ABSTRACT

Title of Dissertation: EXAMINING THE ASSOCIATION BETWEEN INTERPREGNANCY INTERVAL AND MATERNAL HEALTH IN THE POSTPARTUM PERIOD

Gabriela A. Barber, Doctor of Philosophy, 2023

Dissertation Directed By: Associate Professor Marie E. Thoma
Department of Family Science

Interpregnancy interval (IPI) is defined as the period of time between a previous birth and a subsequent conception, usually measured in months. While recommendations issued by the World Health Organization and the American College of Obstetricians and Gynecologists provide guidance for ideal birth spacing, many births occur after non-optimal IPIs – either too short (<18 months) or too long (60+ months). These recommendations were motivated by the body of research on a host of adverse infant and maternal health outcomes associated with non-optimal IPIs. To date, the literature has focused heavily on the association between IPI and adverse infant health outcomes, with limited attention in comparison being given to IPI and maternal health. Within the research on IPI and maternal health, there is a narrow focus on physical health outcomes related to pregnancy/delivery complications, with few studies looking at health outcomes in the postpartum and beyond. In order to fill this gap, this research investigated the association between IPI and several postpartum maternal health outcomes/indicators, including 1) postpartum depression (PPD), 2) attendance at a postpartum checkup, and 3) postpartum contraceptive use (any and type). One of the perennial difficulties in studying IPI is parsing out whether IPI has an independent association with a health outcome or

behavior or is exerting its effects through pregnancy intention, therefore, for each aim, pregnancy intention was tested as a moderator. For each aim, unique cut-offs for IPI were determined after examination of the association between more detailed IPI categories and the outcome of interest. Categories were collapsed into broader IPI classifications when the associations were similar in order to maximize precision of the estimates and in order to allow us to characterize the most clinically relevant exposure for specific health outcomes. In fully adjusted models, individuals who had IPIs less than 18 months were significantly more likely to experience elevated PPD symptoms (aOR: 1.19, 95% CI: 1.02 – 1.39, p=0.024) when compared to individuals with long IPIs, and individuals who had IPIs less than 12 months were significantly less likely to attend their postpartum checkup (aOR: 0.78, 95% CI: 0.66 – 0.93, p=0.006) when compared to those with long IPIs. Pregnancy intention was not found to significantly moderate either of these associations. For the third aim, pregnancy intention was found to moderate the association between IPI and any use of postpartum contraception. Stratified analyses show that it is among unintended pregnancies that there is an association between short IPI and increased use of any contraception in the postpartum. Among unintended pregnancies, those with IPIs less than 6 months (aOR: 2.31, 95% CI: 1.37 – 3.90, p=0.002) and those with IPIs of 6-11 months (aOR: 2.15, 95% CI: 1.48 – 3.10, p=0.001) were more likely to be using any contraception in the postpartum than those with long IPIs, and the magnitude of this association exceeded that of other IPI intervals and pregnancy intention categories. Among those who were using contraception in the postpartum, individuals with IPIs less than 6 months were more likely to be using highly-effective methods (aOR: 1.59, 95% CI: 1.22 – 2.10, p=0.001) than least-effective methods of contraception. Pregnancy intention did not significantly moderate the association between IPI and type of contraception. Future research should continue to explore the association

between IPI and a broader range of maternal health outcomes and work to identify the mechanisms through which IPI may be impacting these outcomes. Recent changes in reproductive policies in the U.S. may also soon change the proportion of individuals who experience short IPIs, therefore making it even more important to understand how this shift may impact a broad range of maternal health behaviors and outcomes. This research highlights how an increase in births occurring after a short IPI would likely increase rates of PPD and increase demand for certain family planning services.

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by

Gabriela A. Barber

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Advisory Committee:
Associate Professor Marie E. Thoma, Chair
Assistant Professor Rebecca A. Gourevitch
Associate Professor Amy B. Lewin
Assistant Professor Quynh C. Nguyen
Associate Professor Julia R. Steinberg

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Introduction

Background and Significance

Interpregnancy interval (IPI) is defined as the period of time between a previous birth and a subsequent conception, usually measured in months. [1] In 2005, the World Health Organization (WHO) issued a recommendation that after a live birth, individuals are recommended to wait 24 months before attempting another pregnancy.[1] The American College of Obstetricians and Gynecologists (ACOG) has also issued a recommendation for optimizing birth spacing as a key component of interpregnancy care, specifying that individuals should be advised to avoid IPIs of less than 6 months and counseled about risks associated with IPIs of shorter than 18 months.[2] These recommendations were motivated by the body of research on a host of adverse infant health outcomes associated with short IPIs, including preterm birth, low birth weight, small for gestational age, and infant death, and adverse maternal health outcomes associated with short IPIs, including increased risk of uterine rupture, uteroplacental bleeding disorders, and precipitous labor. [3–6]

While this body of research has provided medical providers and policy makers with important information that has been used to inform clinical practice and craft recommendations, one of the biggest limitations to this body of work is its often-narrow focus on birth outcomes or pregnancy/delivery complications. Additionally, recent systematic reviews on the adverse health outcomes associated with short IPIs demonstrate that there is much less research on maternal health outcomes compared to infant health outcomes.[4,5]

Of the studies examined on maternal health in these reviews, the majority of maternal health outcomes that have been explored are related to pregnancy and delivery outcomes and not

on outcomes related to the postpartum period, such as depression or receipt of healthcare services for the mother. [5,6] Additionally, the focus in the maternal health literature thus far has been solely on physical health outcomes, with maternal mental health outcomes noticeably absent - despite being the most common complication of childbirth and a public health topic that has garnered increasing attention over the last two decades. [7–9] In a recent work group meeting convened by the Office of Population Affairs in Washington DC, experts in research on IPI themselves identified two areas in need of additional research are the association between IPI and subsequent maternal mental health and conditions related to the immediate postpartum period.[10]

While it is important to have an understanding of the physical health consequences, for mother and baby, of having a non-optimal IPI, overall health encompasses much more than just physical health. Overall health includes one's mental health and one's ability to access healthcare. To date, only one study conducted in 2000 has examined the association between IPI and any indicator of maternal mental health in the postpartum period. This study, using a small clinical sample in Turkey, found that a short IPI was associated with a greater likelihood of experiencing postpartum depression (PPD) symptoms. [11]

PPD is a common condition experienced after pregnancy, with recent estimates suggesting that between 13- 20% of individuals may experience PPD after giving birth in the United States. [12,13] Depending on the severity and symptoms experienced, PPD can be both debilitating for the individual but also impact the infant, the family system, and have enormous societal costs. [14,15] Due to the myriad of consequences that PPD can have, researchers have sought to better understand the risk factors for PPD. Having children in close succession may place increased mental and physical demands on a mother. This in turn could impact one's stress

levels and ability to interact with social support networks, which are risk factors for experiencing PPD. [16,17] Therefore, IPI may be an unrecognized risk factor for PPD.

In addition to PPD, the period after birth marks a critical time for ensuring health care needs and services are met and utilized. Prior research has examined how having a larger number of children, unintended pregnancy, lower SES, and experiencing depression are associated with a reduction in accessing or seeking healthcare after birth, including the postpartum checkup. [18–21] However, prior research has not examined or differentiated the effects of IPI on receipt of healthcare in the postpartum.

Traditionally, the postpartum checkup has been thought of as a one-time visit usually occurring between 4-6 weeks postpartum. However, ACOG has begun to shift recommendations away from this model to recommend that individuals meet at least once in the first three weeks post birth with their medical provider, and then as needed up until they transition to Well Woman Care at around 12 weeks post birth. Before transitioning, they should have a comprehensive postpartum visit. This comprehensive visit includes many components, some of which include screening for perinatal mood or anxiety disorders, screening for tobacco use, assessing comfort and confidence with caring for the newborn, discussing sleep and fatigue and how to engage support individuals in helping with care responsibilities, chronic disease management, and assessing how the physical recovery since childbirth has gone. An important component of the postpartum checkup is also a discussion on future family building plans, birth spacing, and contraception. [22] Research has shown that attendance at a postpartum checkup is a strong predictor for use of effective contraception. [18,23,24] This is critical as effective contraceptive methods are a key component for reducing risk of a subsequent short interpregnancy interval.

It is postulated that short IPI may reduce an individual's ability to attend postpartum checkups due to increased stress and the demands of caring for two small infants and may affect decision making related to future family planning and contraceptive choice. Because many short IPIs are unintended [25], it is also crucial to differentiate the effects of short IPI from pregnancy intention (e.g., short IPI may create barriers that are independent of pregnancy intention) when examining associations with attendance at postpartum checkups and contraceptive use.

This study addresses the current gaps in the literature using a unique dataset provided to me for use by the Centers for Disease Control and Prevention (CDC). This dataset is comprised of merged data from the Pregnancy Risk Assessment Monitoring System (PRAMS) and United States birth certificates and allowed me to examine the association between IPI and PPD and IPI and the receipt of several maternal healthcare services in the postpartum period. Additionally, one of the perennial difficulties in studying IPI is parsing out whether IPI has an independent association with a health outcome or behavior or it is exerting its effects through pregnancy intention. [10] Many pregnancies with a short IPI are reported as unintended, however IPI and pregnancy intention may have distinct and separate mechanisms for impacting one's health. [25] Those with short IPIs may have a greater risk of experiencing mental health difficulties during the postpartum period due to the increased mental and physical demands that are associated with having two very young children. In turn, this could increase stress and decrease one's ability to access social support resulting in a lower likelihood of attending routine medical checkups or accessing contraception. These mechanisms differ from those that potentially explain the relationship between unintended pregnancy and the outcomes, which include preexisting psychosocial problems/concerns, economic disadvantage, and diminished use of routine healthcare services in the past. This unique dataset allowed me to examine whether pregnancy

intention of the index pregnancy (i.e., the pregnancy that determines the interpregnancy interval) confounds or moderates the associations under study. [26]

Note: PRAMS does not currently ask participants their gender identity, and therefore uses gendered terminology throughout their survey. While I recognize that not all birthing persons identify as women or moms, throughout this dissertation I will use the same terminology as the data source.

Specific Aims and Hypotheses

This dissertation examined the association between IPI and several key factors related to maternal health in the postpartum period using the following three specific aims.

Aim 1a: Examine the overall association between IPI and maternal PPD symptoms.

Aim 1b: Assess whether pregnancy intention moderates this association.

- Hypothesis for Aim 1a: Short IPIs will be associated with increased odds of experiencing elevated PPD symptoms in comparison to longer IPIs.
- Hypothesis for Aim 1b: Associations between short IPI and odds of experiencing elevated PPD symptoms will be attenuated among index pregnancies that were considered intended in comparison to those who report that their pregnancy was unintended or they were unsure about their pregnancy intention.

Aim 2a: Examine the association between IPI and attendance at a postpartum checkup.

Aim 2b: Assess whether pregnancy intention moderates this association.

- Hypothesis for Aim 2a: Short IPIs will be associated with reduced odds of attending a postpartum checkup in comparison to longer IPIs.

- Hypothesis for Aim 2b: Associations between short IPI and not attending a postpartum checkup will be attenuated among index pregnancies that were considered intended in comparison to those who report that their pregnancy was unintended or they were unsure about their pregnancy intention.

Aim 3a: Examine the association between IPI and use of contraception (any use, type of method used) in the postpartum period.

Aim 3b: Assess whether pregnancy intention moderates this association.

- Hypothesis for Aim 3a: Compared with longer IPIs, short IPIs will be associated with higher odds of non-use of any method of contraception at the time of survey and higher use of less effective contraceptive methods relative to higher effective methods.
- Hypothesis for Aim 3b: This effect will be attenuated among index pregnancies that were considered unintended and in those where the woman was unsure about her pregnancy intention in comparison to those who report that their pregnancy was intended.

Research Implications

This investigation allowed us to gain a better understanding of IPI's association with a broader range of maternal health outcomes and mother's receipt of important health services in the postpartum period. We know that the postpartum period is a crucial transition point in an individual's life and the mother's health during this period has far reaching effects, not just on her but for the infant and the rest of the family [14,27–30], therefore it is important that they are able to attend and do attend recommended postpartum checkups in order to receive needed support services and receive family planning services during this time. The results of this investigation provide crucial information that can be used by practitioners in order to identify other factors, such as IPI, that may be associated with receipt of these services and provide a better

understanding of how the impact of IPI in the postpartum period may alter and affect later health outcomes. This has the potential to both inform clinical practice and future clinical recommendations. Lastly, recent changes in reproductive policies, i.e. limiting access to abortion, in the United States, may soon increase the proportion of individuals who give birth following a short IPI and/or an unintended pregnancy, therefore making it critical that we gain a better understanding of the individual and joint/interactive effects this could have on the health of birthing people in the United States. [25]

Literature Review

Current Recommendations Regarding Interpregnancy Interval

In 2005, the World Health Organization (WHO) issued a recommendation that after a live birth, individuals should wait 24 months before attempting another pregnancy.[1] This recommendation was based on evidence from studies conducted in multiple locations and contexts around the world, and while an eventual consensus was reached to set the recommendation at 24 months, there was disagreement among the experts that issued this recommendation. While the evidence presented showed a clear risk for IPIs of 18 months or less, it appeared as though there was only what they termed "residual risk" associated with IPIs of 18-27 months. The magnitude and clinical implications of this "residual risk" are open to interpretation. [1]

In the United States, the American College of Obstetricians and Gynecologists (ACOG) has also issued a recommendation for optimizing birth spacing, specifying that individuals should be advised to avoid IPIs of less than 6 months and counseled about risks associated with IPIs of shorter than 18 months.[2] In their recommendations, they stress that as part of interpregnancy care clinicians are advised to speak with individuals about their plans for future childbearing, provide education regarding what is known about optimal birth spacing, and help individuals to secure contraception that aligns with their values and their future childbearing plans. [2] They acknowledge that this is a complex decision that is impacted by many factors, including one's age, desired family size, fertility, etc. In line with the clinical recommendations issued by ACOG, the nation's Health People agenda also identifies 18 months as an important cutoff, with one of the objectives in Healthy People 2030 being to reduce the proportion of pregnancies which are conceived within 18 months of a previous birth.[31]

Notably, while recommendations have cautioned individuals about too short of IPIs, recommendations do not currently address the fact that research has also found negative health outcomes associated with long IPIs (greater than 60 months). This is most likely due to the fact that it is easier to address some of the factors, such as lack of contraceptive knowledge or use, that increase the likelihood of shorter IPIs, as opposed to longer IPIs. Long IPIs may occur due to relationship instability, recurrent pregnancy loss, or infertility, all of which are not factors that are as amenable to intervention.

Calls for a Critical Examination of the Literature on Interpregnancy Interval and Health

In 2017, the Office of Population Affairs called for an expert work group meeting to be convened in Washington, DC to critically evaluate the evidence for the association between IPI and adverse outcomes.[32] The quality of this body of research is relevant to the Office of Population Affairs because of its involvement in the administration of the Title X Family Planning Program, which provides federally funded family planning services through nonprofit health and community-based clinics throughout the United States.[33] Given that this body of research has been used to inform medical recommendations about optimal birth spacing and the primary means of intervening to increase the proportion of pregnancies in the United States that are conceived after an optimal period of time is improving education on family planning and increasing access to contraception, the Office of Population Affairs determined that there was a need to critically evaluate the state of the evidence in light of recent work and advancements in the methodology used to study IPI and health outcomes. The hope was that at this meeting the current research would be critically examined to determine whether there was truly a causal relationship, and not one that resulted due to confounding by maternal characteristics, between short IPI and adverse health outcomes in the United States and identify good practices for

research in this area given the new methodologies that were being used in more recent research to examine this association. At the time, recent studies which were beginning to use a different design – a sibling comparison design – to examine the association between IPI and various health outcomes, and these new studies often found that the association between IPI and adverse health outcomes was attenuated to the null or, in some cases, protective.[34–37]

One of the perennial difficulties in studying IPI and the association it may have with health outcomes is identifying and accounting for all the covariates that may be confounding this relationship. [10,26] Potential covariates include factors such as socioeconomic status and pregnancy intention. In an attempt to address this issue particularly, researchers had begun to use a sibling comparison design to study the association between IPI and various health outcomes. [34,36,38,39] The benefits of this design are that it was thought to account for several of these factors by using an individual as their own control. This within-subjects design however still has several limitations. First, it assumes that confounders remain constant across multiple pregnancies, which may not always be the case. While some confounders may remain constant across pregnancies, such as race, other confounders would likely change over time and with the addition of a child and related financial responsibilities. This could cause an individual's socioeconomic status to vary between pregnancies, as well as their pregnancy intentions. Under this scenario of time-varying confounding, this type of design could introduce bias, rather than reduce it. Second, the use of this study design may limit the generalizability of results, since individuals who are able to be included are only those with three or more pregnancies (i.e., at least two pregnancy intervals for a given person) and discordant on outcomes across those intervals. These individuals may differ in meaningful ways from those with fewer pregnancies. The analytic sample with this design is significantly restricted because only individuals with discordant pregnancy outcomes and

discordant interpregnancy intervals can be included, which is not all individuals with at least two IPIs. [10,26,40]

The work group meeting that was convened highlighted these limitations in the new methodology, identified good practices for research moving forward, and determined areas in need of more research within the field. One of the directions for future research called for research on the association between IPI and subsequent maternal mental health and another area identified as a priority was research on IPI and its association with infant and maternal health in the postpartum period. [10]

Epidemiology of Interpregnancy Interval in the United States

While recommendations by various medical and public health organizations provide guidance on optimal birth spacing and discourage IPIs of less than 18 months, a large percentage of births in the United States occur outside the optimal range for birth spacing, and various groups in the population are more likely to experience IPIs outside the optimal range.

Historically, data regarding IPI in the United States has come from two sources – birth certificate data and the National Survey of Family Growth. While both of these sources currently provide this data, there was a brief period where due to budgetary constraints information regarding IPI was not able to be calculated from information included on the birth certificate. A revision in 2003 made it possible once again to ascertain IPI from birth certificate data.[41]

Prevalence estimates for IPI vary slightly based on the data source and methodology used, however approximately a third of pregnancies are conceived within 18 months of a previous birth, and around 1 in 10 pregnancies in the United States are conceived within 6 months of a previous birth. [25,41] Individuals who are teenagers, initiated childbearing at an older

age, had an unintended pregnancy, were on Medicaid at the time of their delivery, had lower income, or identified as Non-Hispanic Black are most likely to experience short IPIs. [25,41,42]

While the majority of pregnancies that occur after a short IPI are unintentional, approximately a third of pregnancies that occur after a short IPI are considered intentional and well timed. [42] There are a variety of reasons why an individual may choose to space births close together. Short IPIs that were considered well timed and intentional by the individual were most likely to occur to those who were older, those whose previous pregnancy occurred later than they would have liked it to, those whose prior infant had died, and those who were of higher SES. [25,42,43]

Current recommendations focus on reducing the proportion of pregnancies that occur after a short IPI, however it is important to note that there are a large proportion of pregnancies that occur after a long IPI (greater than 60 months) in the United States. Estimates suggest that approximately 1 in 5 pregnancies in the United States occur after a long IPI. [25,41,42] Approximately half of pregnancies with a long IPI are considered well timed and intended. [42] Experiencing a long IPI is associated with being formerly, rather than currently, married, having experienced a pregnancy loss, and having a partner who was negative or ambivalent about the timing of the previous pregnancy. As income increases, the odds of having a long IPI increase. Having a long IPI is less likely if an individual's previous pregnancy occurred in their 30s relative to in their 20s, if they breastfed their prior infant, and if they have more education. [42]

Current Literature on Interpregnancy Interval and Health Outcomes

To date, there is a large body of research on a host of adverse infant health outcomes associated with short IPIs, including preterm birth, low birth weight, small for gestational age, and infant death. [3,4] A smaller, limited number of studies have explored the association between

IPI and maternal health outcomes. Within this limited body of work, evidence suggests that short IPIs are associated with an increased risk of uterine rupture, uteroplacental bleeding disorders, and precipitous labor, however short IPIs have been associated with reduced risk of other maternal outcomes, including labor dystocia and preeclampsia which are more common with long IPIs. [5,6] It is important to highlight that within this literature most studies consider short IPIs to be less than 18 months, and occasionally will further subdivide this group to capture different risk among those who have really short IPIs – less than 6 months – to those who have IPIs between 6 months and 18 months. Long IPIs are generally defined to be anything greater than 59 months. The comparison group is often 18-24 months or 18-59 months, which is considered an optimal window in relation to infant health outcomes but may not represent the optimal window for other health outcomes.

Infant Health Outcomes

Back in 2006, a systematic review was completed on IPI and infant health outcomes with the hope of identifying whether there was an independent relationship between IPI and several infant health outcomes. [3] While there had been a large number of studies done to date examining IPI and infant health outcomes, many were limited by the fact that they did not adjust for important confounding factors, sample sizes were small, and arbitrary cutoffs were used for IPI.

Of the 130 studies found to be relevant, 67 studies were included in the systematic review, with approximately a third of these studies conducted in the United States. A U-shaped pattern emerged for the four birth outcomes identified, preterm birth, low birth weight, small for gestational age, and perinatal mortality, with short IPIs and long IPIs being associated with an increased risk of each of these outcomes.

While this review provided important information that was used to inform policy decisions – such as the birth spacing recommendations by the WHO, an update was conducted in 2017 to not only include the most recent research on this association, but also to determine whether these findings are applicable in a high resource setting, such as the United States. [4] The previous systematic review included studies conducted in many different countries of varying levels of development, and it was unclear if these relationships would hold or whether the optimal birth interval may vary when examining only high-income countries.[3] Only studies conducted in the United States, Canada, Australia, New Zealand, and European countries categorized as "very high" on the UN's Human Development Index were included in this most recent review. The recent review also applied stricter inclusion criteria, such as only including articles that measured IPI since last live birth as opposed to inter birth intervals or post-abortion or post-pregnany loss intervals, only including articles with a strictly defined reference category for IPI with an upper and lower bound, only including articles that adjusted for maternal age and SES, and included at least 100 participants. [4] Only 11 articles from the original review conducted in 2006 were included in the updated review, along with 21 articles that had been published since 2006.

The results of this updated review found consistent and strong evidence for an association between short IPIs and preterm birth and infant death, with weaker evidence for an association between short IPI and being small for gestational age, and no association between short IPI and perinatal death. Across all studies, risk for adverse health outcomes was highest among the shortest IPI category (less than 6 months). [4]

Other studies that have been conducted since the time of this systematic review continue to find evidence for a U-shaped association between IPI and preterm birth - with those who have

short IPIs and those with long IPIs experiencing increased risk of preterm birth[36,37,44], a U-shaped association between IPI and being small for gestational age [44], and a U-shaped association between IPI and low birth weight.[36] Additionally, those with longer IPIs may be at an increased risk of experiencing a stillbirth. [44] In a recent study published this year, the authors used propensity score matching to address the issue of confounding when examining the association between IPI and preterm birth and being small for gestational age. They compared whether short IPIs - less than 6 months, 6-11 months, and 12-17 months - were associated with an increased risk for these outcomes when compared to the reference group of 18-23 months. Results showed that there was no independent association between short IPIs and being small for gestational age, however there was an increased risk for preterm birth for those IPIs of less than 6 months and 6-11 months.[45]

Maternal Health Outcomes

Similarly, a systematic review was conducted in 2006 to determine whether there was an independent association between IPI and adverse maternal health outcomes. [6] This body of literature had suffered from several limitations in the past (similarly to the research on IPI and infant health), including small sample sizes, not controlling for important confounders, and arbitrary cutoffs for IPI. Twenty-two studies were included in this systematic review, and ultimately results showed an association between short IPIs and increased risk of uterine rupture and uteroplacental bleeding disorders, which include placental abruption and placenta previa. Long IPIs were associated with an increased risk of preeclampsia and labor dystocia. [6]

An updated systematic review examining IPI and maternal health outcomes was conducted in 2017, concurrently with the updated systematic review on IPI and infant health outcomes, with similar goals. The researchers sought to include more recent research in the

updated review, to include only studies from high-income countries that were comparable to the United States, and to have stricter inclusion criteria. [5] Only one study from the previous systematic review was included, and 6 additional articles were added that had been published since 2006. This updated review found that short IPIs were associated with an increased risk of precipitous labor, but a decreased risk of labor dystocia and preeclampsia. Among individuals with a prior Cesarean-section, short IPIs were associated with an increased risk of uterine rupture. [5] The focus of this updated review, like the one on infant health, was on the outcomes associated with short IPIs rather than long IPIs due to the fact that it was determined short IPIs are more amenable to intervention.

Research which has been conducted since this systematic review has found evidence for an association between IPI and miscarriage, with those who have short IPIs having less risk of experiencing a miscarriage. [44] Recent research has also continued to provide evidence for the protective effect of shorter IPIs on risk of preeclampsia.[46] In a recent study conducted using data from the Swedish Medical Birth Register, researchers examined the association between IPI and maternal health by creating a composite measure for severe maternal morbidity and moderate maternal morbidity. They included outcomes such as maternal death, maternal sepsis, eclampsia, transfusion, and postpartum hemorrhage in their measures of morbidity. They found that there was an increased risk of experiencing maternal morbidity with increasing IPI.[47] A strength of this study was the broad array of maternal health indicators used, however by grouping them altogether in a composite measure, information about the relationship between IPI and specific maternal health outcomes could not be ascertained. De Silva and Thoma's recent work has examined the relationship between IPI and specific maternal morbidities. They examined the relationship between IPI and the following maternal morbidities: 1) transfusion, 2) admission to

ICU, 3) ruptured uterus, and 4) third- or fourth-degree perineal laceration. They found differing associations between IPI and each outcome, with increased risk of transfusion for those with short or long IPIs (a U-shaped association), risk of admission to the ICU and risk of perineal laceration increased with longer IPIs, and risk of uterine rupture decreased with longer IPIs. [48]

Causal Mechanisms Proposed to Explain the Association Between Interpregnancy Interval and Birth Related Health Outcomes

There are several proposed mechanisms in the literature as to how short IPIs may lead to the negative infant and maternal health outcomes summarized above (i.e. maternal nutrition depletion, folate depletion, cervical insufficiency, vertical transmission of infections, suboptimal lactation related to breastfeeding-pregnancy overlap, sibling competition, transmission of infectious diseases among siblings, incomplete healing of uterine scar from previous cesarean delivery, and abnormal process of remodeling of endometrial blood vessels) and one proposed mechanism that could potentially explain the association between long IPIs and negative health outcomes (i.e. women's physiological regression). While all of these mechanisms have been proposed in the literature, those that have the most evidence to support them include the folate depletion hypothesis, cervical insufficiency, vertical transmission of infections, and incomplete healing of the uterine scar from previous Cesarean-delivery.[49]

- **Folate depletion hypothesis**: This hypothesis has been proposed to explain the association between short IPIs and adverse perinatal outcomes, such as preterm birth, low birth weight, and small for gestational age. [50] Concentrations of folate normally decrease throughout pregnancy and in the postpartum, with this decrease being more pronounced in individuals who breastfeed. [51] This depletion of maternal folate is hypothesized to impact perinatal outcomes should the individual become pregnant shortly after a previous pregnancy before

folate restoration is complete. Strong evidence for this hypothesis comes from a population-based study which looked at whether folate supplementation, both prior to conception and during pregnancy, could buffer the effects of a short IPI on the risk of being small for gestational age and preterm birth. Results showed that supplementation with folate, either before or during pregnancy, mitigated the risk for these two outcomes. [52]

- **Cervical insufficiency**: This hypothesis has also been proposed to explain the association between short IPIs and adverse perinatal outcomes, such as preterm birth. [49] Cervical insufficiency has been identified as a cause of preterm birth[53], and there is evidence to suggest that short IPIs may provide inadequate time for the cervix to return to normal after the previous birth, which could lead to increased risk of adverse perinatal health outcomes in the subsequent birth. [49]
- **Vertical transmission of infections**: This mechanism has been proposed to explain the association between short IPIs and adverse perinatal outcomes, such as preterm birth, low birth weight, and small for gestational age. [49] It is well documented that maternal infections can be associated with increased risk of perinatal health outcomes. [54] Therefore, it has been proposed that the transmission of persistent maternal infections would be greater among individuals with short IPIs, therefore increasing their risk of experiencing an adverse perinatal health outcome for their subsequent pregnancy. [49,55]
- **Incomplete healing of uterine scar**: This has been proposed as a mechanism through which short IPIs occurring after a prior Cesarean-delivery may be associated with adverse maternal health outcomes, such as uterine rupture, uteroplacental bleeding disorders, and premature membrane rupture. [49] The scar from a Cesarean-section takes several months to a year to

heal, therefore those who have births in close succession may be at an increased risk of uterine rupture due to incomplete healing. [56]

Beyond Birth Outcomes

While much of the older literature on the adverse effects of a non-optimal IPI has focused on birth outcomes or delivery related outcomes particularly in low-to-middle income countries, emerging research is beginning to look at the association between IPI and other, later child health outcomes in offspring. Growing evidence suggests that short IPIs are associated with increased risk of injury-related infant mortality [57] and infant morality overall. [58] Research also suggests that both short and long IPIs may be associated with an increased risk of Autism Spectrum Disorders [59–62], very short IPIs may be associated with an increased risk of later diagnosis of Oppositional Defiant Disorder [63], short and long IPIs may be associated with increased risk of Attention Deficit/Hyperactivity Disorder [64], and long IPIs are associated with increased risk of pediatric Obstructive Sleep Apnea Syndrome.[65]

While this shift to consider a broader array of health outcomes later on in life is much needed, this shift appears to have only really begun in the literature on IPI and infant health, not in the literature on IPI and maternal or parental health. The recent systematic reviews cited above demonstrate that there is comparatively much less research on maternal health outcomes compared to infant health outcomes related to IPI.[4,5] Of this research, the maternal health outcomes explored are still usually related to pregnancy and delivery outcomes and not on conditions related to the postpartum period and beyond.[5,6] The few studies that have looked at later life health for parents, both women and men, have found that having closely spaced children may increase one's mortality risk later in life, increases one's risk of having limitations

in day to day living due to a health limitation, and may decrease one's perception of their self rated health. [28,29]

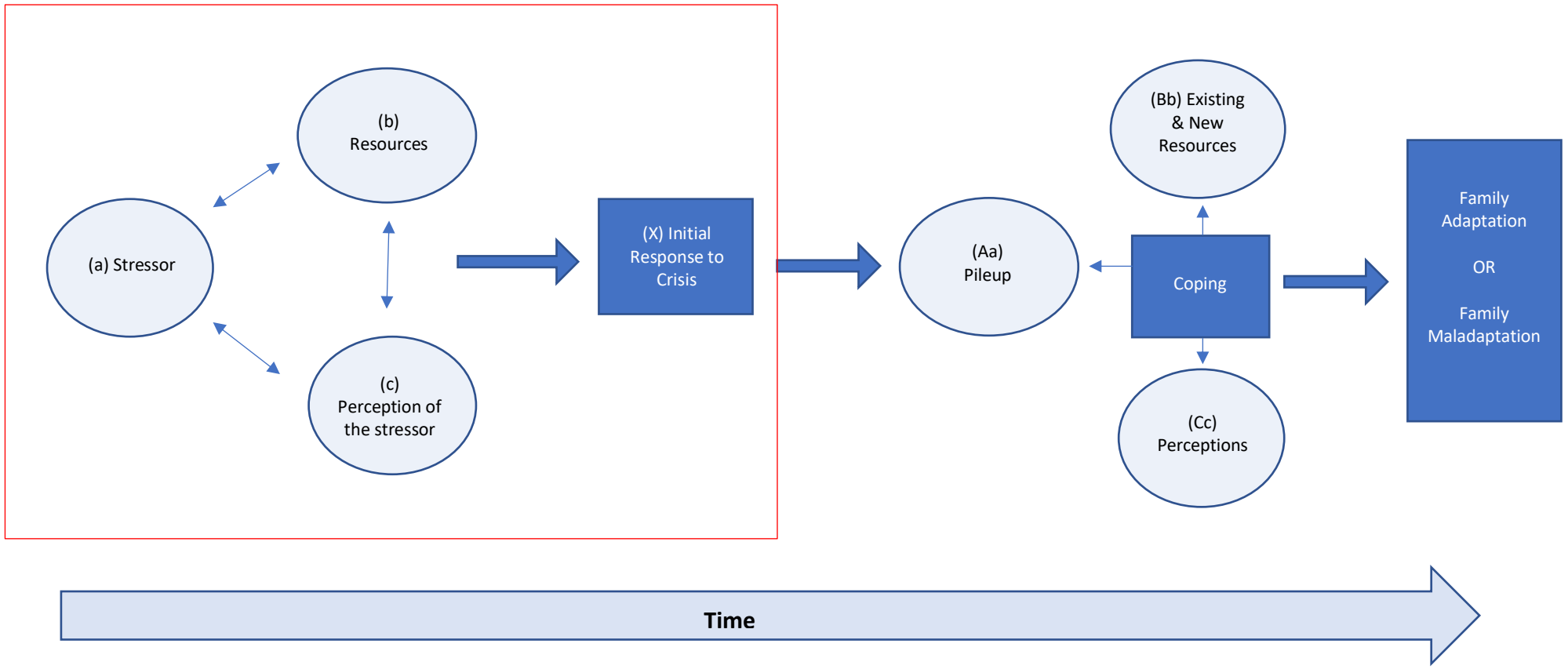
Theoretical Framework for the Current Study

Several frameworks exist in the literature to describe the multiple factors that influence one's ability to respond to and cope with a stressor, including Hill's ABC-X model of family stress and Lazarus and Folkman's stress and coping model.[66,67] Both of these models suggest that once a stressor is encountered, the resources available and perception of the stressor impact the response to the stressor. While Hill's model was conceptualized based on research with families, Lazarus and Folkman's model was originally applied to more individual outcomes. Hill's model was conceptualized in the 1950's, with Lazarus and Folkman creating their model in the 1980's. While there is much overlap in the models, Lazarus and Folkman's model adds on that coping resources are also an important element, and has therefore been a popular framework in the field of psychology. In the 1980's, the Double ABC-X model was created to expand upon the traditional ABC-X model and is a model that is now frequently used in research on family stress and coping. [67,68] It is a useful framework in which to conceptualize the complex interplay of factors that I hypothesize impact the relationship between IPI and our maternal health outcomes/indicators which occur in the postpartum.

The Double ABC-X model posits that the response to a stressor is influenced by a variety of factors, including (a) the stressor itself, (b) the resources available to manage or respond to the stressor, and (c) the perception and meaning associated with the stressor. These all influence one's reaction and initial response to the situation (X) (this is the part of the framework that was outlined in the original ABC-X model). The expanded version adds on that over time there is an additional pileup (aA) response that occurs. This pileup (aA) occurs because of the initial

stressor and refers to both the initial stressor and any chronic strain that may have occurred because of the initial stressor. This pileup along with existing and new resources (bB) and the family's perception (cC) of both the initial stressor, the pileup that has occurred and the existing and new resources all impact the family's ability to cope and whether they adapt to the stressor or maladaptation occurs (Figure 1). Over the last several decades, the ABC-X model and the Double ABC-X model have been used in research focused on a variety of health-related events.[69–74]

Figure 1: Diagram of the Double ABC-X Model of Family Stress Conceptual Framework



Note: The red outline depicts the original ABC-X model before the expansion into the Double ABC-X model.

The current body of literature examining IPI and physical health outcomes paints a picture of how short IPIs are associated with a host of negative health consequences. When examining the association between IPI and other health outcomes, such as the ones in this investigation, short IPIs may still present some challenges to families, however it may not be all negative. There are a variety of factors which may impact one's ability to adapt to having a short IPI and still allow an individual to maintain their health in the postpartum period. Therefore, the Double ABC-X framework proves to be a useful tool for integrating the various variables and mechanisms that may impact the effect that a short IPI has on health in the postpartum period.

Using the Double ABC-X model to conceptualize my research questions, the initial stressor (a) is the short IPI, the resources available at the time of the crisis (b) include support from a partner or family member, socioeconomic means, etc., and the perception of the stressor (c) is the intention and wantedness of the pregnancy. I anticipate that all of these factors will affect the reaction or response to the stressful short IPI (X). The pileup (aA) that occurs after one is aware that they will be having a short IPI can include additional stressors that may be experienced as a result of the pregnancy, such as health complications, couple conflict, etc.. Additional resources (bB) may become available after the pregnancy, such as insurance coverage, and all of this will now impact one's perception of the situation (cC). This myriad of factors, I hypothesize, will ultimately impact mother's mental health in the postpartum and her ability to access postpartum health services and family planning.

Why Might We Expect an Association Between Interpregnancy Interval and Our Outcomes?

Postpartum Depression

Maternal mental health outcomes, including postpartum depression (PPD), have been noticeably absent in the literature on IPI - despite being a public health topic that has garnered

increasing attention over the last two decades, including increased legislation and an objective in the nation's Healthy People 2030 agenda. [7,8] Recent estimates suggest that between 13- 20% of individuals may experience PPD after giving birth in the United States. [12,13] Depending on the severity and symptoms experienced, PPD can be both debilitating for the individual but also impact the infant, the family system, and have enormous societal costs. [14,15] Due to the myriad of consequences that PPD can have, researchers have sought to better understand the risk factors for PPD. Research seeking to understand what factors increase an individual's risk of PPD has largely focused on biological factors, such as changes in hormones after birth (e.g., progesterone, estrogen, or oxytocin), genetic predispositions, or contextual factors such as prior mental health, pregnancy intention, or stress [16,17,75–79].

Having children in close succession may place increased demands on a parent, taxing them emotionally, physically, socially, and financially. Given the preponderance of evidence supporting the role of stress as a strong predictor for PPD, especially chronic stress, relational stress, and perceived stress [16,80,81], it can be hypothesized that IPI may be an important, yet unrecognized, risk factor for PPD.

Additionally, the increased demands of having two young children can possibly impact one's mental health through decreasing perception of social support and inability to access social supports. Lack of social support is another strong predictor for PPD.[16,80,82] The postpartum is a challenging period for a variety of reasons, including the increased amount of time that must be spent nurturing and caring for a new baby.[83] This leaves less time for engaging with other adults and making time for social engagements one may have been able to engage in previously, which could increase one's feelings of social isolation and decrease feelings of perceived social support. Social support is an important buffer during challenging times [84–86], and social support

decreases one's likelihood of ruminating on family stress - and if rumination does occur it affects one's mood less among those who feel as though they have adequate social support. [87] While all individuals may struggle to access support in the postpartum, those who also have another young child may find it even harder to do so.

While current recommendations by various health organizations recommend screening for PPD at prenatal care visits, postpartum checkups, and well-baby visits [8,88–90], universal screening rates remain low in many medical practices due to a variety of reasons, including time constraints, lack of resources, physician's specialty, and whether or not there is a screening protocol in place. [91–97] Therefore, understanding more about the relationship between IPI and risk of experiencing PPD symptoms has important implications for clinical practice, with IPI potentially being able to provide medical professionals with information regarding the risk one faces for experiencing PPD symptoms.

Attendance at a Postpartum Checkup

The postpartum period is a time that is often filled with much joy, but also much transition. After giving birth, the birthing person must physically recover from childbirth and transition into their new role as a parent for the new baby. There are a variety of complications that can arise during this period, which can have a lasting effect on the birthing person, both now and in the future, if not appropriately addressed. [86] Therefore, attendance at the recommended postpartum checkup is crucial, however ACOG estimates that depending on the population examined up to 40% of individuals may not attend a postpartum checkup.[22]

Given the importance of this healthcare service, researchers have extensively examined the factors that are associated with non-attendance at the postpartum checkup in an effort to create interventions to help increase access and attendance. One consistent predictor for non-

attendance at the postpartum checkup is lack of or inadequate prenatal care.[19,98] Research has also shown that those who opt for home births rather than hospital births are also less likely to attend the postpartum checkup [19], however this may have more to do with beliefs about healthcare and health interventions. Those who opt to give birth at home may do so to avoid medicalizing child birth more than necessary, and therefore may also choose to interact less with the healthcare system in the postpartum. We see that those who take their newborns to their 1-week well-baby visit are also more likely to attend their own postpartum checkup, as opposed to those who do not bring their newborn in for their 1-week well-baby visit. [19] Various sociodemographic factors also predict non-attendance at the postpartum checkup, including having lower education, less income, being younger, being uninsured, and being unmarried. [19,99,100] Those whose pregnancy was unintended are less likely to attend this checkup, as are those who are experiencing PPD. [20,21] Those that are more socially disadvantaged may struggle, more so than most, to make it to this medical visit because of several barriers which have been highlighted in the literature, such as trying to manage the increased emotional stress that accompanies their new or expanded role as a parent, managing the newborn's hectic schedule, trying to coordinate too many moving parts such as childcare or work schedules, and generally having less time for self-care. [100–102] Mothers will typically choose to prioritize their child's medical care above their own. [101] There is also emerging evidence to suggest that better access to paid family leave may increase attendance at postpartum checkups. [103]

While all of these barriers can be present for any individual, I hypothesize that those who have short IPIs, and therefore two young children, may be more likely to face some of these barriers. It is hypothesized that having a short IPI may reduce an individual's ability to attend postpartum checkups due to increased stress and the demands of caring for two small infants.

Having two young infants, rather than one, may make it harder to coordinate everyone's schedules so that the individual is able to attend a medical appointment for themself.

Contraception

Contraception as an Intervention to Encourage Optimal Birth Spacing

Given the evidence on the risks associated with short IPIs, guidelines indicate that medical providers should provide education to their patients and inform them of the risks associated with closely spaced births. [2,22] However, it is ultimately patients choice how they would like to space their births. While there are risks associated with long IPIs, the factors that lead to one having a longer IPI are often less amenable to intervention, such as in cases of previous pregnancy loss, lack of a partner, etc., therefore less emphasis has been placed on working to reduce the proportion of pregnancies which are conceived after long IPIs.[42] The focus has been on interventions to reduce the proportion of pregnancies which are conceived after a short IPI, of which the most effective intervention is increasing access to and use of contraception.

There are various contraceptive options available in the United States, each with a different level of effectiveness at preventing pregnancy. [104] Approximately, 2/3 (65.35%) of women of reproductive age in the United States are currently using contraception according to data from the National Survey of Family Growth (2017-2019). [105] Contraceptive use is highest among certain groups. Those who identify as Non-Hispanic white are more likley to use contraception than those who identify as Non-Hispanic Black or Hispanic.[105] Contraceptive use increases with age. While only 38.7% of women between the ages of 15-19 report currently using contraception, 72.3% of women between 30-39 report currently using contraception, and 74.8% of women between the ages of 40-49 report using contraception. [105] The most common

contraceptive methods are female sterilization, the pill, long acting reversible contraception (LARC), and the male condom. [105]

Which contraceptive method individuals choose to use varies with age and race. Female sterilization is more common among those of an older age, whereas pill use generally decreased with increasing age. Use of LARCs is most common among individuals in their 20s or 30s, compared with those in their teens or 40s. The pill is most common among Non-Hispanic white individuals, and condom use is lowest among those who identify as Non-Hispanic white. [105] Individuals who had a recent unintended pregnancy are more likely to choose LARCs over other methods of contraception. [18] There are a variety of other factors that also influence one's choice of contraception, including price, access, religious beliefs, pregnancy desires, fertility, concern about side effects and other health effects, and many others. [106,107]

Contraceptive Use In the Postpartum

Researchers have examined the association between contraception, as an exposure, and IPI, as an outcome, which has led to the use of contraception as an intervention to decrease the proportion of pregnancies which are conceived after a short IPI. [108–110] Overall, those who use more effective contraceptive methods are less likely to get pregnancy and to have a short IPI compared to those who do not use contraception or use a less effective method. What researchers have not yet examined is the converse of this association – how does IPI impact contraceptive use and choice in the postpartum.

Many individuals report wanting to be on contraception in the postpartum period, with many indicating that contraceptive options and counseling should be available early in the postpartum period. [102] Contraceptive counseling is important in general, however it is much

needed at this time period since the contraceptive options available to individuals during this period may be different depending on their breastfeeding status.[111]

Over the last three decades, immediate (i.e. right after delivery) IUD and implant insertion has become more popular among individuals and has been found to greatly reduce the odds of experiencing a short IPI. [108,112,113] In a recent study examining choice of immediate contraception post-delivery, the researchers found that individuals who gave birth via Cesarean-section were more likely than those delivering vaginally to choose tubal ligation as their method of contraception immediately post-delivery, those who were younger were more likely to opt for LARCs rather than tubal ligation immediately post-delivery, and individuals with public insurance were more likely than those with private insurance to choose LARCs immediately post-delivery. [113] Contraception immediately post-delivery has gained popularity in recent years due the decreased burden it places on individuals – they don't have to coordinate follow up visits for insertion or implantation, find childcare, and ensure that they still have insurance coverage at the time of insertion or implantation.

While more and more individuals are opting for immediate contraceptive options, those who do not should receive contraceptive options counseling at their postpartum checkup. [22] However, several barriers may make it harder for individuals to make it to this visit to obtain those more effective methods of contraception. I hypothesize that those individuals with short IPIs and therefore have two young children to care for may be less likely to make it to these appointments, and either opt for no contraception or less effective methods that can be purchased or obtained without a medical consult (i.e. condoms, natural family planning, etc.).[114] Attendance at a postpartum checkup is a strong predictor for use of effective contraception after pregnancy.

[18,23,24,115] This complex interplay of factors and forces makes this study important in establishing how does IPI impact contraceptive use in the postpartum period.

Unintended Pregnancy in the United States

Unintended pregnancy, as commonly defined in the literature, refers to a pregnancy that was mistimed or unwanted. Mistimed pregnancies occurred earlier than the individual had wanted, and unwanted pregnancies occur when the individual indicates that they never wanted a baby or did not want another baby. The opposite of an unintended pregnancy is a pregnancy that occurred at around the time that the individual had wanted to become pregnant. [116]

As of 2011, it is estimated that approximately 45% of pregnancies in the United States are unintended, according to data from the National Survey of Family Growth. Of those 45% of unintended pregnancies, it is estimated that 27% were mistimed and 18% were unwanted. [117] Unintended pregnancies are consistently associated with inadequate prenatal care, increased risk of smoking during pregnancy and in the postpartum, PPD, decreased breastfeeding, and increased risk of having an infant born with low birth weight or preterm birth. [116–119] Those who are below the federal poverty level, are not married, are younger, have less education, and who identify as Black/African American or Hispanic are at greater risk of experiencing an unintended pregnancy than their counterparts [117,120].

Given pregnancy intention's associations with the variables included in my analyses and the fact that many pregnancies which are conceived after a short IPI are unintended[25], it is important that I attempt to disentangle and differentiate between the effect that unintended pregnancy has on our outcomes and IPI has on our outcomes. I hypothesize that both pregnancy intention and IPI will be associated with our outcomes – PPD, attendance at the postpartum checkup, and contraceptive use – however through different pathways. In the case of short IPI,

increased demands on one's resources, both physical and mental, may lead to increased stress and less/fewer health maintenance behaviors, which could impact maternal mental health, attendance at the postpartum checkup, and contraceptive use. In the case of unintended pregnancy, those who experience an unintended pregnancy are often those who are more socially disadvantaged and may be experiencing pre-existing psychosocial problems/concerns, which can impact their ability to access and navigate the healthcare system and obtain contraception and impact their postpartum mental health. [121–123] Those who have experienced a short, but intended, IPI and those who have experienced a short and unintended IPI are distinct groups with very different experiences, and in order to best provide care and create appropriate interventions, we must have an accurate understanding of the risk each of these groups face for our outcomes.

Current Study

This investigation allows us to gain a better understanding of IPI's association with a broader range of maternal health outcomes and mother's receipt of important health services in the postpartum period, which are important areas in need of research. As mentioned in the introduction, to the best of my knowledge, only one study has investigated the association between IPI and maternal mental health[11], and no studies have looked at whether there is an association between IPI and attendance at a postpartum checkup and whether IPI is associated with subsequent contraceptive use and choice.

I hypothesize that the increased demands, both mentally and physically, of having two young children (i.e., a short IPI) will increase one's odds of experiencing PPD symptoms, decrease one's likelihood of having attended the recommended postpartum checkup, and will be associated with increased odds of not using contraception in the postpartum and using a less effective method if one is using contraception. Critically, all associations have been tested to see

if pregnancy intention moderates the association, given that having closely spaced pregnancies in which the second pregnancy is unintended pregnancy vs. having closely spaced pregnancies in which the second pregnancy was intended provide very different contexts, and I wanted to ensure that the associations between IPI and our outcomes are not being driven by pregnancy intention. I hypothesize that for those individuals whose second pregnancy was intended, the association between having a short IPI and experiencing PPD symptoms and the association between having a short IPI and not attending the postpartum checkup will be weaker than for those who reported that their second pregnancy was unintended or that they were unsure about their pregnancy intention. I hypothesize that those who planned for closely spaced pregnancies may be more equipped to handle the stress that is associated with this and have been able to plan and put supports in place for this time to allow them to recover, both mentally and physically from childbirth, engage in self-care, and maintain their health by going to appointments. Conversely, I hypothesize that for those individuals whose second pregnancy was unintended or they reported being unsure about their pregnancy intention, the association between having a short IPI and using a less effective method of contraception will be weaker than for those who reported that their second pregnancy was intended or were ambivalent/unsure about their intention. While overall, it is predicted that those with short IPIs will be less likely to use highly effective methods of contraception, due to barriers in accessing services to get these methods (e.g. attending routine medical appointments, scheduling LARC insertion, etc.), I anticipate that those who had an unintended second pregnancy will be more motivated to put measures in place to prevent future unintended pregnancies and may prioritize this.

The conceptualization of the relationship between these variables using the Double ABC-X model is unique in that it highlights and takes into account the multiple factors that affect the

impact that a non-optimal IPI has on maternal mental health and receipt of healthcare services in the postpartum. While the focus thus far in terms of interventions to reduce the burden and adverse effects associated with short IPIs has been focused on increasing contraceptive use, and there are no interventions for decreasing pregnancies after long IPIs, I hope the findings from this study, along with the current framework, will allow us to broaden the scope of this conversation and lead to potentially new interventions to mitigate or reduce the negative outcomes associated with non-optimal IPIs. As the Double ABC-X model states, there are multiple things that influence one's reaction to the situation – the stressor itself (a), but also the resources one has available (b), the perception of the situation (c), the pileup that occurs as one/the family copes with the situation (aA), new resources that might become available (bB), and the perception of all the changes that have occurred because of all of these factors (cC).

Methods

Data Source and Population

Data from phase 7 (2012-2015) of The Pregnancy Risk Assessment Monitoring System (PRAMS), an ongoing, cross-sectional, state-based survey that is conducted by the Centers for Disease Control and Prevention (CDC), was used in this investigation. PRAMS began in 1987 and serves to assess and gather information about new mothers' experiences, attitudes, and behaviors before and during pregnancy and in the postpartum period. [124,125]

PRAMS uses a complex sample design within each jurisdiction in order to be representative of individuals giving birth to a live infant in that jurisdiction that year. Analysis weights are calculated with sampling, nonresponse, and noncoverage components taken into account. In order for researchers to receive data for a jurisdiction, a minimum response threshold must be met by that jurisdiction for that year. [124,125] For phase 7, 37 states and New York City were able to release data during at least one year within the phase.

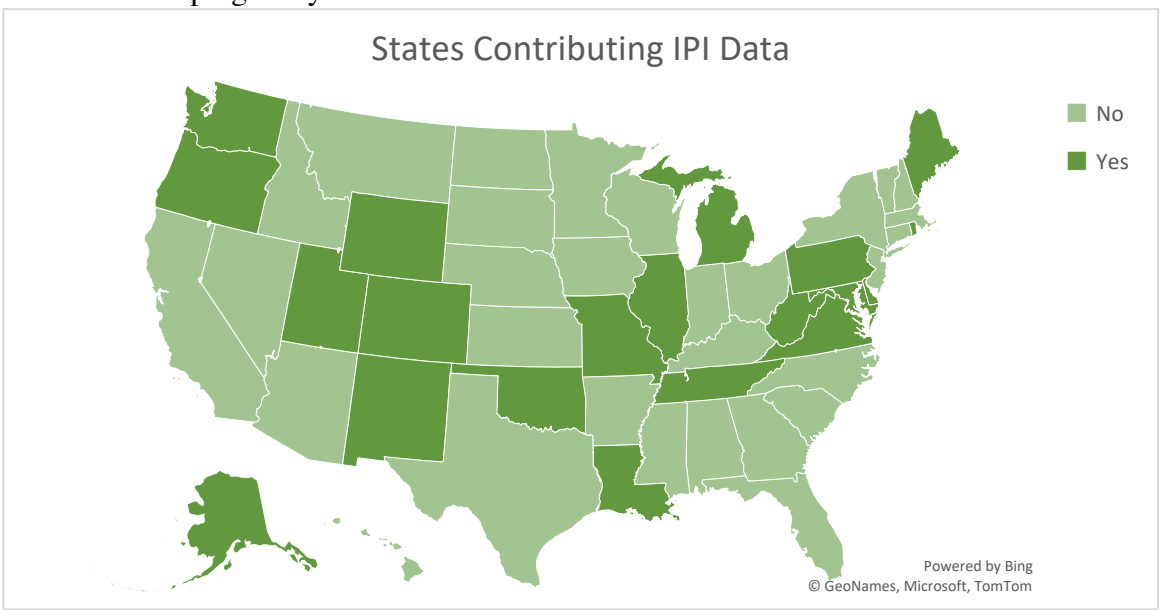
A select number of individuals who have given birth that year within that jurisdiction are selected from birth certificate records and invited to participate in PRAMS. Depending on the jurisdiction, the number of individuals selected each year varies between 1,000 and 3,000, and certain subgroups of individuals are over sampled. Each individual jurisdiction utilizes a stratification plan that is in alignment with their priorities and needs. First contact with a participant is made through the mail, however if an individual is non responsive, PRAMS follows up via phone calls. Incentives and rewards are offered by the jurisdictions in order to increase participation. Selected individuals are surveyed between 2 to 6 months postpartum. [124,125]

The PRAMS survey is composed of core questions - which are asked of all participants, standard questions - which states can choose whether they would like to ask or not, and state

specific questions - which are developed by the individual state for inclusion in their survey that year. Some data from the birth certificate records are included with the typical PRAMS data files. [124,125]

In addition to the typical PRAMS data files, the data for this dissertation were enhanced with additional measures from the birth certificate. Specifically, to calculate interpregnancy interval (IPI), information regarding the date of a woman's last live birth was needed. This variable is not included in the traditional PRAMS data file that can be distributed by the CDC and required special permission from each individual jurisdiction (i.e. state) to add into the data file. Thus, this enhanced data file with information on the specific date of last live birth allows calculation of interpregnancy intervals for all births in the analytic file that can be linked to specific outcomes in the PRAMS survey. I received approval from 20 out of the 37 states (Figure 2).

Figure 2: Graphical Depiction Showing the States that Contributed the Data Necessary to Calculate Interpregnancy Interval



Analytic Sample for Aims 1 & 2

The analytic sample for aims 1 & 2 were participants within the phase 7 dataset who had at least one prior birth, delivered a singleton for their most recent delivery, and whose infant was alive at the time of survey.

Analytic Sample for Aim 3

The analytic sample for aim 3 was participants within the phase 7 dataset who had at least one prior birth, delivered a singleton for their most recent delivery, and whose infant was alive at the time of survey. Additionally, participants were excluded if they reported that they were not actively engaging in heterosexual intercourse at the time of survey, had a hysterectomy, or it was indecipherable/unknown what they reported for their type of contraception. When analyzing the type of contraception, analyses were further restricted to respondents who reported using any contraceptive method.

Variables

Exposure: Interpregnancy Interval

The variable for IPI was created by calculating the interbirth interval (date of current birth – date of last live birth) and subtracting the gestational age. This produced the IPI, or the interval between last live birth and conception of the most recent pregnancy. I first examined IPI in 6-month intervals up to 23 months, between 24-59 months, and 60+ months. For each aim, unique cut-offs were determined after examination of the association between these detailed categories and the outcome. Categories were collapsed into broader IPI classifications when the associations were similar across the 6-month groupings in order to maximize precision of the estimates. Pregnancies with implausible IPI values reported due to erroneous reporting (anything less than 1 months was considered to be an implausible IPI) were excluded. The reference group

in all analyses was the longest IPI classification given that this was the group I hypothesized would have the lowest odds of experiencing each of the outcomes of interest.

Outcomes

Aim 1: Postpartum Depression (PPD) Symptoms

Elevated PPD symptoms were assessed using two core questions within PRAMS, which roughly correspond to the PHQ-2, which has been validated in prior studies. [126] Participants are asked to respond in the PRAMS survey indicating how often they have experienced each of two symptoms since giving birth using a 5-point Likert-type scale, which includes the response options of always, often, sometimes, rarely, or never. The questions are: (1) how often they felt down, depressed or hopeless since their new baby was born and (2) how often they had little interest or little pleasure in doing things since their new baby was born. Those who reported "always" or "often" experiencing any of the symptoms were coded as experiencing elevated PPD symptoms, which is in line with PRAMS researchers' suggestions on how to code PPD. [127]

Aim 2: Postpartum Checkup

Whether or not the participant has attended their recommended postpartum checkup was assessed using one core question in the PRAMS survey, which asks "Since your new baby was born, have you had a postpartum checkup for yourself? A postpartum checkup is the regular checkup a woman has about 4-6 weeks after she gives birth." Participants were able to respond either yes or no to this question.

Aim 3: Contraception

Current contraceptive use was assessed in two ways. First, a dichotomous variable for current contraceptive use (yes/no) was created. This variable was created using the core question in the PRAMS survey which asks "Are you or your husband or partner doing anything now to

keep from getting pregnant? Some things people do to keep from getting pregnant include using birth control pills, condoms, withdrawal, or natural family planning." Respondents could either select yes or no to this question.

If a respondent indicated that they and their partner were doing something to keep from getting pregnant again, they were asked to answer a follow up question which provided several contraceptive options and asked the respondent to indicate "What kind of birth control are you or your husband or partner using now to keep from getting pregnant?" Response options include: tubes tied or blocked (female sterilization), vasectomy (male sterilization), birth control pill, condoms, injection (Depo-Provera), contraceptive implant (Implanon), contraceptive patch (OrthoEvra) or vaginal ring (NuvaRing), IUD (including Mirena or ParaGard), natural family planning (including rhythm method), withdrawal (pulling out), not having sex (abstinence), or other. Respondents can indicate that multiple methods are being used. I created a categorical variable based on the effectiveness of the contraceptive method. The categories included: 1) Sterilization (tubes tied or blocked (female sterilization) and vasectomy (male sterilization)), 2) Highly-effective methods - LARCs (contraceptive implant (Implanon) and IUD (including Mirena or ParaGard)), 3) Moderately effective methods (birth control pill, injection (Depo-Provera), contraceptive patch (OrthEvra) or vaginal ring (NuvaRing)), and 4) Least effective methods (condoms, natural family planning (including rhythm method), and withdrawal (pulling out)).[128] Respondents who indicated using multiple methods were categorized with the most effective method that they used. Respondents who indicated "other" to this question and who chose to write in what contraception they were using were recategorized into the appropriate category above, when possible. Based on write in answers, several types of contraception were identified as not being available within the PRAMS' response options. Participants indicating

that they were using vaginal contraceptive film, spermicide, cervical cap or diaphragm were recategorized into the least effective contraception category.

Effect Modifier: Pregnancy Intention

Pregnancy intention is being thought of as both a confounder in the conceptualization of this study and a potential moderator. Pregnancy intention influences length of IPI and all of the outcomes that are being studied (therefore justifying its role as a confounder), but I also hypothesize that the association between IPI and each of the outcomes will be different (in magnitude or direction) based on pregnancy intention. Therefore, I will test for moderation, and if there is no evidence for moderation, pregnancy intention will be left in regression models as a confounder for each aim.

In PRAMS, pregnancy intention is assessed with the question: "Thinking back to just before you got pregnant with your new baby, how did you feel about becoming pregnant?" Participants can either respond that they had: 1) wanted to be pregnant sooner, 2) wanted to be pregnant later, 3) wanted to be pregnant then, 4) didn't want to be pregnant then or at any time in the future, or 5) I wasn't sure what I wanted. Those who responded with options 1 or 3 were categorized as having an intended pregnancy. Those who responded with either options 2 or 4 were categorized as having an unintended pregnancy, and those who responded with the 5th choice were categorized as being unsure about their pregnancy intention at the time that they became pregnant.

Covariates

Table 1: Roles for Each Covariate in Analyses for Each Aim

	Aim 1	**Aim 2**	**Aim 3**
Maternal Age at Previous Birth	Confounder	Confounder	Confounder
Maternal Race/Ethnicity	Confounder	Confounder	Confounder
Maternal Pre-Conception Insurance	Confounder	Confounder	Confounder
Maternal Postpartum Insurance	-----	Sensitivity Analysis	Sensitivity Analysis
Maternal Education	Confounder	Confounder	Confounder
Marital Status	Confounder	Confounder	Confounder
Previous Live Births	Confounder	Confounder	Confounder
Prior Adverse Pregnancy Outcome – Preterm Birth	Confounder	-----	-----
Prior Adverse Pregnancy Outcome – Low Birth Weight	Confounder	-----	-----
Depression Before Pregnancy	Confounder	-----	-----
Care During Pregnancy – Prenatal Care	Descriptives Table		
Care During Pregnancy – Engagement with Preparation Services for Baby	Descriptives Table		
Vaginal Delivery	Descriptives Table		
Infant Admission to ICU	Descriptives Table		
Current Breastfeeding	-----	-----	Sensitivity Analysis
Time Since Birth[1]	Covariate	Covariate	Covariate

Note: "-----" indicates that the variable does not have a role in the analyses for that aim.
[1] While time since birth is a covariate given its relationship to the outcomes, it was controlled for in analyses to increase the precision of estimates.

Sociodemographics: Maternal age at previous birth, maternal race/ethnicity, maternal pre-conception insurance, maternal postpartum insurance, maternal education, and marital status

- Categorical data for maternal age at the time of a woman's current birth is available as part of the PRAMS data file. Maternal age at the time of this most recent birth is grouped as follows: 17 years old or younger, 18-19 years old, 20-24 years old, 25-29 years old, 30-34 years old, 35-39 years old, and 40+ years old. For my analyses, I needed to ascertain the estimated maternal age at the time of her previous birth. In order to create an

estimate of this, I took the median age in months within each woman's reported age category at the time of her current birth and subtracted from it her IPI in months. This provided a rough estimate of her age category at her previous birth. I then created the following categories for estimated maternal age at previous birth: <20 years old, 20-24 years old, 25-29 years old, 30-34 years old, and 35+ years.

- Maternal race/ethnicity includes the following categories: non-Hispanic white, non-Hispanic Black, Hispanic, Asian/Pacific-Islander, and other. This variable was created using two variables from the PRAMS dataset: 1) the maternal race variable – where participants may indicate which of the following racial categories they identify with white, black, American Indian, Chinese, Japanese, Filipino, Hawaiian, Other- Asian, Other-nonwhite, Alaska Native, or mixed race and 2) the Hispanic ethnicity variable – where participants indicate whether they identify as Hispanic (yes/no).
- Maternal pre-conception insurance status at the time of delivery includes the following categories: private, Medicaid, other public insurance, self-pay and other.
- Maternal postpartum insurance status at the time of delivery includes the following categories: private, Medicaid, other public insurance, self-pay and other.
- Maternal education includes the following categories: 0-8 years, 9-11 years, 12 years, 13-15 years, and 16+ years.
- Marital status includes married or other. These are the two categories provided in the PRAMS data, therefore there is no further information as to the relationship statuses of those who selected "other".

Previous live births

- The number of prior births an individual has had was coded as one, two, or three or more.

Prior adverse pregnancy outcome

- Whether the individuals previous pregnancy resulted in a preterm birth was ascertained via the PRAMS survey, where participants were asked to respond yes or no to the following question, "Was the baby just before your new one born earlier than 3 weeks before his or her due date?"
- Whether the individuals previous pregnancy resulted in a low-birth-weight baby was ascertained via the PRAMS survey, where participants were asked to respond yes or no to the following question, "Did the baby born just before your new one weigh 5 pounds, 8 ounces (2.5 kilos) or less at birth?"

Depression before pregnancy

- History of depression pre pregnancy was coded as yes or no and was ascertained based on a question from the PRAMS questionnaire, which asked participants whether "Before you got pregnant with your new baby, did a doctor, nurse, or other health care worker tell you that you had any of the following health conditions – depression?"

Care during pregnancy – prenatal care

- Participants are asked on the PRAMS questionnaire the following question regarding prenatal care: "How many weeks or months pregnant were you when you had your first visit for prenatal care? Do not count a visit that was only for a pregnancy test or only for WIC (the Special Supplemental Nutrition Program for Women, Infants, and Children)." Women can either provide the time point in their pregnancy (in weeks or months) when they had their first prenatal care visit or indicate that they did not receive prenatal care during their pregnancy. I created a binary variable indicating whether a participant received prenatal care or not (yes/no) during their pregnancy.

Care during pregnancy – engagement with preparation services for baby

Preparation for baby

- Participants are asked a series of questions in the PRAMS survey regarding services that they utilized while pregnant to prepare for the arrival of their baby. These include the following three questions, 1) "During your most recent pregnancy, did you take a class or classes to prepare for childbirth and learn what to expect during labor and delivery?", 2) "During your most recent pregnancy, did a home visitor come to your home to help you prepare for your new baby? A home visitor is a nurse, a health care worker, a social worker, or other person who works for a program that helps pregnant women", and 3) "Since your new baby was born, has a home visitor come to your home to help you learn how to take care of yourself or your new baby? A home visitor is a nurse, a health care worker, a social worker, or other person who works for a program that helps mothers of newborns." I created a categorical variable indicating whether or not a participant engaged with support services to prepare to take care of their baby and themselves postpartum and how many of those support services she engaged with. Therefore, my variable has four levels including: no support services, one support service, two support services, and three support services.

Vaginal delivery

- The manner of delivery was ascertained using a birth certificate variable which indicates whether the participant had a vaginal delivery or not.

Infant admission to ICU

- Whether or not the baby spent time in the infant ICU after delivery is asked on the PRAMS survey. The following response options are available: “yes”, “no”, and “I don’t know”.

Current breastfeeding

- Current breastfeeding was assessed using the following question in PRAMS, “Are you currently breastfeeding or feeding pumped milk to your new baby?” Participants can answer yes or no to this question.

Time since birth

- While the goal of PRAMS is to survey individuals between 2-6 months postpartum, individuals differ in the amount of time it takes them to complete the survey once they have been initially contacted. Time since birth was calculated by taking the date of survey completion and subtracting the infants birth date in order to determine at what point in the postpartum (in months) an individual was completing the survey.

Analytic Plan

Aim 1

Analyses were conducted using STATA Version 17, taking the complex sample design into account per recommendations from the CDC. Descriptive bivariate statistics were conducted, along with unadjusted and adjusted binomial logistic regression analyses to examine the association between IPI and elevated PPD symptoms. Regression analyses only included individuals who were not missing data on any of the variables included in the fully adjusted model. Confounders were added in a step-wise manner, with an unadjusted model, a model adjusting for sociodemographics, and a third model adjusting for sociodemographics, previous live births, prior adverse pregnancy outcomes, depression before pregnancy, and time since birth.

An interaction model was run to determine whether there was an interaction between IPI and pregnancy intention. Given there was no evidence of moderation, pregnancy intention was added in as a confounder to the fourth and fully adjusted model. Adjusted predicted probabilities for experiencing elevated PPD symptoms within each pregnancy intention group for each IPI category were calculated to illustrate the relationship between IPI and PPD was consistent across intention group despite variation in the prevalence of PPD in each intention group.

Aim 2

Analyses were conducted using STATA Version 17, taking the complex sample design into account per recommendations from the CDC. Descriptive bivariate statistics were conducted, along with unadjusted and adjusted binomial logistic regression analyses to examine the association between IPI and attendance at the recommended postpartum checkup. Regression analyses only included individuals who were not missing data on any of the variables included in the fully adjusted model. Confounders were added in a step-wise manner, with an unadjusted model, a model adjusting for sociodemographics, and a third model adjusting for sociodemographics, previous live births, and time since birth. An interaction model was run to determine whether there was an interaction between IPI and pregnancy intention. There was no evidence of moderation, therefore pregnancy intention was added in as a confounder to the fourth and fully adjusted model. A sensitivity analysis was conducted where the analytic sample was restricted to those who had insurance in the postpartum period.

Aim 3

Analyses were conducted using STATA Version 17, taking the complex sample design into account per recommendations from the CDC. Descriptive bivariate statistics were conducted, along with unadjusted and adjusted binomial and multinomial logistic regressions to

examine the association between IPI and current contraceptive use and type. Approximately, 2% of the analytic sample indicated that they were already either pregnant or wanting to become pregnant, these individuals were excluded from regression analyses. Regression analyses only included individuals who were not missing data on any of the variables included in the fully adjusted model. An unadjusted logistic regression was first run to examine the association between IPI and any contraceptive use, and then a fully adjusted model, which included the following confounders - maternal age at previous birth, maternal race/ethnicity, maternal pre-conception insurance status, maternal education, marital status, previous live births, and time since birth – was run. Sensitivity analyses were conducted stratifying the sample by current breastfeeding status and restricting based on attendance at postpartum checkup and postpartum insurance. An interaction model was run to determine whether there was an interaction between IPI and pregnancy intention. There was evidence of an interaction, therefore stratified models based on pregnancy intention were presented as well. Adjusted predicted probabilities for using any contraception in the postpartum period within each pregnancy intention group for each IPI category were calculated.

Multinomial logistic regressions to examine the association between IPI and type of contraception used among those reporting use of contraception were completed. The fully adjusted multinomial logistic regression examining the association between IPI and type of contraceptive use in the postpartum period included the following confounders - maternal age at previous birth, maternal race/ethnicity, maternal pre-conception insurance status, maternal education, marital status, previous live births, time since birth, and pregnancy intention. Results were then further stratified based on pregnancy intention, even though there was not a significant effect of moderation.

Results

Descriptive Characteristics by Interpregnancy Interval (Aims 1 and 2)

In the analytic sample, 4.7% of births occurred after an IPI of less than 6 months, 11.0% had IPIs between 6 - 11 months, 14.7% had IPIs between 12-17 months, 49.7% had IPIs between 18-59 months, and 19.9% had IPIs greater than or equal to 60 months. Overall, 11.6% of the analytic sample had elevated PPD symptoms, and 89.5% had attended their postpartum checkup.

Table 2 presents select maternal and infant characteristics by IPI, weighted to represent the population of mothers who participated in PRAMS during this time period among states included in analyses. The majority of women identified as non-Hispanic white, had private insurance before their pregnancy and in the postpartum, and were married at the time of survey completion. The majority of individuals in the analytic sample had only one prior birth, engaged in prenatal care during their most recent pregnancy, described their most recent pregnancy as intended, had a vaginal delivery, and were currently breastfeeding.

When stratified by IPI, those with shorter IPIs and long IPIs were more likely to identify as non-Hispanic Black and report being unmarried at the time of survey completion compared to those with IPIs in the middle range. Those with short IPIs were more likely to be on Medicaid before their most recent pregnancy and in the postpartum. Engagement with prenatal care services was high among all IPI groups (99.0% and higher). Those with shorter IPIs were less likely to report currently breastfeeding and were more likely to report that their most recent pregnancy was unintended or they were unsure about their pregnancy intention compared to those with longer IPIs (Table 2). Differences across IPI categories were statistically significant (p values <0.001) for all covariates with the exception of prenatal care, which did not vary significantly ($p=0.162$).

Table 2: Aims 1 & 2: Descriptive Table of Analytic Sample for Aims 1 & 2
Percent distribution of select characteristics by interpregnancy interval among singleton, second-born or higher births; PRAMS 2012-2015

		Interpregnancy Interval (IPI)					
	Total 100% (N=39,250)	**Less than 6 months 4.7% (N=1,982)**	**6-11 months 11.0% (N=4,204)**	**12-17 months 14.7% (N=5,376)**	**18-59 months 49.7% (N=19,311)**	**60+ months 19.9% (N=8,377)**	**P-Value [1]**
Elevated PPD Symptoms							
Yes	11.6	17.5	12.4	11.1	10.8	12.1	<0.001
Postpartum Check Up							
Yes	89.5	84.8	88.3	90.1	90.2	89.2	<0.001
Maternal Age at Previous Birth							
Teenager	8.9	7.1	3.8	1.9	10.5	13.3	<0.001
20-24 years	27.5	32.8	22.9	19.6	25.6	39.2	
25-29 years	31.3	29.9	33.1	31.7	30.5	32.2	
30-34 years	23.5	20.8	27.2	32.7	24.4	13.2	
35+ years	8.8	9.3	13.0	14.2	8.9	2.2	
Maternal Race/Ethnicity							
Non-Hispanic White	63.7	61.1	67.7	71.5	65.9	51.0	<0.001
Non-Hispanic/Black	12.1	16.4	12.1	9.2	11.1	15.9	
Hispanic	10.8	10.8	9.3	7.9	9.7	16.5	
Asian/Pacific Islander	3.6	2.4	2.4	3.6	4.0	3.7	
Other	9.7	9.3	8.5	7.8	9.3	12.9	
Maternal Pre-Conception Insurance							
Private	52.2	35.4	51.3	58.7	55.2	44.1	<0.001
Medicaid	23.5	41.3	25.8	20.9	21.6	25.0	
Other Public Insurance	3.5	3.9	4.8	3.2	3.5	3.2	
Self-Pay	18.4	17.0	15.7	15.4	17.2	25.5	
Other	2.4	2.4	2.4	1.8	2.6	2.2	
Maternal Postpartum Insurance							
Private	49.9	33.0	49.8	57.1	53.1	40.5	<0.001
Medicaid	29.3	43.1	29.2	23.8	27.5	34.4	
Other Public Insurance	3.4	4.7	4.8	3.4	3.2	2.8	
Self-Pay	14.9	16.1	13.8	13.2	13.7	19.7	
Other	2.5	3.1	2.4	2.5	2.5	2.6	
Maternal Education							
0-8 years	4.0	5.1	3.0	3.1	3.4	6.3	<0.001
9-11 years	10.3	19.5	11.7	9.0	9.3	10.9	
12 years	24.3	30.1	23.4	20.2	23.4	28.6	

13-15 years	30.0	26.7	27.4	25.4	30.0	36.3	
16+ years	31.4	18.7	34.5	42.4	34.1	17.9	
Marital Status							
Married	67.6	53.2	70.9	76.0	70.7	55.0	<0.001
Other	32.4	46.8	29.1	24.0	29.3	45.1	
Previous Live Births							
One	54.3	48.7	54.7	55.4	56.0	50.5	<0.001
Two	27.1	24.0	24.1	25.0	27.0	31.4	
Three or more	18.6	27.3	21.2	19.6	17.0	18.1	
Prior Adverse Pregnancy Outcome							
Preterm Birth							
Yes	11.4	15.7	11.1	9.1	11.1	13.1	<0.001
Low Birth Weight							
Yes	10.6	13.9	10.1	8.9	10.2	12.4	<0.001
Depression Before Pregnancy							
Yes	10.7	14.3	10.4	8.1	10.0	13.4	<0.001
Care During Pregnancy							
Prenatal Care							
Yes	99.5	99.0	99.3	99.4	99.5	99.6	0.162
Engagement with Preparation Services for Baby							
No support services	78.1	77.1	80.0	80.4	78.5	74.5	<0.001
One support service	15.9	14.5	14.4	14.0	15.9	18.7	
Two support services	4.9	6.6	4.5	4.5	4.6	5.5	
Three support services	1.1	1.8	1.1	1.0	1.0	1.3	
Vaginal Delivery							
Yes	67.9	69.7	71.2	70.8	67.9	63.6	<0.001
Infant Admission to ICU							
Yes	9.2	11.6	8.3	6.7	8.8	12.0	<0.001
Current Breastfeeding							
Yes	59.3	37.7	61.3	69.5	61.1	50.4	<0.001
Time Since Birth							
<3 months	4.0	4.2	3.9	3.8	4.3	3.7	<0.001
3-5 months	65.7	56.6	66.0	69.3	66.7	62.5	
5-7 months	25.9	31.9	25.4	23.5	24.6	29.7	
7+ months	4.4	7.3	4.7	3.4	4.4	4.1	
Pregnancy Intention							
Unintended	28.7	54.0	44.1	30.7	23.8	25.2	<0.001
Not Sure	15.1	19.2	13.4	12.9	14.2	19.2	
Intended	56.1	26.8	42.5	56.4	62.1	55.6	

Note: Missing values were <5% for all covariates, except for current breastfeeding (14.5% missing)
Note: While raw numbers are presented in the heading for each IPI group, all percentages reported throughout the table are weighted taking into account the survey design.
[1] Pearson's chi-square statistic with correction for the complex design

Aim 1 Analyses: Interpregnancy Interval and Postpartum Depression

The prevalence of elevated PPD symptoms was 12.2% for individuals with IPIs less than 18 months, 10.6% for individuals with IPIs equal to or greater than 18 months but less than 60 months, and 11.9% for individuals with IPIs greater than or equal to 60 months. Using a binomial logistic regression, I examined whether elevated PPD symptoms differed by three IPI groups (less than 18 months, 18-59 months, and 60+ months). A final unweighted sample of N=34,420 individuals who participated in PRAMS from 2012-2015 were included in regression analyses (weighted N=1,676,031). Unadjusted and adjusted ORs for the relationship between IPI and PPD are presented in Table 3. Initially, we explored the association between IPI and PPD symptoms among more granular IPI groups, however groups were collapsed due to the similarity in the associations (see Supplemental Table 1).

In the unadjusted model, individuals who had IPIs between 18 months and 59 months had significantly lower odds of PPD (OR: 0.87, 95% CI: 0.76 – 1.00, p=0.043) when compared to those who had IPIs of 60 months or greater. There was no statistically significant difference in odds of experiencing elevated PPD symptoms between those with IPIs of less than 18 months when compared to those with IPIs of 60 months or greater (OR: 1.03, 95% CI: 0.89 – 1.18, p=0.721).

After adjusting for sociodemographics, including maternal age at previous birth, maternal race/ethnicity, maternal pre-conception insurance, maternal education, and marital status, the direction of the effect changed. Results after adjustment for these confounders showed an

increase in odds of experiencing elevated PPD symptoms in those with IPIs less than 18 months when compared to those with IPIs greater than or equal to 60 months (aOR: 1.19, 95% CI: 1.02 – 1.38, p=0.023), and there was no significant difference in odds of experiencing elevated PPD symptoms between those with IPIs of 18-59 months and those with IPIs greater than or equal to 60 months (aOR: 1.00, 95% CI: 0.87 – 1.14, p=0.976). The magnitude of this association increased after the addition of the following confounders - previous pregnancy outcomes, depression before pregnancy, and time since birth. Those who had IPIs less than 18 months were significantly more likely to experience elevated PPD symptoms (aOR: 1.28, 95% CI: 1.10 – 1.49, p=0.001) when compared to those with IPIs greater than or equal to 60 months. Those who had IPIs greater than 18 months but less than 60 months were still not significantly more likely to experience elevated PPD symptoms (aOR: 1.05, 95% CI: 0.92 – 1.21, p=0.474) when compared to those with IPIs greater than or equal to 60 months.

An interaction term was fit to determine whether pregnancy intention moderated the association between IPI and PPD. There was not a statistically significant interaction between IPI and pregnancy intention, indicating that the relationship between IPI and elevated PPD symptoms did not differ among levels of pregnancy intention (Figure 3). Regardless of the participant's reported pregnancy intention, the shorter the IPI the higher the adjusted predicted probability of experiencing elevated PPD symptoms.

As pregnancy intention was not found to be a significant moderator, pregnancy intention was treated as a confounder and included in the fully adjusted regression model. Results were attenuated after the addition of this confounder; however, those who had IPIs less than 18 months were still significantly more likely to experience elevated PPD symptoms (aOR: 1.19, 95% CI: 1.02 – 1.39, p=0.024) when compared to those with IPIs greater than or equal to 60

months. Those who had IPIs greater than 18 months but less than 60 months were not significantly more likely to experience elevated PPD symptoms (aOR: 1.04, 95% CI: 0.91 – 1.19, p=0.571) when compared to those with IPIs greater than or equal to 60 months.

Table 3: Aim 1: Logistic Regression Results for Interpregnancy Interval Predicting Postpartum Depression for PRAMS Sample; 2012-2015

	Model 1	**Model 2**	**Model 3**	**Model 4**
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
IPI				
Less than 18 months	1.03 (0.89 – 1.18)	1.19 (1.02 – 1.38)*	1.28 (1.10 – 1.49)*	1.19 (1.02 – 1.39)*
18 – 59 months	0.87 (0.76 – 1.00)*	1.00 (0.87 – 1.14)	1.05 (0.92 – 1.21)	1.04 (0.91 – 1.19)
60+ months	Ref.	Ref.	Ref.	Ref.
Maternal Age at Previous Birth				
Teenager		1.27 (0.97 – 1.65)	1.47 (1.10 – 1.95)*	1.41 (1.06 – 1.87)*
20-24 years		1.42 (1.13 – 1.78)*	1.55 (1.23 – 1.97)*	1.52 (1.20 – 1.92)*
25-29 years		1.26 (1.01 – 1.57)*	1.30 (1.04 – 1.63)*	1.29 (1.03 – 1.61)*
30-34 years		0.98 (0.78 – 1.23)	1.00 (0.80 – 1.27)	0.99 (0.78 – 1.25)
35+ years		Ref.	Ref.	Ref.
Maternal Race/Ethnicity				
Non-Hispanic White		Ref.	Ref.	Ref.
Non-Hispanic Black		1.02 (0.86 – 1.20)	1.23 (1.04 – 1.46)*	1.18 (0.99 – 1.40)
Hispanic		0.74 (0.62 – 0.89)*	0.90 (0.75 – 1.08)	0.90 (0.75 – 1.08)
Asian/Pacific Islander		1.74 (1.38 – 2.20)*	2.10 (1.66 – 2.66)*	2.07 (1.63 – 2.62)*
Other		0.96 (0.81 – 1.14)	1.09 (0.91 – 1.30)	1.09 (0.91 – 1.30)
Maternal Pre-Conception Insurance				
Private		Ref.	Ref.	Ref.
Medicaid		1.51 (1.30 – 1.75)*	1.33 (1.14 – 1.55)*	1.30 (1.12 – 1.52)*
Other Public Insurance		1.04 (0.80 – 1.36)	0.97 (0.74 – 1.27)	0.95 (0.72 – 1.25)
Self-Pay		1.10 (0.93 – 1.30)	1.09 (0.92 – 1.29)	1.06 (0.90 – 1.26)
Other		1.69 (1.21 – 2.36)*	1.53 (1.07 – 2.19)*	1.50 (1.05 – 2.14)*
Maternal Education				
0-8 years		1.22 (0.86 – 1.72)	1.16 (0.82 – 1.65)	1.15 (0.81 – 1.63)
9-11 years		1.79 (1.45 – 2.23)*	1.57 (1.25 – 1.97)*	1.55 (1.23 – 1.94)*
12 years		1.73 (1.45 – 2.06)*	1.58 (1.32 – 1.90)*	1.54 (1.29 – 1.85)*
13-15 years		1.45 (1.24 – 1.69)*	1.33 (1.14 – 1.56)*	1.30 (1.11 – 1.52)*
16+ years		Ref.	Ref.	Ref.
Marital Status				
Married		Ref.	Ref.	Ref.
Other		1.26 (1.11 – 1.43)*	1.17 (1.03 – 1.33)*	1.09 (0.96 – 1.25)
Previous Live Births				
One			0.87 (0.75 – 1.02)	0.91 (0.78 – 1.06)
Two			0.90 (0.76 – 1.05)	0.91 (0.77 – 1.06)
Three or more			Ref.	Ref.
Prior Adverse Pregnancy Outcome				
Preterm birth				
Yes			1.16 (0.98 – 1.36)	1.15 (0.97 – 1.36)
No			Ref.	Ref.

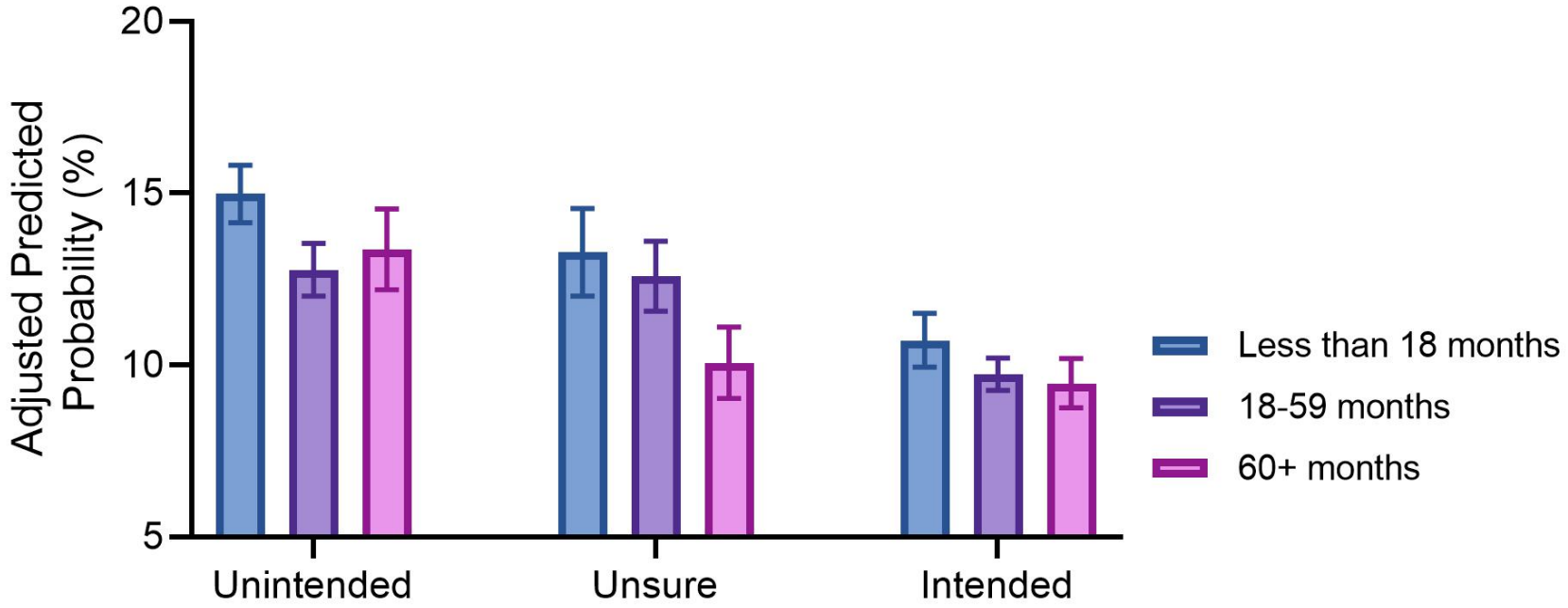
Low Birth Weight			1.06 (0.88 – 1.26)	1.05 (0.88 – 1.26)
Yes			Ref.	Ref.
No				
Depression Before Pregnancy				
Yes			3.78 (3.33 – 4.30)*	3.71 (3.26 – 4.21)*
No			Ref.	Ref.
Time Since Birth				
<3 months			1.01 (0.71 – 1.45)	1.01 (0.70 – 1.44)
3-5 months			1.01 (0.80 – 1.27)	1.01 (0.81 – 1.27)
5-7 months			0.74 (0.58 – 0.94)*	0.75 (0.59 – 0.95)*
7+ months			Ref.	Ref.
Pregnancy Intention				
Unintended				1.45 (1.28 – 1.65)*
Not Sure				1.26 (1.08 – 1.46)*
Intended				Ref.

*Indicates significance at the 0.05 level.

Note: Unweighted N =34,420, Weighted N = 1,676,031

Note: 12% of analytic sample was missing on one or more of the confounders and were dropped from regression analyses.

Figure 3: Aim 1: Predicted Probability of Experiencing Elevated Postpartum Depressive Symptoms By Pregnancy Intention and Interpregnancy Interval for PRAMS Sample; 2012-2015



Note: Confounders adjusted for include maternal age at previous birth, maternal race/ethnicity, maternal preconception insurance, maternal education, marital status, previous live birth, prior adverse pregnancy outcomes – preterm birth, prior adverse pregnancy outcomes – low birth weight, depression before pregnancy, and time since birth.
Note: The adjusted predicted probability of experiencing elevated PPD symptoms and standard error are reported for each IPI group within the categories of pregnancy intention.

Aim 2 Analyses: Interpregnancy Interval and Postpartum Checkup

Using a binomial logistic regression, I examined whether attendance at the postpartum checkup differed by five IPI groups (less than 12 months, 12-17 months, 18-23 months, 24-59 months, and 60+ months). A final unweighted sample of N=36,142 individuals who participated in PRAMS from 2012-2015 were included in regression analyses (weighted N=1,754,723). Unadjusted and adjusted ORs for the relationship between IPI and attendance at postpartum checkup are presented in Table 4.

In the unadjusted model, individuals who had shorter IPIs (less than 12 months) had significantly lower odds of attending the postpartum checkup (OR: 0.84, 95% CI: 0.71 – 0.99, p=0.035) when compared to those who had long IPIs of 60 months or greater. None of the other IPI groups different in a statistically meaningful way from the reference group in odds of attending the postpartum checkup in the unadjusted analysis.

After adjusting for sociodemographics, including maternal age at previous birth, maternal race/ethnicity, maternal pre-conception insurance, maternal education, and marital status, the magnitude of the association increased. After adjustment for these confounders, results showed those with IPIs less than 12 months were much less likely to attend their postpartum checkup than those with a long IPI (aOR: 0.78, 95% CI: 0.66 – 0.92, p=0.004). The addition of previous live births and time since birth marginally increased this effect further. Those with IPIs less than 12 months (aOR: 0.76, 95% CI: 0.64 – 0.91, p=0.002) and those with IPIs between 12-17 months (aOR: 0.82, 95% CI: 0.68 – 0.99, p=0.038) were less likely to attend their postpartum checkup than those with long IPIs.

An interaction term was fit to determine whether pregnancy intention moderated the association between IPI and attendance at a postpartum checkup. There was not a statistically

significant interaction between IPI and pregnancy intention, indicating that the relationship between IPI and attendance at a postpartum checkup did not differ among levels of pregnancy intention. As pregnancy intention was not found to be a significant moderator, pregnancy intention was treated as a confounder and included in the fully adjusted regression model. Results were attenuated after the addition of this confounder, however those who had IPIs less than 12 months were still significantly less likely to attend their postpartum checkup (aOR: 0.78, 95% CI: 0.66 – 0.93, p=0.006) when compared to those with IPIs greater than or equal to 60 months.

Table 4: Aim 2: Logistic Regression Results for Interpregnancy Interval Predicting Attendance at Postpartum Check Up for PRAMS Sample; 2012-2015

	Model 1	**Model 2**	**Model 3**	**Model 4**
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
IPI				
Less than 12 months	0.84 (0.71 – 0.99)*	0.78 (0.66 – 0.92)*	0.76 (0.64 – 0.91)*	0.78 (0.66 – 0.93)*
12 – 17 months	1.10 (0.92 – 1.31)	0.84 (0.70 – 1.02)	0.82 (0.68 – 0.99)*	0.83 (0.69 – 1.00)
18 – 23 months	1.13 (0.93 – 1.36)	0.87 (0.71 – 1.06)	0.83 (0.68 – 1.02)	0.83 (0.68 – 1.02)
24 - 59 months	1.12 (0.97 – 1.29)	0.96 (0.83 – 1.12)	0.96 (0.83 – 1.11)	0.96 (0.83 - 1.11)
60+ months	Ref.	Ref.	Ref.	Ref.
Maternal Age at Previous Birth				
Teenager		1.15 (0.89 – 1.49)	0.88 (0.67 – 1.16)	0.89 (0.67 – 1.18)
20-24		1.17 (0.94 – 1.45)	0.98 (0.78 – 1.22)	0.98 (0.78 – 1.23)
25-29		1.12 (0.91 – 1.38)	1.03 (0.83 – 1.27)	1.03 (0.83 – 1.27)
30-34		1.32 (1.05 – 1.65)*	1.26 (1.01 – 1.59)*	1.26 (1.01 – 1.59)*
35+		Ref.	Ref.	Ref.
Maternal Race/Ethnicity				
Non-Hispanic White		Ref.	Ref.	Ref.
Non-Hispanic Black		1.09 (0.92 – 1.29)	1.11 (0.93 – 1.32)	1.13 (0.95 – 1.34)
Hispanic		1.03 (0.87 – 1.21)	1.01 (0.86 – 1.19)	0.99 (0.84 – 1.16)
Asian/Pacific Islander		0.80 (0.60 – 1.07)	0.76 (0.56 – 1.02)	0.76 (0.57 – 1.03)
Other		0.87 (0.74 – 1.04)	0.88 (0.74 – 1.04)	0.87 (0.73 – 1.03)
Maternal Pre-Conception Insurance				
Private		Ref.	Ref.	Ref.
Medicaid		0.50 (0.43 – 0.59)*	0.53 (0.45 – 0.63)*	0.54 (0.46 – 0.64)*
Other Public Insurance		0.57 (0.43 – 0.75)*	0.58 (0.44 – 0.77)*	0.59 (0.45 – 0.78)*
Self-Pay		0.55 (0.46 – 0.64)*	0.56 (0.47 – 0.66)*	0.57 (0.48 – 0.67)*
Other		0.41 (0.29 – 0.56)*	0.41 (0.30 – 0.58)*	0.42 (0.30 – 0.59)*
Maternal Education				
0-8 years		0.29 (0.22 – 0.38)*	0.33 (0.25 – 0.44)*	0.33 (0.25 – 0.44)*
9-11 years		0.36 (0.29 – 0.45)*	0.41 (0.33 – 0.52)*	0.42 (0.33 – 0.52)*
12 years		0.53 (0.43 – 0.64)*	0.58 (0.48 – 0.70)*	0.59 (0.49 – 0.72)*
13-15 years		0.66 (0.55 – 0.79)*	0.71 (0.59 – 0.85)*	0.72 (0.60 – 0.87)*

16+ years		Ref.	Ref.	Ref.
Marital Status				
Married		Ref.	Ref.	Ref.
Other		0.78 (0.68 – 0.88)*	0.76 (0.67 – 0.86)*	0.79 (0.69 – 0.90)*
Previous Live Births				
One			1.53 (1.32 – 1.77)*	1.49 (1.28 – 1.72)*
Two			1.25 (1.08 – 1.45)*	1.24 (1.07 – 1.44)*
Three or more			Ref.	Ref.
Time Since Birth				
<3 months			0.66 (0.46 – 0.95)*	0.66 (0.46 – 0.95)*
3-5 months			0.88 (0.68 – 1.13)	0.88 (0.69 – 1.13)
5-7 months			0.96 (0.75 – 1.25)	0.96 (0.75 – 1.25)
7+ months			Ref.	Ref.
Pregnancy Intention				
Unintended				0.87 (0.77 – 0.99)*
Not Sure				0.77 (0.66 – 0.88)*
Intended				Ref.

*Indicates significance at the 0.05 level.
Note: Unweighted N =36,142, Weighted N = 1,754,723
Note: 8% of analytic sample was missing on one or more of the confounders and were dropped from regression analyses.

When restricted to include only individuals who had insurance coverage in the postpartum period, regardless of whether it was private insurance or Medicaid, the association between short IPIs and likelihood of attending postpartum checkups was attenuated and no longer significant (Table 5a). Results showed little variation in odds of attending the postpartum checkup across all IPI groups less than 60 months compared with IPIs of 60+ months. When restricted to only individuals who had no insurance in the postpartum (Table 5b), those with IPIs of less than 12 months were less likely to attend their postpartum checkup (aOR: 0.68, 95% CI: 0.49 – 0.96, p=0.027) compared to those with longer IPIs.

Table 5a: Aim 2: Logistic Regression Results for Interpregnancy Interval Predicting Attendance at Postpartum Check Up – Restricted Sample to Only Those with Insurance in the Postpartum; PRAMS 2012-2015

	Any Insurance	**Private Insurance**	**Medicaid**
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**
IPI			
Less than 12 months	0.84 (0.68 – 1.04)	0.87 (0.60 – 1.26)	0.83 (0.64 – 1.08)
12 – 17 months	0.87 (0.70 – 1.09)	0.93 (0.64 – 1.34)	0.80 (0.59 – 1.07)
18 – 23 months	0.77 (0.61 – 0.97)*	0.84 (0.57 – 1.22)	0.67 (0.49 – 0.92)*
24-59 months	0.91 (0.77 - 1.09)	0.84 (0.63 - 1.12)	0.94 (0.75 - 1.18)
60+ months	Ref.	Ref.	Ref.

*Indicates significance at the 0.05 level.

Note: Models adjusted for maternal age at previous birth, maternal race/ethnicity, maternal pre-conception insurance status, maternal education, marital status, previous live births, time since birth, and pregnancy intention.

Table 5b: Aim 2: Logistic Regression Results for Interpregnancy Interval Predicting Attendance at Postpartum Check Up – Comparison of Those with Insurance to Those who are Uninsured; PRAMS 2012-2015

	Any Insurance	**No Insurance**
	OR (95% CI)	**OR (95% CI)**
IPI		
Less than 12 months	0.84 (0.68 – 1.04)	0.68 (0.49 – 0.96)*
12 – 17 months	0.87 (0.70 – 1.09)	0.72 (0.49 – 1.05)
18 – 23 months	0.77 (0.61 – 0.97)*	0.93 (0.62 – 1.39)
24-59 months	0.91 (0.77 - 1.09)	1.06 (0.80 – 1.41)
60+ months	Ref.	Ref.

*Indicates significance at the 0.05 level.

Note: Models adjusted for maternal age at previous birth, maternal race/ethnicity, maternal pre-conception insurance status, maternal education, marital status, previous live births, time since birth, and pregnancy intention.

Descriptive Characteristics by Interpregnancy Interval (Aim 3)

In the analytic sample for this aim, 4.7% of individuals had IPIs of less than 6 months, 11.0% had IPIs between 6 - 11 months, 14.6% had IPIs between 12-17 months, 12.4% had IPIs between 18-23 months, 37.5% had IPIs between 24-59 months, and 19.7% had IPIs greater than or equal to 60 months. Overall, 86.2% of the analytic sample reported that they were using some form of contraception in the postpartum. Among those who indicated that they were using contraception, 22.3% reported having had a sterilization procedure, 20.2% reported using highly effective methods of contraception, 28.4% reported using moderately effective methods of contraception, and 29.2% reported using least effective methods of contraception.

Table 6 presents select maternal characteristics by IPI, weighted to represent the population of mothers who participated in PRAMS during this time period. The majority of participants identified as non-Hispanic white, had private insurance before their pregnancy and in the postpartum, and were married at the time of survey completion. The majority of individuals in the analytic sample had only one prior birth, were currently breastfeeding, and described their most recent pregnancy as intended.

Those with short IPIs and long IPIs were more likely to identify as non-Hispanic Black and be unmarried compared to those with IPIs in the middle range. Those with short IPIs were more likely to be on Medicaid before their most recent pregnancy and in the postpartum compared to those with longer IPIs. Those with short IPIs were less likely to report currently breastfeeding, were more likely to report that their most recent pregnancy was unintended or they were unsure about their pregnancy intention, and were more likely to be experiencing elevated PPD symptoms compared to those with longer IPIs (Table 6). All covariates were statistically significantly different (p values <0.001).

Table 6: Aim 3: Descriptive Table of Analytic Sample for Aim 3
Percent distribution of select characteristics by interpregnancy interval among singleton, second-born, or higher births; PRAMS 2012-2015

		Interpregnancy Interval (IPI)						
	Total 100% (N=35,967)	**Less than 6 months 4.7% (N=1,818)**	**6-11 months 11.0% (N=3,849)**	**12-17 months 14.6% (N=4,956)**	**18-23 months 12.4% (N=4,212)**	**24-59 months 37.5% (N=13,517)**	**60+ months 19.7% (N=7,615)**	**P-Value [1]**
Postpartum Contraceptive Use								
Yes	86.2	88.6	86.5	84.7	85.9	86.6	85.8	0.0849
Type of Contraception [2,3]								
Sterilization	22.3	23.3	19.9	18.9	20.1	22.5	26.9	<0.001
Highly effective methods	20.2	24.2	20.6	18.9	20.8	20.6	18.9	
Moderately effective methods	28.4	31.1	29.0	27.6	26.1	28.2	29.6	
Least effective methods	29.2	21.3	30.5	34.6	33.0	28.8	24.6	
Maternal Age at Previous Birth								
Teenager	9.0	7.1	3.8	1.9	1.5	13.5	13.5	<0.001
20-24 years	27.6	33.4	23.0	20.0	17.3	28.6	38.9	
25-29 years	31.5	30.0	33.4	31.9	31.4	30.5	32.3	
30-34 years	23.5	20.1	27.5	32.6	35.7	20.5	13.1	
35+ years	8.6	9.6	12.4	13.7	14.2	6.9	2.2	
Maternal Race/Ethnicity								
Non-Hispanic White	63.6	62.2	67.4	71.3	70.8	64.2	50.4	<0.001
Non-Hispanic/Black	11.8	14.7	12.1	9.0	8.8	11.4	15.4	
Hispanic	11.2	11.4	9.7	7.9	8.8	10.5	17.4	
Asian/Pacific Islander	3.7	2.3	2.4	3.7	3.8	4.0	3.9	
Other	9.8	9.5	8.5	8.1	7.7	9.9	12.9	
Maternal Pre-Conception Insurance								
Private	52.4	36.2	51.7	58.7	60.0	53.7	44.7	<0.001
Medicaid	23.1	40.6	24.8	20.5	19.3	21.9	24.2	
Other Public Insurance	3.5	3.9	4.8	3.2	2.9	3.5	3.0	
Self-Pay	18.8	16.9	16.2	15.7	15.4	18.3	26.0	
Other	2.4	2.3	2.5	2.0	2.3	2.6	2.2	
Maternal Postpartum Insurance								
Private	50.2	33.8	50.2	57.1	58.3	51.6	41.1	<0.001
Medicaid	28.7	42.7	28.3	23.2	23.4	28.5	33.2	
Other Public Insurance	3.4	4.9	4.7	3.3	2.8	3.3	2.6	
Self-Pay	15.3	15.7	14.4	13.7	13.4	14.1	20.4	
Other	2.5	2.9	2.4	2.7	2.0	2.5	2.6	

Maternal Education								
0-8 years	4.1	4.9	3.0	3.4	3.1	3.6	6.8	<0.001
9-11 years	10.3	19.3	11.3	9.4	8.7	9.5	10.9	
12 years	24.4	30.7	23.9	20.0	20.0	24.6	28.9	
13-15 years	30.0	26.4	27.1	25.6	27.2	31.0	35.6	
16+ years	31.2	18.7	34.7	41.8	41.0	31.4	17.9	
Marital Status								
Married	68.5	54.1	72.0	76.9	76.9	69.7	56.3	<0.001
Other	31.5	45.9	28.0	23.1	23.1	30.3	43.7	
Previous Live Births								
One	54.1	48.9	54.7	55.1	57.3	55.0	50.4	<0.001
Two	27.4	23.6	24.0	25.0	25.3	28.1	31.9	
Three or more	18.6	27.6	21.3	19.9	17.4	16.9	17.8	
Current Breastfeeding								
Yes	58.9	37.5	60.8	69.3	67.4	58.4	49.7	<0.001
Time Since Birth								
<3 months	3.9	4.1	3.6	3.7	4.0	4.2	3.5	<0.001
3-5 months	65.7	57.0	62.3	68.9	68.6	66.2	62.2	
5-7 months	26.1	31.8	25.3	24.1	22.9	25.2	30.2	
7+ months	4.4	7.1	4.9	3.4	4.4	4.8	4.1	
Pregnancy Intention								
Unintended	28.2	54.2	43.5	30.4	23.1	23.3	24.3	<0.001
Not Sure	14.8	18.5	13.4	12.7	12.9	14.1	18.9	
Intended	57.0	27.3	43.1	56.9	64.0	62.7	56.8	
Elevated PPD Symptoms								
Yes	11.2	16.5	11.7	10.6	9.7	10.8	11.9	<0.001

Note: Those who reported not actively engaging in heterosexual intercourse, having had a hysterectomy, or whose response was indecipherable or unknown for type of contraception used were excluded from the analytic sample for this aim.

Note: Missing values were <5% for all covariates, except for current breastfeeding (14.5% missing)

Note: While raw numbers are presented in the heading for each IPI group, all percentages reported throughout the table are weighted taking into account the survey design.

[1] Pearson's chi-square statistic with correction for the complex design

[2] Participants were categorized into mutually exclusive groups for which type of contraception they were using. If a participant indicated using multiple methods, they were grouped according to the most effective method that they reported using.

[3] Sterilization procedures included having tubes tied or a vasectomy. Highly effective methods included the implant and IUD. Moderately effective methods included the birth control pill, injection, contraceptive patch, or vaginal ring. Least effective methods included condoms, natural family planning, withdrawal, spermicide, vaginal contraceptive film, diaphragms or cervical cap.

Aim 3 Analyses: Interpregnancy Interval and Postpartum Contraceptive Use

Any Contraceptive Use

Using a binomial logistic regression, I examined whether any postpartum contraceptive use differed by six IPI groups (less than 6 months, 6-11 months, 12-17 months, 18-23 months, 24-59 months, and 60+ months). A final unweighted sample of N=32,036 individuals who participated in PRAMS from 2012-2015 were included in regression analyses (weighted N=1,559,761). Results of the unadjusted regression are presented below in text, and results of the fully adjusted regression are presented in Table 7a in the first column.

In the unadjusted model, individuals who had shorter IPIs (less than 6 months) had significantly higher odds of using any contraception in the postpartum (OR: 1.41, 95% CI: 1.04 – 1.90, p=0.026) when compared to those who had long IPIs of 60 months or greater. None of the other IPI groups different in a statistically meaningful way from the reference group in odds of using any contraception in the postpartum in the unadjusted analysis. In the fully adjusted model, after adjusting for maternal age at previous birth, maternal race/ethnicity, maternal pre-conception insurance status, maternal education, marital status, previous live births, and time since birth, results showed those with IPIs less than 6 months were still more likely to be using any contraception in the postpartum (aOR: 1.52, 95% CI: 1.12 – 2.07, p=0.007) compared to those with long IPIs.

Stratified analyses based on current breastfeeding demonstrated that this association was only present among those who were not currently breastfeeding. Among individuals who were currently breastfeeding, there were no statistically significant associations between IPI and contraceptive use in the postpartum. Among individuals who were not currently breastfeeding, those with IPIs of less than 6 months were more likely to be using any contraception in the

postpartum (aOR: 2.11, 95% CI: 1.28 – 3.48, p=0.003) compared to those with long IPIs (Table 7a).

In further sensitivity analyses where the sample was restricted to those who had had a postpartum checkup already (aOR: 1.90, 95% CI: 1.30 – 2.77, p=0.001) and to those who had insurance in the postpartum (aOR: 1.85, 95% CI: 1.31 – 2.61, p=0.001) both demonstrated that the association between short IPI and increased odds of using any contraception in the postpartum period remained and the magnitude of the association increased (Table 7a). When restricting to only those who do not have insurance coverage in the postpartum period, there was no association between IPI and contraceptive use. In analyses that stratified based on whether the woman was currently experiencing elevated PPD symptoms or not, those who did not have elevated PPD symptoms exhibited a similar pattern to the complete sample - with those with IPIs of less than 6 months having greater odds of using contraception (aOR: 1.62, 95% CI: 1.15 – 2.27, p=0.006) compared to those with longer IPIs. Among individuals with elevated PPD symptoms, there was a lot of variability in the data (Table 7b).

Table 7a: Aim 3: Logistic Regression Results for Interpregnancy Interval Predicting Any Contraceptive Use – Including Sensitivity Analyses Stratifying Based on Breastfeeding and Restricting Based on Attendance at a Postpartum Checkup and Postpartum Insurance; PRAMS 2012-2015

	Complete Case Analysis	**Among Women Currently Breastfeeding**	**Among Women not Currently Breastfeeding**	**Among Women Who Attended Postpartum Visit**	**Among Women Who Have Postpartum Insurance**
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
IPI					
Less than 6 months	1.52 (1.12 – 2.07)*	1.23 (0.74 – 2.04)	2.11 (1.28 – 3.48)*	1.90 (1.30 – 2.77)*	1.85 (1.31 – 2.61)*
6 - 11 months	1.15 (0.94 – 1.41)	1.08 (0.82 – 1.43)	1.37 (0.96 – 1.97)	1.19 (0.96 – 1.49)	1.28 (1.02 – 1.60)*
12 – 17 months	0.91 (0.76 – 1.09)	0.90 (0.70 – 1.16)	1.14 (0.80 – 1.63)	0.93 (0.76 – 1.14)	0.98 (0.80 – 1.20)
18 – 23 months	0.97 (0.80 – 1.17)	0.94 (0.73 – 1.22)	1.42 (0.98 – 2.06)	0.97 (0.79 – 1.20)	1.01 (0.82 – 1.24)
24-59 months	1.01 (0.87 – 1.18)	0.95 (0.77 – 1.18)	1.12 (0.87 – 1.44)	1.06 (0.90 – 1.25)	1.02 (0.87 – 1.20)
60+ months	Ref.	Ref.	Ref.	Ref.	Ref.

*Indicates significance at the 0.05 level.

Note: Models adjusted for maternal age at previous birth, maternal race/ethnicity, maternal pre-conception insurance status, maternal education, marital status, previous live births, and time since birth.

Note: 2% of analytic sample indicated either wanting to be pregnant or being pregnant at the time of survey. These individuals were excluded in regression analyses.

Table 7b: Aim 3: Logistic Regression Results for Interpregnancy Interval Predicting Any Contraceptive Use Stratified by Elevated Postpartum Depressive Symptom Status; PRAMS 2012-2015

	Complete Case Analysis	**Among Women without Elevated PPD Symptoms**	**Among Women with Elevated PPD Symptoms**
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**
IPI			
Less than 6 months	1.52 (1.12 – 2.07)*	1.62 (1.15 – 2.27)*	1.31 (0.62 – 2.76)
6 - 11 months	1.15 (0.94 – 1.41)	1.08 (0.87 – 1.35)	1.74 (1.05 – 2.91)*
12 – 17 months	0.91 (0.76 – 1.09)	0.87 (0.71 – 1.05)	1.19 (0.68 – 2.07)
18 – 23 months	0.97 (0.80 – 1.17)	0.96 (0.78 – 1.18)	0.93 (0.56 – 1.54)
24-59 months	1.01 (0.87 – 1.18)	0.95 (0.81 – 1.12)	1.51 (1.01 – 2.25)*
60+ months	Ref.	Ref.	Ref.

*Indicates significance at the 0.05 level.

Note: Models adjusted for maternal age at previous birth, maternal race/ethnicity, maternal pre-conception insurance status, maternal education, marital status, previous live births, and time since birth.

Note: 2% of analytic sample indicated either wanting to be pregnant or being pregnant at the time of survey. These individuals were excluded in regression analyses.

An interaction term was fit to determine whether pregnancy intention moderated the association between IPI and use of any contraception in the postpartum period. There was a statistically significant interaction between IPI and pregnancy intention (p value <0.001). Results stratified by pregnancy intention are presented in Table 8a, Table 8b, and Figure 4. Stratified analyses show that it is among unintended pregnancies that there is an association between short IPI and increased use of any contraception in the postpartum. Among unintended pregnancies, those with IPIs less than 6 months (aOR: 2.31, 95% CI: 1.37 – 3.90, p=0.002) and those with IPIs of 6-11 months (aOR: 2.15, 95% CI: 1.48 – 3.10, p=0.001) were more likely to be using any contraception in the postpartum than those with IPIs of 60 months or greater, and the magnitude of association exceeded that of other IPI intervals and pregnancy intention categories.

Table 8a: Aim 3: Logistic Regression Results for Interpregnancy Interval Predicting Any Contraceptive Use Stratified by Pregnancy Intention – Including Sensitivity Analyses Stratifying Based on Breastfeeding and Restricting Based on Attendance at a Postpartum Checkup and Postpartum Insurance; PRAMS 2012-2015

	Complete Case Analysis	**Among Women Currently Breastfeeding**	**Among Women not Currently Breastfeeding**	**Among Women Who Attended Postpartum Visit**	**Among Women Who Have Postpartum Insurance**
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
Unintended Pregnancy					
IPI					
Less than 6 months	2.31 (1.37 – 3.90)*	1.06 (0.48 – 2.36)	5.92 (2.60 – 13.49)*	2.59 (1.35 – 4.98)*	3.04 (1.74 – 5.32)*
6 - 11 months	2.15 (1.48 – 3.10)*	2.04 (1.16 - 3.58)*	2.96 (1.57 – 5.60)	2.16 (1.45 - 3.22)*	2.13 (1.42 – 3.22)*
12 – 17 months	1.06 (0.75 – 1.50)	0.77 (0.46 – 1.29)	1.76 (0.92 – 3.34)*	1.05 (0.72- 1.54)	1.08 (0.73 – 1.60)
18 – 23 months	1.41 (0.94 – 2.12)	1.23 (0.67 – 2.24)	2.46 (1.20 – 5.07)*	1.44 (0.92 – 2.25)	1.57 (1.00 – 2.45)*
24-59 months	1.20 (0.88 – 1.64)	1.14 (0.70 – 1.87)	1.22 (0.76 – 1.96)	1.35 (0.95 – 1.92)	1.28 (0.90 – 1.83)
60+ months	Ref.	Ref.	Ref.	Ref.	Ref.
Unsure Pregnancy Intention					
IPI					
Less than 6 months	0.88 (0.47 – 1.62)	1.00 (0.28 – 3.54)	0.78 (0.31 – 1.93)	1.03 (0.48 – 2.20)	1.27 (0.61 – 2.64)
6 - 11 months	0.52 (0.32 – 0.83)*	0.46 (0.23 – 0.94)*	0.49 (0.23 – 1.05)	0.56 (0.32 – 0.96)*	0.64 (0.37 – 1.10)
12 – 17 months	0.59 (0.38 – 0.93)*	0.54 (0.28 – 1.04)	0.64 (0.29 – 1.44)	0.56 (0.34 – 0.92)*	0.69 (0.42 – 1.12)
18 – 23 months	0.63 (0.40 - 1.01)	0.60 (0.31 – 1.18)	0.69 (0.30 – 1.57)	0.53 (0.32 – 0.88)*	0.69 (0.41 – 1.13)
24-59 months	0.72 (0.50 – 1.03)	0.62 (0.35 – 1.12)	0.59 (0.33 – 1.03)	0.70 (0.47 – 1.04)	0.78 (0.53 – 1.16)
60+ months	Ref.	Ref.	Ref.	Ref.	Ref.
Intended Pregnancy					
IPI					
Less than 6 months	1.25 (0.76 – 2.05)	1.41 (0.66 – 2.98)	1.11 (0.49 – 2.53)	1.78 (1.00 – 3.15)*	1.27 (0.72 – 2.25)
6 - 11 months	0.97 (0.73 – 1.29)	0.90 (0.62 – 1.29)	1.20 (0.69 – 2.10)	0.98 (0.72 – 1.34)	1.11 (0.81 – 1.52)
12 – 17 months	0.95 (0.74 – 1.22)	1.03 (0.76 – 1.41)	0.98 (0.58 – 1.66)	1.00 (0.77 – 1.30)	1.04 (0.80 – 1.36)
18 – 23 months	0.95 (0.74 – 1.21)	0.95 (0.70 – 1.30)	1.42 (0.85 – 2.37)	0.98 (0.75 – 1.28)	0.99 (0.76 – 1.29)
24-59 months	1.05 (0.87 – 1.27)	0.99 (0.77 – 1.28)	1.35 (0.95 – 1.91)	1.08 (0.88 – 1.33)	1.03 (0.83 – 1.27)
60+ months	Ref.	Ref.	Ref.	Ref.	Ref.

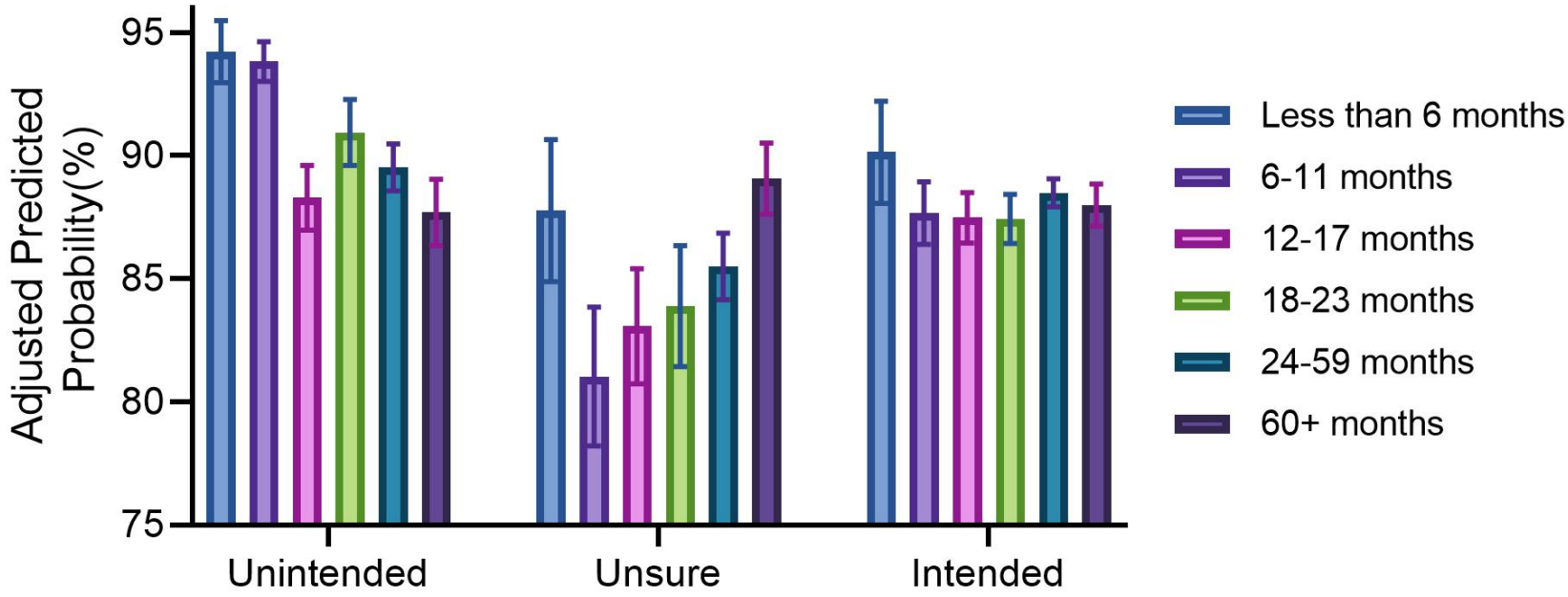
*Indicates significance at the 0.05 level.
Note: Models adjusted for maternal age at previous birth, maternal race/ethnicity, maternal pre-conception insurance status, maternal education, marital status, previous live births, and time since birth.
Note: 2% of analytic sample indicated either wanting to be pregnant or being pregnant at the time of survey. These individuals were excluded in regression analyses.

Table 8b: Aim 3: Logistic Regression Results for Interpregnancy Interval Predicting Any Contraceptive Use Stratified by Pregnancy Intention – Including Sensitivity Analyses Stratifying by Elevated Postpartum Depressive Symptom Status; PRAMS 2012-2015

	Complete Case Analysis	**Among Women without Elevated PPD Symptoms**	**Among Women with Elevated PPD Symptoms**
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**
	Unintended Pregnancy		
IPI			
Less than 6 months	2.31 (1.37 – 3.90)*	2.67 (1.54 – 4.63)*	1.63 (0.59 – 4.52)
6 - 11 months	2.15 (1.48 – 3.10)*	1.97 (1.30 – 2.98)*	3.18 (1.42 – 7.14)*
12 – 17 months	1.06 (0.75 – 1.50)	0.99 (0.68 – 1.44)	1.32 (0.53 – 3.29)
18 – 23 months	1.41 (0.94 – 2.12)	1.35 (0.87 – 2.11)	1.69 (0.59 – 4.84)
24-59 months	1.20 (0.88 – 1.64)	1.08 (0.76 – 1.53)	2.09 (1.02 – 4.28)*
60+ months	Ref.	Ref.	Ref.
	Unsure Pregnancy Intention		
IPI			
Less than 6 months	0.88 (0.47 – 1.62)	0.81 (0.42 – 1.58)	1.44 (0.29 – 7.12)
6 - 11 months	0.52 (0.32 – 0.83)*	0.46 (0.28 – 0.76)*	1.00 (0.28 – 3.63)
12 – 17 months	0.59 (0.38 – 0.93)*	0.56 (0.35 – 0.92)*	0.56 (0.16 – 1.94)
18 – 23 months	0.63 (0.40 - 1.01)	0.61 (0.37 – 1.01)	0.52 (0.15 – 1.88)
24-59 months	0.72 (0.50 – 1.03)	0.70 (0.48 – 1.04)	0.86 (0.33 – 2.26)
60+ months	Ref.	Ref.	Ref.
	Intended Pregnancy		
IPI			
Less than 6 months	1.25 (0.76 – 2.05)	1.34 (0.75 – 2.40)	0.93 (0.32 – 2.73)
6 - 11 months	0.97 (0.73 – 1.29)	0.96 (0.71 – 1.31)	1.06 (0.48 – 2.36)
12 – 17 months	0.95 (0.74 – 1.22)	0.91 (0.70 – 1.19)	1.54 (0.69 – 3.43)
18 – 23 months	0.95 (0.74 – 1.21)	0.97 (0.74 – 1.26)	0.83 (0.42 – 1.65)
24-59 months	1.05 (0.87 – 1.27)	0.99 (0.81 – 1.22)	1.78 (0.99 – 3.21)
60+ months	Ref.	Ref.	Ref.

*Indicates significance at the 0.05 level.
Note: Models adjusted for maternal age at previous birth, maternal race/ethnicity, maternal pre-conception insurance status, maternal education, marital status, previous live births, and time since birth.
Note: 2% of analytic sample indicated either wanting to be pregnant or being pregnant at the time of survey. These individuals were excluded in regression analyses.

Figure 4: Aim 3: Predicted Probability of Using Any Contraception By Pregnancy Intention and Interpregnancy Interval for PRAMS Sample; 2012-2015

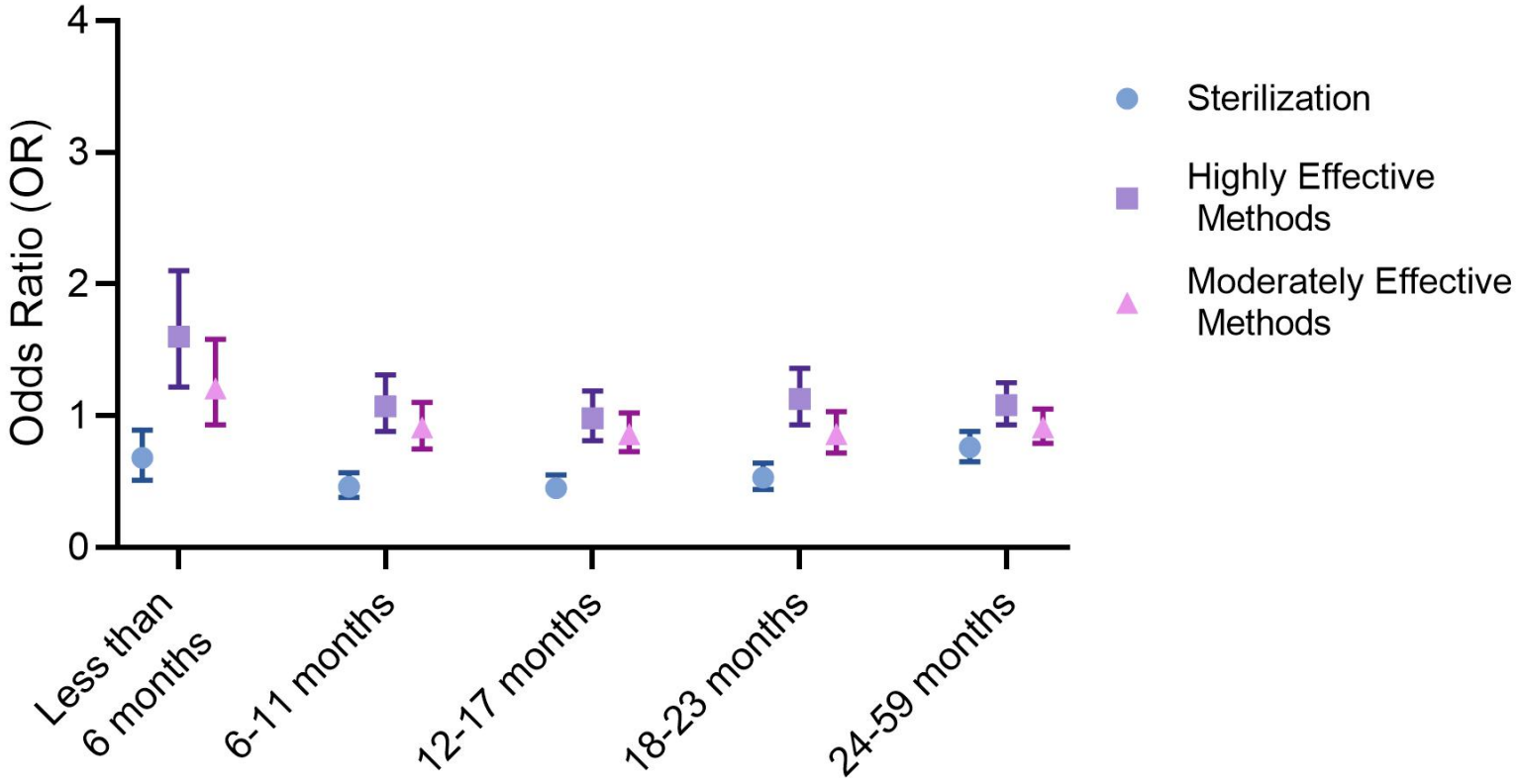


Note: Confounders adjusted for include maternal age at previous birth, maternal race/ethnicity, maternal pre-conception insurance status, maternal education, marital status, previous live births, and time since birth.
Note: The adjusted predicted probability of using any contraception and standard error are reported for each IPI group within the categories of pregnancy intention.

Type of Contraception Used

Among those who reported using contraception in the postpartum period, a multinomial logistic regression was conducted to determine whether there was an association between type of contraception used and IPI. In the unadjusted model, those in all IPI groups, except for those with IPIs of less than 6 months, sterilization was less likely to be used than least-effective methods of contraception (p values <0.001). Those with IPIs less than 6 months (OR: 1.60, 95% CI: 1.24 – 2.08, p<0.001) were more likely to be using highly-effective methods of contraception as opposed to least-effective methods. Those with IPIs between 12-17 months (OR: 0.72, 95% CI: 0.61 – 0.86, p<0.001) and those with IPIs between 18-23 months (OR: 0.80, 95% CI: 0.67 – 0.96, p=0.018) were less likely to be using highly-effective methods of contraception as opposed to least-effective methods. Those with IPIs less than 6 months (OR: 1.30, 95% CI: 1.00 – 1.67, p=0.047) were more likely to be using moderately-effective methods of contraception as opposed to least-effective methods, and those in all other IPI categories were less likely to be using moderately-effective methods of contraception as opposed to least-effective methods (p values <0.02). In fully adjusted analyses, controlling for maternal age at previous birth, maternal race/ethnicity, pre conception insurance, maternal education, marital status, previous live births, time since birth, and pregnancy intention, sterilization was less likely to be used than least-effective methods of contraception across all IPI groups now (p values <0.001). Those with IPIs less than 6 months were still more likely to be using highly-effective methods (aOR: 1.59, 95% CI: 1.22 – 2.10, p=0.001) than least-effective methods. All others associations disappeared after accounting for these confounders (Figure 5). Pregnancy intention was not found to be a significant moderator for the association between IPI and type of contraception, therefore it was initially included as only a confounder in the fully adjusted model.

Figure 5: Aim 3: Figure Depicting Results of Multinomial Logistic Regression for Interpregnancy Interval and Type of Contraception Used in the Postpartum; PRAMS 2012-2015



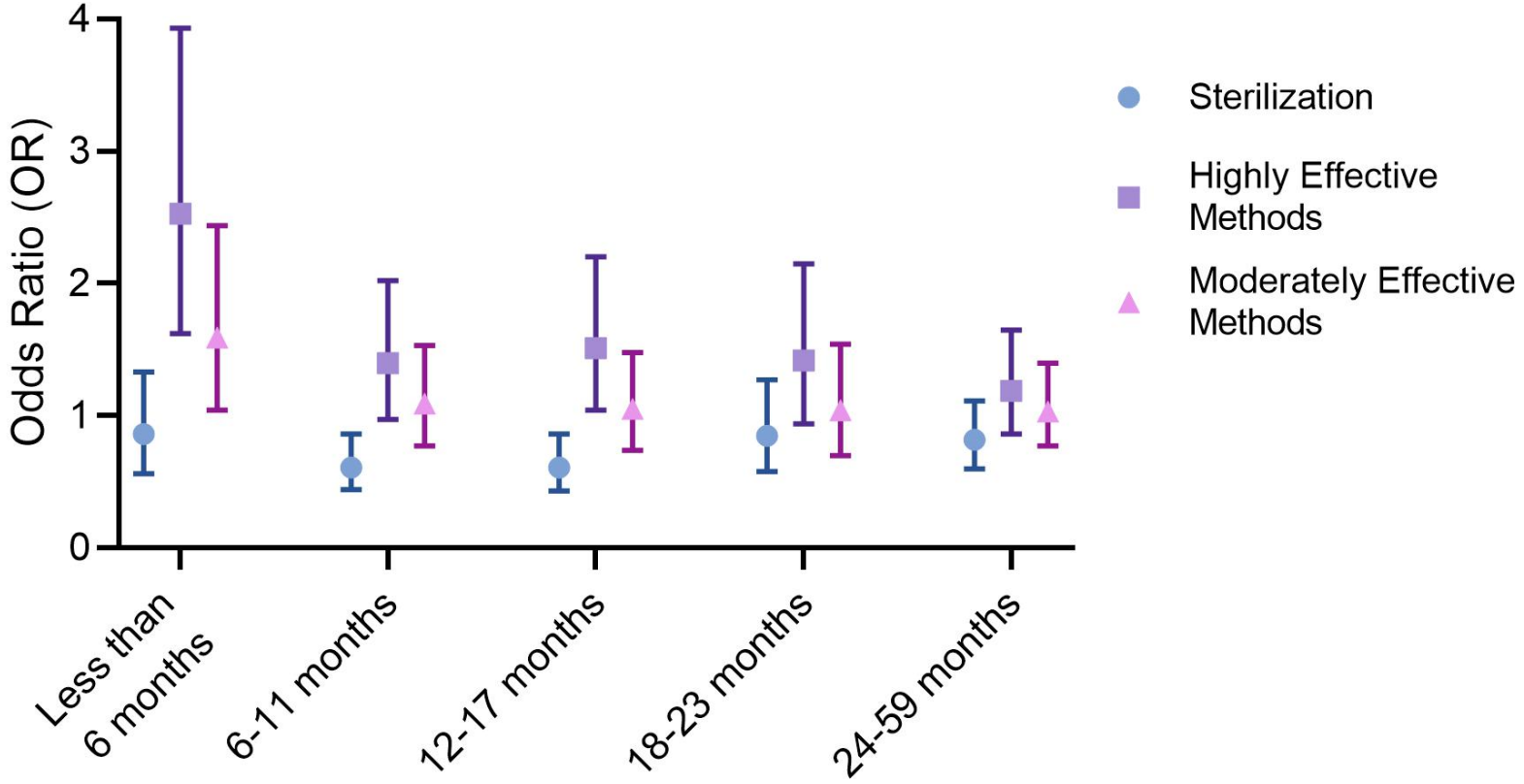
Note: Reference group for IPI was 60+ months.
Note: Base category for type of contraception were least effective methods.
Note: Model adjusted for maternal age at previous birth, maternal race/ethnicity, maternal pre-conception insurance status, maternal education, marital status, previous live births, and time since birth.
Note: Odds ratios and confidence intervals are reported for each type of contraception for each IPI group.

Results were further stratified by pregnancy intention, given that a significant interaction was found between IPI and pregnancy intention for any use of contraception in the previous set of analyses; however, no significant interaction was found for type of contraception used among those who used contraception. Figures 6a and 6b present the stratified analyses because the magnitude of the relationship between IPI and type of contraception appeared different based on pregnancy intention. Fully adjusted results for the stratified analyses are presented below and in Figures 6a and 6b.

Among unintended pregnancies, those with IPIs of 6-11 months (aOR: 0.61, 95% CI: 0.44 – 0.86, p=0.005) and those with IPIs of 12-17 months (aOR: 0.61, 95% CI: 0.43 – 0.86, p=0.006) were less likely to have used a sterilization procedure compared to least effective contraceptive methods, those with IPIs less than 6 months (aOR: 2.53, 95% CI: 1.62 – 3.93, p=<0.001) and between 12-17 months (aOR: 1.51, 95% CI: 1.04 – 2.20, p=0.030) were more likely to be using a highly effective contraceptive method compared to a least effective method, and those with IPIs less than 6 months (aOR: 1.59, 95% CI: 1.04 – 2.44, p=0.032) were more likely to be using a moderately effective contraceptive method compared to a least effective method (Figure 6a).

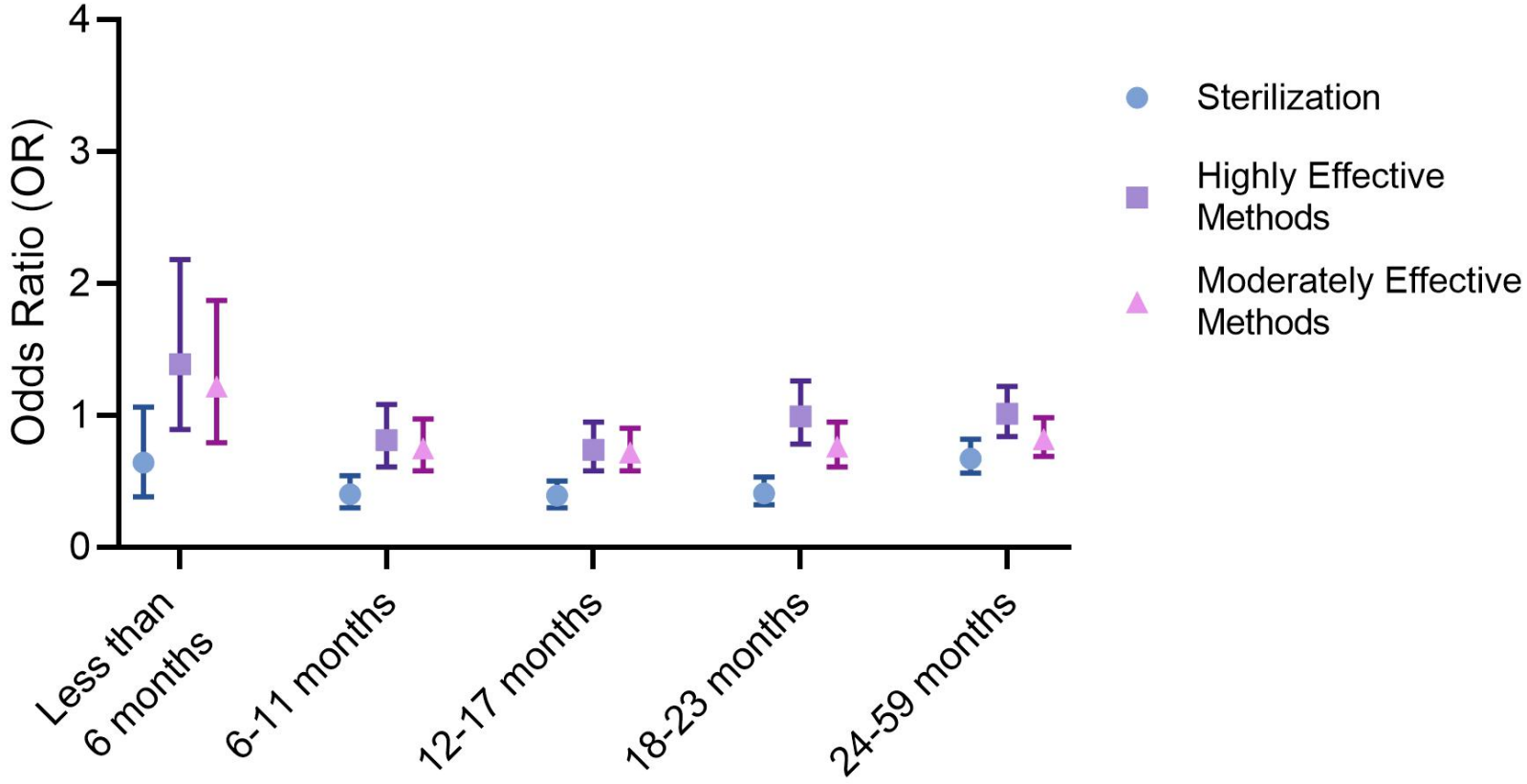
Among intended pregnancies, across all IPI groups sterilization procedures were less common than use of a least effective contraceptive method (p values <0.09), those with an IPI of 12-17 months (aOR: 0.74, 95% CI: 0.58 – 0.95, p=0.019) were less likely to be using a highly effective method of contraception when compared to a least effective method, and across all IPI groups, except those with IPIs of less than 6 months, individuals were less likely to be using a moderately effective method of contraception as compared to a least effective method of contraception (p values <0.05) (Figure 6b).

Figure 6a: Aim 3: Figure Depicting Results of Multinomial Logistic Regression for Interpregnancy Interval and Type of Contraception Used in the Postpartum – Sample Restricted to Those With an Unintended Pregnancy; PRAMS 2012-2015



Note: Reference group for IPI was 60+ months.
Note: Base category for type of contraception were least effective methods.
Note: Model adjusted for maternal age at previous birth, maternal race/ethnicity, maternal pre-conception insurance status, maternal education, marital status, previous live births, and time since birth.
Note: Odds ratios and confidence intervals are reported for each type of contraception for each IPI group.

Figure 6b: Aim 3: Figure Depicting Results of Multinomial Logistic Regression for Interpregnancy Interval and Type of Contraception Used in the Postpartum – Sample Restricted to Those With an Intended Pregnancy; PRAMS 2012-2015



Note: Reference group for IPI was 60+ months.
Note: Base category for type of contraception were least effective methods.
Note: Model adjusted for maternal age at previous birth, maternal race/ethnicity, maternal pre-conception insurance status, maternal education, marital status, previous live births, and time since birth.
Note: Odds ratios and confidence intervals are reported for each type of contraception for each IPI group.

Factors Associated with Being Excluded from Complete Cases Analyses for Each Aim

For each of my aims, I analyzed only data from individuals who were not missing on any of the confounders to be included in the fully adjusted model for that aim. Multiple imputations were not performed due to the complex survey design of the data.

For the first aim, 4,830 individuals were excluded from regression analyses due to missing data for one of the confounders. Those who had between 13-15 years of education were more likely to be missing data on key variables, which led to them being excluded from the sample used in regression analyses. Those who completed the survey within the first 3 months after their birth were less likely to be excluded from the final sample due to missing data on key variables (Table 9).

For the second aim, 3,107 individuals were excluded due to missing data on one of the confounders. Those who completed the survey within the first 3 months after their birth were less likely to be excluded from regression analyses for aim 2 due to missing data (Table 9).

For the third aim, 3,079 individuals were excluded from regression analyses due to missing data. Those identifying as "other" for their pre-conception insurance status, those with less than a high school education, and those with two previous births were more likely to be excluded from regression analyses due to missing data (Table 9).

I controlled for each of these variables which were associated with missingness in regression analyses.

Table 9: Logistic Regression Results Depicting Factors Associated with Missingness for Each Aim; PRAMS 2012-2015

	Aim 1	Aim 2	Aim 3
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**
Maternal Age at Previous Birth			
Teenager	0.49 (0.22 – 1.07)	0.59 (0.18 – 2.01)	0.54 (0.25 – 1.15)
20-24 years	0.58 (0.30 – 1.10)	1.27 (0.50 – 3.20)	0.64 (0.35 – 1.18)
25-29 years	0.78 (0.43 – 1.42)	0.90 (0.37 – 2.19)	0.61 (0.33 – 1.13)
30-34 years	0.83 (0.45 – 1.51)	1.01 (0.41 – 2.49)	1.07 (0.60 – 1.91)
35+ years	Ref.	Ref.	Ref.
Maternal Race/Ethnicity			
Non-Hispanic White	Ref.	Ref.	Ref.
Non-Hispanic/Black	1.28 (0.74 – 2.19)	1.10 (0.54 – 2.23)	1.54 (0.99 – 2.40)
Hispanic	1.14 (0.68 – 1.92)	1.11 (0.56 – 2.21)	1.08 (0.66 – 1.79)
Asian/Pacific Islander	1.81 (0.89 – 3.68)	0.83 (0.29 – 2.34)	1.09 (0.49 – 2.42)
Other	1.58 (0.95 – 2.61)	0.81 (0.45 – 1.46)	0.72 (0.43 – 1.22)
Maternal Pre-Conception Insurance			
Private	Ref.	Ref.	Ref.
Medicaid	1.26 (0.77 – 2.04)	1.08 (0.62 – 1.88)	1.08 (0.66 - 1.77)
Other Public Insurance	1.41 (0.58 – 3.45)	1.06 (0.33 – 3.46)	1.43 (0.56 – 3.66)
Self-Pay	1.27 (0.77 – 2.11)	1.02 (0.53 – 1.97)	1.26 (0.77 – 2.07)
Other	1.79 (0.79 – 4.02)	1.86 (0.72 – 4.77)	2.81 (1.28 – 6.17)*
Maternal Education			
0-8 years	1.35 (0.62 – 2.98)	1.51 (0.51 – 4.47)	4.90 (2.30 – 10.46)*
9-11 years	1.57 (0.81 – 3.03)	1.31 (0.63 – 2.74)	2.08 (1.05 – 4.11)*
12 years	1.39 (0.85 – 2.28)	1.52 (0.86 – 2.68)	1.66 (0.98 – 2.79)
13-15 years	1.63 (1.02 – 2.61)*	0.68 (0.34 – 1.35)	1.09 (0.64 – 1.84)
16+ years	Ref.	Ref.	Ref.
Marital Status			
Married	Ref.	Ref.	Ref.
Other	1.06 (0.69 – 1.62)	1.10 (0.67 – 1.82)	1.07 (0.64 – 1.55)
Previous Live Births			
One	0.98 (0.6 1- 1.59)	0.75 (0.41 – 1.38)	1.32 (0.85 – 2.04)
Two	1.34 (0.84 – 2.14)	1.25 (0.68 – 2.31)	1.75 (1.13 – 2.73)*
Three or more	Ref,	Ref.	Ref.
Prior Adverse Pregnancy Outcome			
Preterm birth			
Yes	0.57 (0.32 – 1.04)	----- [1]	----- [1]
No	Ref.		
Low Birth Weight			
Yes	1.27 (0.74 – 2.16)	----- [1]	-----[1]
No	Ref.		
Depression Before Pregnancy			
Yes	0.70 (0.38 – 1.29)	----- [1]	----- [1]
No	Ref.		
Time Since Birth			
<3 months	0.18 (0.04 – 0.90)*	0.05 (0.01 – 0.23)*	0.51 (0.17 – 1.52)
3-5 months	0.72 (0.32 – 1.65)	0.51 (0.20 – 1.26)	0.62 (0.31 – 1.23)
5-7 months	1.16 (0.50 – 2.70)	0.69 (0.28 – 1.72)	0.80 (0.40 – 1.59)
7+ months	Ref.	Ref.	Ref.
Pregnancy Intention			
Unintended	0.78 (0.52 – 1.15)	1.16 (0.69 – 1.96)	1.08 (0.75 – 1.57)
Not Sure	1.07 (0.69 – 1.66)	1.15 (0.65 – 2.03)	0.98 (0.64 – 1.48)
Intended	Ref.	Ref.	Ref.

*Indicates significance at the 0.05 level.
[1] Indicates that this variable was not used in regression analyses for this aim.

Discussion

Aim 1: Interpregnancy Interval and Postpartum Depression

Among the sample, approximately 30% had IPIs that were less than 18 months, 50% had IPIs that were between 18-59 months, and 20% had IPIs that were at least 60 months or longer. These estimates are similar to estimates produced from data from the National Survey of Family Growth (NSFG), a survey administered by the National Center for Health Statistics at the CDC to understand trends in family structure, fertility and demographics in the United States. NSFG data estimates that approximately 29% of births occur after an IPI of less than 18 months, 52% occur after an IPI between 18-59 months, and 18% occur after an IPI of at least 60 months or greater.[41] Among the sample in this study, 12% reported having elevated PPD symptoms, which is also comparable with recent estimates of the prevalence of PPD in the United States using other data sources.[13]

The results of this study suggest that individuals with short IPIs (less than 18 months), compared to those with long IPIs (greater than or equal to 60 months), were more likely to experience elevated PPD symptoms. This association remained, and grew stronger in magnitude, after adjusting for a wide range of confounders, including maternal age, insurance status, marital status, depression before pregnancy, and pregnancy intention. While those with pregnancies that were unintended or that they were unsure about the pregnancy intention were more likely to experience PPD symptoms than those with intended pregnancies, there was no evidence that pregnancy intention significantly moderated the association between IPI and PPD symptoms. This was contrary to the initial hypothesis. While adjustment for pregnancy intentions attenuated the association between IPI and PPD, a significant association remained for shorter IPI and PPD, suggesting short IPI may have an independent effect on experiencing PPD.

While universal screening for PPD has been identified as a national priority [88–90] given the enormous impact it has on individuals, families, and society [15,129], it has proved difficult to achieve this ideal in busy medical settings due to a variety of factors, including time constraints, lack of clear screening protocols, available resources, etc. [91–93,95] Additionally, individuals vary in whether they attend postpartum checkups, when in the postpartum period they attend these visits, and the amount and type of information they feel comfortable or have time disclosing in these visits.[19,102,130–132] Analysis of PRAMS data from previous surveys has found that the fourth most cited unmet need of individuals in the postpartum is help with identifying and addressing PPD. [133] This suggests, and other research in the field supports, that this part of the postpartum checkup – where mental health needs are assessed and addressed, is lacking. As mentioned above, the first barrier is lack of recognition of symptoms. This may occur because individuals may be hesitant to disclose information related to mental health during these visits because of the stigma that is still sometimes attached to mental health challenges and providers often feel unprepared to handle questions and assessment of mental health concerns. If an individual were to screen positive for postpartum depression and their symptoms were recognized, ensuring that follow up resources are provided to them and they are able to access them are further challenges frequently encountered.[132,134–136]

While ideally all individuals should be screened for depression in the postpartum period as part of their comprehensive postpartum checkup, and current recommendations outline this [88,89,137], this may not be possible to achieve in all settings, and in resource limited settings, there may need to be other approaches used to help identify those most at risk for PPD and direct limited resources to them. Therefore, having a sense of the wide range of risk factors that increase one's chances of experiencing PPD is pertinent information that medical providers can

use to identify individuals who may be more (or less) at risk for experiencing PPD and directing limited resources appropriately.

To date a variety of risk factors for PPD have been identified in the literature, including a past history of depression, stress, lack of social support, unintended pregnancy, however research exploring the potential role of IPI as a risk factor for PPD has been almost entirely absent in the literature. [16,17] To my knowledge, only one previous study has attempted to investigate the association between IPI and PPD, finding similar results to ours indicating that shorter IPIs are associated with increased risk of experiencing PPD symptoms.[11] However, this study was conducted using a small, clinical sample in Turkey several decades ago. The results of this study both confirm and build on this finding suggesting that having pregnancies in close succession to one another, *whether planned or not*, appears to increase one's risk of experiencing PPD.

This is likely due to the increased demands placed on an individual who is caring for two young infants at one time, whether this was planned or not. Having two young infants can result in increased stress, constraints on one's time, and less ability to engage in self-care. This all increases ones likelihood of experiencing PPD and ability to seek care for PPD. Maternal self-care can be defined as "a mother's ability to care for her own physical and emotional needs", with examples including eating properly, getting adequate sleep, and delegating tasks to others in your social support network who are available to help.[138] Research has shown that stress and lack of social supports and connections makes it harder for mom's to engage in needed self-care activities, and self-care has been associated with less fatigue in the postpartum and greater quality of life in the postpartum. [139–142] Future research should continue to investigate the mechanisms through which short IPIs increase risk of PPD, which was outside the scope of this study.

Collectively, the results of this study show that individuals with short IPIs may be at an increased risk of developing PPD, and therefore ensuring that individuals are provided with psychoeducational materials about PPD is vital. IPI may potentially serve as a "red flag" alerting medical providers to ensure that these individuals receive this information, which should include information about how to recognize the symptoms of PPD and resources to utilize to address PPD symptoms, and follow up screening for symptoms. Additionally, my results show that reducing short IPIs may also be an under explored way in which to potentially reduce the prevalence of PPD in the United States.

Ultimately, increasing the amount of mental health providers and psychiatrists who have expertise and training in working with individuals in the perinatal period is much needed. At a recent congressional briefing, the Policy Center for Maternal Mental Health unveiled Maternal Mental Health State Report Cards. These outlined a variety of measures that support maternal mental health and provided grades for states on how well they are doing in each domain. The results showed that only a couple of states in the United States had enough mental health providers who had achieved a high level of training and expertise in working with those in the perinatal period to meet the need for perinatal mental health services in the state, and there was a scarcity of psychiatrists and nurse practitioners who were qualified to prescribe medication to those in the perinatal period.[143] Ensuring that insurance covers needed perinatal mental health services is also essential.

Aim 2: Interpregnancy Interval and Attendance at Postpartum Checkup

Among the sample, approximately 90% of participants indicated that they had attended their recommended postpartum checkup since giving birth. There was some variation based on IPI, with only about 85% of individuals who had IPIs of less than 6 months attending their postpartum check, 88% of individuals with IPIs of 6-11 months attending their postpartum checkup, 90% of individuals with IPIs of 12-17 months attending their postpartum checkup, 90% of individuals with IPIs of 18-59 months attending their postpartum checkup, and 89% of individuals with IPIs of 60 months or greater attending their postpartum checkup. In all regression models, those with IPIs of less than 12 months were slightly less likely than those with long IPIs (60 months or greater) to attend their postpartum checkup; however, the overall prevalence remained high. Contrary to the hypothesis, pregnancy intention did not moderate this association, and therefore pregnancy intention was included as a confounder in the fully adjusted model.

While the postpartum checkup is meant to be a comprehensive visit that all individuals who have recently given birth should attend, in the United States, it is clear from data that this ideal has not been achieved. Estimates vary greatly depending on the data source, however a recent systematic review looking at the wide range of articles in recent years that have looked at postpartum visit attendance estimated that approximately 72% of individuals in the United States attend this visit. [144] In my sample, closer to 90% of individuals report attending this visit. This discrepancy could be due to social desirability bias. PRAMS relies on self-report, and it is possible that survey respondents are over reporting attendance at this visit due to the importance that they know is attached to the visit. The sample could also be accurately reporting their attendance at this visit, which might be indicative that this sample is comprised of more

advantaged individuals, with greater access to care, and who were able to participate in this survey. While prevalence estimates are high in comparison to other data sources, other research using PRAMS reports comparable estimates for attendance at postpartum checkup. [145,146] One study investigating the incongruence between self-report of postpartum visit attendance via PRAMS and Medicaid medical records showed that the discrepancy was mostly accounted for by bundling of medical service codes, leading to under estimates of how many individuals were attending a postpartum checkup when looking at medical records alone.[145]

While federal law requires that individuals be provided with Medicaid coverage for at least the first 60 days postpartum, after that there is variability in which states provide extended coverage for up to one year or not. As of March 2023, 31 states and Washington D.C. have implemented a 12-month extension, however that leaves almost 20 states with less coverage.[147] Data for this analysis was collected between 2012-2015, which was well before states began to increase their postpartum Medicaid coverage. Therefore, a portion of individuals in the sample would have lost pregnancy-related Medicaid coverage by the time of survey completion, which could have potentially impacted their ability to access medical care, including the routine comprehensive postpartum checkup. Due to this, in a sensitivity analysis I restricted the sample to only those reporting that they had insurance at the time of the survey (approximately 82% of the sample) to examine whether results would remain in a sample with equal access to care. When restricted to only individuals with postpartum insurance coverage, there was no longer an association between short IPI and attendance at the postpartum checkup, and the magnitude of the associations between IPI categories less than 60 months compared to before were relatively comparable with a slightly lower (non-significant) odds of having a postpartum checkup. This finding held when stratifying based on type of insurance in the postpartum period (private vs.

Medicaid).

Collectively, these results suggest that, among those with insurance coverage, IPI may not be associated with odds of attending the postpartum checkup, however among a population with mixed access to care, those with short IPIs may be less likely to attend this visit. Additionally, because this sample may have been more likely to attend postpartum care compared to national averages, further research is needed to understand how shorter IPIs may influence this outcome.

More and more states are extending their postpartum insurance coverage to 12 months postpartum, which will provide more individuals with access to important health care in the postpartum period. This is crucial given the fact that approximately a third of pregnancy related deaths occur between 43 and 365 days postpartum.[129] Topics discussed at the postpartum checkup are not limited to only recovery from childbirth, but include topics that have the potential to alter future health trajectories for the individual. In the comprehensive postpartum checkup, providers discuss management of chronic health conditions, family planning and options for contraception, and immunizations. Therefore, attendance at these visits helps to ensure overall health for an individual and connect them with resources to maintain their health as they transition out of the postpartum.

There are a variety of ways in which to increase access to health care services, with insurance coverage being only one of them. Ensuring that there are enough providers throughout the country to provide care to those in the perinatal period, ensuring that providers are able to provide culturally competent care, providing reliable and wide-reaching public transportation systems, providing paid leave to parents, and providing affordable childcare options are all other important resources that we as a society need to work toward providing to also diminish barriers to accessing healthcare and to support parents.

Aim 3: Interpregnancy Interval and Contraception

Among the sample, approximately 86% of participants reported using some form of contraception in the postpartum period. Twenty-nine percent of individuals in the sample indicated using one of the least-effective methods of contraception. Twenty-eight percent of individuals in the sample indicated that they were using a moderately-effective method of contraception. Sterilization procedures were the third most common type of contraception that individuals reported using in the postpartum, with 22% of the sample indicating that this was their method of contraception. Highly-effective methods, such as the implant and IUD, were the least commonly used methods, with 20% of the sample reporting using them.

There was some variation among the different IPI groups in terms of the most common type of contraception used in the postpartum. Sterilization procedures were most common among those with long IPIs (60 months or longer). Highly-effective and moderately-effective methods were most common among the short IPIs (less than 6 months). Least-effective methods were most common among those with IPIs in the mid-range (including the IPI groups of 12-17 months and 18-23 months).

Contrary to the hypothesis, those with short IPIs were more likely to be using contraception in the postpartum compared to those with long IPIs. When the sample was restricted to those who were not breastfeeding, the magnitude of the association between short IPI and any use of contraception increased. No association between IPI and any contraceptive use was found among individuals who were currently breastfeeding at the time of survey completion. This suggests that other factors, besides IPI, factor into choice of contraceptive use in this group.

In sensitivity analyses, which restricted to those who had attended their postpartum

checkup and to those who were insured in the postpartum period, the magnitude of the association between short IPI and increased use of any contraceptive was amplified. This is likely due to the increased access both of these groups had to contraceptive counseling and options, but it does reinforce that those with short IPI who also were able to access care were more likely to begin using a conceptive method in the postpartum period. Contraception is one of the topics discussed in the comprehensive postpartum checkup, and insurance coverage ensures that a wide range of contraceptive options are available to an individual.

Given the evidence showing that depression can impact contraceptive use and choice[148,149], in sensitivity analyses, I examined whether experiencing current elevated depressive symptomology impacted the association between IPI and use of contraception in the postpartum period. Results showed that among those without current elevated PPD symptoms, having an IPI of less than 6 months was associated with increased use of postpartum contraception. Among those who were experiencing elevated PPD symptoms, there was a lot of variability in the data, and those with IPIs of less than 6 months were no longer more likely to be using contraception in the postpartum period compared to those with longer IPIs. These results suggest that current depressive symptoms may impact thought processes, evaluation, and decision-making in ways that impact contraceptive use, making this another important factor for providers to consider when providing contraceptive counseling to individuals.

Pregnancy intention was a significant moderator for the association between IPI and any contraceptive use in the postpartum in the presence of the other confounders that were included in the model; therefore, results were presented stratified by pregnancy intention. Individuals who reported that their last pregnancy was unintended ***and*** after a short IPI were much more likely to report using contraception in the postpartum when compared to those who reported that their last

pregnancies were intended or they were unsure about their pregnancy intention regardless of IPI. Among intended pregnancies, there is no association between IPI and any contraceptive use. Among pregnancies where the intention was unsure, there is a lot of variation in the data making it hard to draw conclusions; however, there is some evidence to suggest that these individuals are potentially less likely to be using contraception overall and that ambiguity in intention may lead to similar contraceptive use across IPI groups. This is in line with other evidence in the literature that finds an association between pregnancy ambivalence and nonuse of contraception.[150]

In fully adjusted analyses examining the association between IPI and type of contraception among those who used contraception in the postpartum period, sterilization was an uncommon method of contraception across all IPI categories, and those with short IPIs (less than 6 months) were more likely to be using highly-effective methods as opposed to least-effective methods. This was in contrast to the original hypothesis, and there was no evidence of pregnancy intention moderating this association.

Despite there being no statistically significant evidence of moderation for IPI and type of contraception, results were presented stratified by pregnancy intention because the magnitude of the relationship appeared to differ based on pregnancy intention and there was evidence of moderation in the previous analysis for any use of contraception. Among unintended pregnancies, those with shorter IPIs were more likely to be using highly-effective or moderately-effective methods of contraception when compared to those with long IPIs.

Collectively, these results suggest that those who had an unintended pregnancy that occurred after a short IPI may not only be more motivated to use contraception to prevent a future pregnancy but are also more likely to be using more effective methods than those who had unintended pregnancies after longer IPIs or those who had intended pregnancies. It appears that

there may be a cumulative effect here where having both a short IPI and an unintended pregnancy together may be more motivating for an individual to elect for more effective methods of contraception in the postpartum period. Whereas, having only one of these stressors by itself may not lead to these contraceptive decisions. These results could also suggest that when both of these factors are present, the previous pregnancy was both unintended and in close succession to the previous one, providers are more likely to push certain contraceptive options on individuals.

Having an understanding of postpartum contraceptive choices and motivations for accessing contraception is important information for informing clinical practice given that we know that the majority of individuals resume sexual activity within the first 3-4 months following birth.[151] In particular, having a greater understanding of the contraceptive choices of these particular groups – those with a history of closely spaced pregnancies and those with a history of unintended pregnancy – can help provide useful information to practitioners about how to direct resources and approach conversations with these individuals about future family planning to prevent future unintended pregnancies. There has been a push in recent years to promote the use of highly-effective methods of contraception in order to help reach our goals of reducing the rate of unintended pregnancy in the United States and to decrease the proportion of births that occur after a short interval. The results of this study are suggestive that health care providers may be reaching their target audiences with this information, and individuals are choosing to use these more effective methods of contraception when provided with information regarding them. Providers must continue to prioritize providing information regarding the full range of contraceptive options and benefits associated with each one to patients and to reduce any stigma and misconceptions about contraception and breastfeeding, which still exist. [152,153] Ultimately, it is an individual's choice which method of contraception they are most comfortable

using and feel is appropriate for their situation, so providers must approach these conversations in a way that still allows the individual to exercise autonomy over their reproductive decisions.

Strengths and Limitations

One of the largest strengths to this study and the analyses completed is that they were completed using a non-clinical sample that is representative of birthing people from 20 states in the United States. Additionally, this uniquely compiled data set allowed me to consider the associations between IPI and a variety of maternal outcomes in the postpartum period, while controlling for a host of important covariates that are traditionally hard to account for in studies of IPI, such as pregnancy intentions and other socioeconomic indicators. Lastly, literature on IPI and postpartum health outcomes is extremely limited and is a gap in the current body of literature. Therefore, the focus on postpartum outcomes in this study begins to address this gap.

There are several limitations to note as well. For aim 1, the measure of PPD is not as robust as others. The two questions PRAMS uses to assess PPD roughly correspond to the PHQ-2 which is a validated screen for PPD that is often used in medical settings, however it is often followed by a more robust screen with greater sensitivity and specificity and/or a diagnostic interview to determine whether the patient truly meets criteria for PPD.[126] Additionally, another limitation lies in the measure of past history of depression. This is assessed in PRAMS using the following question, "Before you got pregnant with your new baby, did a doctor, nurse, or other health care worker tell you that you had any of the following health conditions – depression?". This measure is not fully able to capture participant's complete past history with depression, which is an important and strong risk factor for experiencing PPD.

For aim 2, we see higher than expected percentages of individuals who report having attended their comprehensive postpartum checkup. This may suggest that this sample is more

advantaged and more engaged with health care services. However, if this is the case, and there is still evidence of an association between short IPI and decreased attendance at a postpartum checkup, we would expect the association to be pronounced in a sample that is less advantaged and engaged with health care services. It is also possible that there is misreporting due to social desirability bias or that individuals may simply be indicating that they have been to a medical visit in the postpartum when they respond yes to this question. This may not necessarily be the comprehensive postpartum checkup that PRAMS is intending to reference. At the time of data collection (2012-2015), ACOG still recommended that postpartum care be comprised of a comprehensive postpartum checkup within the first 6 weeks postpartum. Since then, ACOG has revised their guidelines for care in the postpartum to recommend that postpartum care be a continuous process that involves multiple visits that are more individualized to the particular patient and their needs. Patients should see their provider within the first three weeks postpartum, receive ongoing care as needed, and transition to Well Woman Care at around 12 weeks postpartum after a comprehensive checkup.[22] While this new standard of care allows for more individualized treatment and will hopefully address some of the racial disparities and increasing rate of maternal morbidity that we are seeing, it also recommends that individuals should be attending more visits (at least two if not more) in the postpartum period. Given this change in the structure of postpartum care and the increased demand it may potentially place on individuals, future research should continue to explore the potential association between IPI and postpartum care attendance perhaps with continuous measures. There are still many states in which postpartum Medicaid coverage ends at 60 days [147], which may pose some challenges and introduce disparities in ability to access continued care and follow the new recommendations given that these new recommendations suggest care visits should extend further into the

postpartum period than before.

For aim 3, we also see higher than expected use of contraception among the sample. This could once again be suggestive that the sample is more advantaged with greater engagement with health care services than the overall population. Another limitation to note with this aim is that the PRAMS question regarding contraceptive use asks about current use – at the present time. Therefore, this provides only a snapshot of contraceptive use in the postpartum. Many individuals switch types of contraception often and have periods of nonuse[150], therefore future research should utilize longitudinal designs to gather a greater understanding of the patterns of contraceptive use and whether there is continued long term use of the methods that individuals report starting early in the postpartum period. As insurance coverage changes, this may impact individuals contraceptive options that they have available to them and therefore impact their contraceptive behaviors in ways that I wasn't able to capture with this one-time measure.

A limitation that impacts all analyses is that not all states who participate in PRAMS released IPI data to me. Therefore, while results are presumably generalizable to the birthing people in the 20 states that provided data, it is unclear whether they are generalizable to the broader population of birthing individuals in the United States. Future research should continue to investigate the associations between IPI and postpartum mental health, postpartum visit attendance, and contraception using other samples.

Concluding Remarks and Implications

This investigation sought to fill current gaps that exist in the literature on the health outcomes associated with short IPIs. Thus far, the body of research focused on IPI and health has been dominated by a focus on infant health outcomes, and when the focus has shifted to maternal health outcomes, it is often on pregnancy/delivery complications related to one's physical

health.[4–6] Health complications related to pregnancy can occur well into the postpartum period, and many important health decisions continue to be made in the postpartum period as well. In fact, the majority of pregnancy-related maternal deaths (53%) in the United States occur in the postpartum period, after individuals leave the hospital between 7 and 365 days postpartum, and the most frequent underlying cause of pregnancy-related deaths in the United States are mental health conditions. [129] Therefore, this investigation sought to explore IPIs association with a variety of maternal health outcomes, including an outcome related to maternal mental health, and health care indicators in the postpartum period.

The results show that regardless of pregnancy intention, those with short IPIs (less than 18 months) are at an increased risk of experiencing elevated PPD symptoms relative to those with IPIs greater than 60 months. Among those with insurance coverage, IPI may not be associated with odds of attending a comprehensive postpartum checkup, however among a population with mixed access to care, those with IPIs of less than 1 year may be less likely to attend this visit, regardless of pregnancy intention. Lastly, those who had IPIs of less than 6 months were more likely to be using any contraception in the postpartum period when compared to those with IPIs of 60 months of greater. The magnitude of this association was stronger among those who had insurance in the postpartum and among those who had attended their postpartum checkup, suggesting that both of these are important to providing access to contraception for individuals. Pregnancy intention was found to moderate this association with the association between short IPI and increased use of any contraception in the postpartum remaining significant only among the population of individuals who reported that their last pregnancy had been unintended. While individuals with short IPIs and an unintended pregnancy were more likely to

be using contraception, they were also more likely to be using more effective methods of contraception.

The results of this investigation provide important information for health care providers that work with pregnant and postpartum individuals. Additionally, recent changes in reproductive policies in the United States may soon increase the proportion of individuals who experience short IPIs that lead to a live birth, therefore making it even more important to understand how this shift may impact rates of PPD and receipt of certain postpartum health care services. The majority of pregnancies that occur after a short IPI are unintended [25], and with new restrictions being put in place to limit access to abortion services in areas of the United States, we may soon see an increase in the number of unintended pregnancies which are carried to term. While current research has already shown that increasing restrictive abortion policies will likely lead to a greater incidence of adverse birth outcomes, such as preterm birth and low birthweight, and maternal deaths[154,155], this research highlights the implications on increasing rates of PPD and demand for certain family planning services.

Future research should continue to explore the relationship between IPI and a broader range of maternal mental health conditions, such as postpartum anxiety. As these conditions continue to be the most prevalent underlying cause of maternal deaths in the United States, it is imperative that we have a better understanding of the mechanisms through which IPI may be impacting maternal mental health. Similarly, a greater understanding of the mechanisms through which IPI may impact future thinking about contraception and contraceptive decisions is needed. A better understanding of these mediators could also potentially lead to more effective interventions to decrease rates of maternal mental health conditions and increase use of contraception and highly-effective methods of contraception.

Going back to the conceptual framework, the Double ABC-X model, we see that currently the emphasis has been placed on reducing the likelihood of a - the stressor. In this case, this would be the proportion of births that occur after a short IPI. We have tried to achieve this through increased education and access to contraception, however as this data shows, there are many individuals who plan and have intended pregnancies after a short IPI. There are a variety of reasons why one may choose to do this (i.e. to have children close in age to one another, due to concerns about advancing age and declining fertility, etc.). Therefore, we must continue to explore how other factors impact one's ability to handle and manage the stressor of a short IPI, both mentally and physically – which the conceptual framework highlights are equally as important in determining whether adaptation or maladaptation occurs as a response to the stressor. This may be access to resources, such as paid parental leave, more accessible and affordable childcare options, peer support networks, increased access to insurance, etc.. Some preliminary research already suggests that in various populations and contexts access to paid parental leave positively impacts parental mental health [30,156] and for some populations increased access to insurance in the postpartum also decreases mental health difficulties for parents.[157] Increased access to insurance in the postpartum period has also been associated with, in certain populations, an increase in likelihood of attending postpartum medical visits.[157] A more thorough understanding of how these, and other, resources may impact the relationship between short IPIs and mental health and health care utilization may prove helpful in designing interventions to combat these public health issues.

Supplemental Tables

Supplemental Table 1: Aim 1: Logistic Regression Results for Interpregnancy Interval Predicting Postpartum Depression for PRAMS Sample (More Granular IPI Categories); 2012-2015

	OR (95% CI)
IPI	
Less than 12 months	1.19 (1.00 – 1.42)
12-17 months	1.19 (0.99 – 1.43)
18-23 months	1.02 (0.84 – 1.24)
24-59 months	1.05 (0.91 – 1.21)
60+ months	Ref.

Note: Unweighted N=34,420; Weighted N=1,676,031

Note: Confounders adjusted for include maternal age at previous birth, maternal race/ethnicity, maternal preconception insurance, maternal education, marital status, previous live birth, prior adverse pregnancy outcomes – preterm birth, prior adverse pregnancy outcomes – low birth weight, depression before pregnancy, time since birth, and pregnancy intention.

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