–
Reading	3740	0.00 (1.00)	−6.09,2.75	–
Child externalizing problems				
Conduct	4517	0.00 (1.00)	−1.17,12.22	–
Oppositional Defiant	4515	0.00 (1.00)	−1.27,3.17	–
Attention-Deficit/Hyperactivity	4515	0.00 (1.00)	−1.23,3.15	–

Note: IPI = interpregnancy interval. SD = standard deviation. Number of years of maternal education was assessed in 2012. Maternal IQ was assessed in 1980. Maternal depression was assessed in 1992. Maternal alcohol use and dependence symptoms were assessed in 1994. Maternal delinquency was evaluated for maternal ages 15 to 22 years. Family income was reported by mothers when they were 30 years old. Infant temperament was evaluated between birth and 23 months. The child cognitive ability measures were based on biennial assessments between ages 9 and 12 years. The child externalizing problem measures were based on biennial assessments between ages 4 and 9 years.

Table 2.

Correlates of short and long IPI

	IPI ≤ 1 year	IPI of 1 to 3 years	IPI > 3 years
	OR (95% CI)		OR (95% CI)
Later born (i.e., third born or later; reference group second born)	1.52 (1.19,1.94)	reference	1.22 (0.99,1.50)
Hispanic (reference group White)	1.70 (1.29,2.23)	reference	1.55 (1.23,1.95)
African American (reference White)	1.77 (1.39,2.26)	reference	1.81 (1.47,2.22)
Teenage childbearing of focal child	2.81 (1.97,4.01)	reference	0.13 (0.05,0.29)
Childbearing of focal child after age 35 years	0.57 (0.33,1.00)	reference	2.01 (1.43,2.83)
Low maternal education (i.e., < 12 years education)	1.61 (1.19,2.18)	reference	1.37 (1.04,1.81)
Maternal IQ (Z-scored)	0.72 (0.63,0.81)	reference	0.72 (0.65,0.79)
Maternal depression (Z-scored)	1.16 (1.02,1.32)	reference	1.11 (0.99,1.23)
Maternal lifetime alcohol problems (Z-scored)	1.01 (0.98,1.05)	reference	1.01 (0.98,1.05)
Maternal delinquency (Z-scored)	1.22 (1.08,1.38)	reference	1.19 (1.07,1.32)
Family income (square root and Z-scored)	0.78 (0.63,0.97)	reference	0.87 (0.76,0.98)
Any half-siblings in family	1.44 (1.12,1.84)	reference	2.90 (2.36,3.57)
Pregnancy loss (i.e., miscarriage, stillbirth, or abortion) during IPI	0.44 (0.26,0.74)	reference	2.12 (1.58,2.86)

Note: IPI = interpregnancy interval. OR=odds ratio. CI=confidence interval.

Table 3.

Association between short and long IPI and child outcomes

	Unadjusted	Minimally adjusted	Fully adjusted
Birth outcomes			
	***b* (95% CI)**	***b* (95% CI)**	***b* (95% CI)**
Birth weight (grams)			
Short IPI	−139.12 (−212.85,−65.39)	−140.88 (−213.51,−68.24)	−89.15 (−158,96,−19.35)
Long IPI	−82.85 (−147.48,−18.22)	−87.08 (−151.03,−23.14)	−38.60 (−104.26,27.07)
Birth weight (grams) adjusted for gestational age			
Short IPI	−137.91(−210.94,−64.89)	−126.31 (−190.48,62.14)	−73.94 (−135.16,−12.71)
Long IPI	−84.89 (−147.49,−20.29)	−62.34 (−118.95,−5.73)	−34.09 (−92.71,24.54)
Gestational age (weeks)			
Short IPI	−0.09 (−0.33,0.15)	−0.09 (−0.33,0.15)	−0.10 (−0.34,0.13)
Long IPI	−0.18 (−0.36,0.00)	−0.18 (−0.37,0.00)	−0.04(−0.23,0.16)
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**
Preterm birth			
Short IPI	1.32 (0.91,1.90)	1.33 (0.92,1.94)	1.29 (0.89,1.88)
Long IPI	1.21 (0.88,1.66)	1.22 (0.88,1.68)	1.04 (0.74,1.47)
Infant temperament (for all measures M=0 and SD =1)			
	***b* (95% CI)**	***b* (95% CI)**	***b* (95% CI)**
Infant activity level			
Short IPI	−0.02 (−0.26,0.23)	−0.02 (−0.26,0.23)	−0.11 (−0.35,0.14)
Long IPI	−0.14 (−0.32,0.04)	−0.14 (−0.33,0.04)	−0.21 (−0.39,−0.02)
Infant predictability			
Short IPI	0.01 (−0.21,0.22)	0.02 (−0.20,0.23)	0.07 (−0.14,0.28)
Long IPI	−0.04 (−0.19,0.12)	−0.04(−0.19,0.12)	0.03 (−0.13,0.20)
Infant fearfulness			
Short IPI	0.07 (−0.09,0.24)	0.06 (−0.11,0.23)	−0.01 (−0.17,0.16)

	Unadjusted	Minimally adjusted	Fully adjusted
Long IPI	−0.04 (−0.15,0.07)	−0.04 (−0.15,0.07)	−0.09 (−0.22,0.03)
Infant positive affect			
Short IPI	−0.01 (−0.16,0.17)	0.01 (−0.16,0.17)	0.02 (−0.15,0.18)
Long IPI	0.07 (−0.05,0.02)	0.07 (−0.05,0.18)	0.06 (−0.06,0.19)
Infant fussiness			
Short IPI	0.17 (0.01,0.32)	0.17 (0.01,0.33)	0.08 (−0.08,0.23)
Long IPI	0.03 (−0.08,0.14)	0.03 (−0.08,0.14)	−0.04 (−0.16,0.08)
Cognitive ability (for all measures M=0 and SD =1)			
	***b* (95% CI)**	***b* (95% CI)**	***b* (95% CI)**
Digit span			
Short IPI	−0.09 (−0.23,0.04)	−0.09 (−0.22,0.04)	0.01 (−0.12,0.14)
Long IPI	−0.13 (−0.24,−0.01)	−0.12 (−0.24,−0.00)	−0.04 (−0.16,0.08)
PPVT			
Short IPI	−0.23 (−0.35,−0.11)	−0.20 (−0.32,−0.08)	−0.01 (−0.11,0.09)
Long IPI	−0.09 (−0.20,0.02)	−0.08 (−1.19,0.03)	0.03 (−0.08,0.14)
Math			
Short IPI	−0.26 (−0.40,−0.12)	−0.25 (−0.39,−0.11)	−0.04 (−0.16,0.08)
Long IPI	−0.15 (−0.27,−0.04)	−0.15 (−0.26,−0.04)	−0.06 (−0.17,0.05)
Reading recognition			
Short IPI	−0.20 (−0.32,−0.07)	−0.19 (−0.32,−0.06)	−0.03 (−0.14,0.09)
Long IPI	−0.10 (−0.21,0.01)	−0.09 (−0.20,0.03)	0.04 (−0.08,0.15)
Reading			
Short IPI	−0.19 (−0.32,−0.6)	−0.17 (−0.30,−0.05)	−0.00 (−0.12,0.11)
Long IPI	−0.11(−0.22,−0.01)	−0.10 (−0.21,0.01)	0.05 (−0.06,0.15)
Externalizing problems (for all measures M=0 and SD =1)			
	***b* (95% CI)**	***b* (95% CI)**	***b* (95% CI)**
Conduct			
Short IPI	0.04 (−0.07,0.16)	0.05 (−0.07,0.16)	−0.02 (−0.13,0.09)

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	Unadjusted	Minimally adjusted	Fully adjusted
Long IPI	0.00 (−0.11,0.11)	−0.01 (−0.11,0.10)	−0.07 (−0.18,0.05)
Oppositional defiant			
Short IPI	0.00 (−0.13,0.13)	0.02 (−0.11,0.15)	−0.05 (−0.17,0.07)
Long IPI	−0.03 (−0.14,0.08)	−0.02 (−0.13,0.08)	−0.05 (−0.15,0.06)
Attention-Deficit/Hyperactivity			
Short IPI	0.01 (−0.12,0.14)	0.03 (−0.09,0.16)	−0.08 (−0.20,0.04)
Long IPI	0.05 (−0.05,0.16)	0.05(−0.05,0.16)	0.02 (−0.08,0.13)

Note: IPI = interpregnancy interval. Short IPI defined as 1 year or less. Long IPI defined as more than 3 years. Reference IPI was 1 to 3 years. *b*=estimated beta weight. OR = odds ratio. CI=confidence interval. The *unadjusted* models did not control for any covariates. The *minimally adjusted* models controlled for child sex and birth order. The *fully adjusted* models controlled for child sex and birth order; maternal race/ethnicity, age at childbearing, education, IQ, depression, alcohol use and dependence symptoms, and delinquency; family income; whether families included half-siblings; and whether a miscarriage, stillbirth, or abortion occurred within the focal child's IPI.