Interpregnancy Intervals and Perinatal and Child Health in Sweden: A Comparison Within Families and Across Social Groups

Kieron Barclay[1,2,3], Anna Baranowska-Rataj[4], Martin Kolk[3,5,6], Anneli Ivarsson[7]

1. Max Planck Institute for Demographic Research
2. Department of Social Policy, London School of Economics and Political Science
3. Department of Sociology, Stockholm University
4. Department of Sociology, Umeå University
5. Centre for Cultural Evolution, Stockholm University
6. Institute for Futures Studies, Stockholm, Sweden
7. Department of Public Health and Clinical Medicine, Umeå University

Abstract

Until recently a large body of research conducted in high-income countries had unambiguously shown that children born after an especially short or especially long birth interval are at an elevated risk of preterm birth, low birth weight, being small for gestational age, as well as other poor perinatal outcomes. However, a handful of recent studies that have adjusted for shared family background more effectively have cast doubt on that conclusion. We use Swedish population data on cohorts born 1981-2010 and sibling fixed effects models to examine whether the length of the birth interval preceding the index person has an impact on the risk of preterm birth, low birth weight, and hospitalization during childhood. We additionally present for the first time for this particular research question analyses stratified by salient social characteristics such as maternal educational level, and maternal country of birth. Overall, we find few effects of birth intervals on our outcomes except for very short birth intervals. Short interpregnancy intervals (<7 months) and very long intervals (>60 months) increase the probability of low birth weight and preterm birth. We also find that longer intervals (>42 months) decrease the probability of hospitalization during the first year of life, but interpregnancy intervals greater than 30 months increase the probability of hospitalization between ages 1-3. We find few differences in the patterns by maternal educational level, or by maternal country of origin after holding the mother's highest attained education constant. The results from this study contribute to the ongoing debate about whether the length of interpregnancy intervals matter for perinatal and child health in high-income countries.

Introduction

A large body of work has examined how the length between birth intervals is related to birth outcomes and the health of the child. For the most part, this literature has consistently shown that particularly short interpregnancy intervals (e.g. less than 18 months), and particularly long birth intervals (e.g. greater than 60 months) increase the risk of a range of poor outcomes (Conde-Agudelo et al., 2006). Past studies have also suggested that short birth intervals were associated with poor long-term outcomes such as lower cognitive ability, achieving lower grades in school, and being less likely to make subsequent educational transitions (Powell & Steelman, 1990, 1993), suggesting that there were either consequent effects of the poor perinatal outcomes, or that the short spacing between siblings also had a negative effect on the development environment within the household. Recently, however, a series of studies have attempted to control for shared frailty by comparing siblings born to the same mother. Several studies in high-income countries have found that after adopting this approach, the association between particularly short or long birth intervals and poor perinatal outcomes is completely removed (Ball et al., 2014; Class et al., 2017; Hanley et al., 2017). In this study we use Swedish population data to examine whether interpregnancy intervals are associated with preterm birth, low birth weight (LBW), very low birth weight (VLBW), being small for gestational age (SGA), as well as hospitalization during childhood. We also examine whether different patterns are observed amongst more vulnerable sections of the population, such as children born to mothers with low levels of education, and children born to immigrant mothers. Potential differences across social groups have been ignored in the most recent body of literature that has attempted to control for unobserved shared frailty in the sibling group.

Our focus on health outcomes of children beyond the first year of life, which we examine by studying child hospitalization, has not been examined in previous research. The risk of hospitalization during childhood would be related to birth interval length by a different set of mechanisms than the risk of preterm birth, LBW, and SGA, and would, in addition to adverse effects very early in life, also be related to the degree of parental investment and attention available to each child during childhood (Blake, 1981). Having closely spaced children, and particularly a larger number of closely spaced children, would make it more difficult for the parents to monitor the wellbeing of each child, which might be related to the risk of hospitalization from accidents as well as other diseases and illnesses. Similarly, a focus on hospitalization allows us to examine if eventual poor perinatal outcomes of shortly spaced children have repercussions on health later in childhood, as well as to identify at what ages such effects are felt.

Previous Empirical Research

Until very recently, the overwhelming body of evidence demonstrated convincingly that short interpregnancy intervals were bad for the health of the child as well as the mother. For example, a meta-analysis of 67 studies by Conde-Agudelo et al. (2006) found that short and long intervals were associated with poor outcomes in both high-income countries as well as low-income countries. In both high- and low-income settings birth intervals were found to be associated with the risk of poor outcomes such as preterm birth, low birth weight, and being small for gestational age, while short birth intervals were also associated with even more severe outcomes such as perinatal mortality in low-income contexts (Conde-Agudelo et al., 2006). A further meta-analysis by Conde-Agudelo et al. (2007) showed that both particularly short and long birth intervals are also associated with risks for maternal health. On the strength of this evidence, the World Health Organization (WHO) has issued universal recommendations that potential mothers should wait at least 24 months after the previous birth before conceiving again (WHO, 2006).

In the past four years, however, a series of studies that have studied the effects of birth spacing by comparing siblings who are discordant on birth interval length have called these longstanding conclusions into question (Klebanoff, 2017). The logic behind this approach is that by controlling for shared within-family frailty, otherwise unobserved, it is possible to isolate the effects of the length of the birth or interpregnancy interval itself net of risk factors shared amongst siblings that are potentially correlated with the length of birth intervals. The first known study to apply a sibling fixed effects analysis to this research question, Ball et al. (2014), using data from Australia, found that the association between short interpregnancy intervals (defined as 0-5 months) and the risk of preterm birth, LBW, and SGA was almost entirely removed after applying sibling fixed effects. This result has subsequently been replicated in other high-income contexts such as Canada (Hanley et al., 2017) and Sweden (Class et al., 2017). Similar analyses conducted using data from the United States (Mayo et al., 2017; Shachar et al., 2016) and the Netherlands (Koullali et al., 2017), however, have shown that short intervals are still associated with the risk of poor perinatal outcomes even after adjusting for shared maternal frailty. The Centers for Disease Control and Prevention in the United States have suggested that more research is needed to fully understand the relationship between the length of interpregnancy intervals and health risks for both the mother and the child (Copen et al., 2015). Research on infant mortality in less developed contexts using sibling comparison models have found that short birth intervals matter at lower levels of development but that the negative effects are substantially weaker at higher levels of development (Molitoris, 2017; Molitoris et al., 2018)

A related body of research focusing on adult health (Barclay & Kolk 2018) and educational and socioeconomic consequences of short birth intervals for outcomes later in life (Barclay & Kolk 2017; Buckles & Munnich, 2012; Powell & Steelman, 1990, 1993) have examined birth intervals with varying results. Typically, adverse effects, such as lower grades or lower educational attainment, are found in studies not adequately controlling for family background (Powell & Steelman, 1990, 1993), but these negative effects disappear in studies applying sibling comparisons (Barclay & Kolk 2017, 2018). Our examination of childhood health and hospitalization bridges the divide between previous research on perinatal outcomes with previous research focusing on adult outcomes, by examining whether birth intervals have negative consequences in the sensitive years between ages 0-10, which themselves have been shown to be a critical period for later life health and socioeconomic outcomes (Blackwell et al., 2001; Haas, 2008; Palloni, 2006).

Potential Mechanisms Linking Interval Length to Poor Outcomes

Although the focus of our study is not to identify or evaluate the mechanisms that may link the length of interpregnancy intervals to perinatal outcomes and child health, a brief review of these potential mechanisms is valuable in order to contextualize the debate over whether the length of birth intervals should matter or not for child outcomes.

Broadly speaking there are three groups of explanations that may account for an association between the length of interpregnancy intervals and child outcomes: physiological mechanisms, social and environmental mechanisms, and selection and confounding (Barclay & Kolk, 2018; Conde-Agudelo et al., 2012). Physiological mechanisms that may be particularly important in the Swedish context include maternal nutrient depletion, folate depletion, and physiological regression. Maternal nutrient depletion and folate depletion essentially refer to a lack of recovery time between pregnancies, which may mean that the fetus does not have access to all of the resources needed to adequately develop (Conde-Agudelo et al., 2012; Smits & Essed, 2001). The physiological regression theory is related to the risks associated with very long interpregnancy intervals, and is related to the physical adaptations that women undergo when they first become pregnant (Zhu et al., 1999). A long interval may lead to a physiological transformation for the mother back to the physical state of a woman who has not yet experienced a pregnancy, meaning that the mother is less physically primed for childbearing. This theory may explain why both first-born children (i.e. the first pregnancy for the mother) and children born after long intervals may be more likely to be born preterm or LBW, because in neither case is the mother physically primed for childbearing (Conde-Agudelo et al., 2006; Kramer, 1987).

Social and environmental mechanisms that are relevant to the risk of hospitalization essentially revolve around sibling competition for finite parental resources, where short birth intervals should lead to less parental attention and supervision for each child. Finally, selection and confounding mechanisms refer to the fact that interpregnancy intervals are not randomly distributed in the population. For example, in the United States, short birth intervals are particularly likely to be unintended, and to be found amongst socioeconomically and sociodemographically disadvantaged groups such as teenage mothers, and racial and ethnic minority groups (Gemmill & Lindberg, 2013). However, short intervals are also common amongst high SES mothers who delay first childbearing to older ages and have to reduce birth intervals in order to achieve desired fertility (Gemmill & Lindberg, 2013). Long birth intervals may also be a consequence of difficulty conceiving and therefore linked to lower underlying fecundity and maternal health. As a result, it is important to adjust for all factors that are shared amongst siblings in the sibling group in order to try to isolate the effects of birth intervals net of confounding factors. As we have discussed above, when this approach is applied, the longstanding conclusions regarding the negative effects of short and long birth intervals are no longer so clear (Ball et al., 2014; Barclay & Kolk, 2017, 2018; Class et al., 2017; Hanley et al., 2017; Koullali et al., 2017; Molitoris et al., 2018; Shachar et al., 2016).

Key Contributions of This Study

In this study we aim to extend the literature on the association between the length of interpregnancy intervals and child outcomes in two key ways. First, the most recent studies on this topic applying a sibling-comparison design have focused on identifying the main effects of birth intervals on perinatal outcomes, and have ignored the potential for differences across social groups, such as by maternal educational level, or amongst children born to immigrant mothers. Our first key contribution will be to examine whether the association between the length of interpregnancy intervals and perinatal outcomes and child health varies by these salient social groups. Specifically, we will examine whether the patterns differ between mothers who have a tertiary education and mothers who have less than tertiary education, and we will examine whether the patterns differ between children born to: 1) native-born Swedish mothers; 2) immigrant mothers from the EU-15 nations[1], Norway, Switzerland, and non-European OECD countries; 3) immigrant mothers from Central and Eastern Europe; and 4) immigrant mothers from the rest of the world.

Given that immigrant groups are a much smaller proportion of the population, negative effects of short birth intervals amongst this more vulnerable section of the population could be subsumed by the lack of an association in the native-born population in a pooled analysis of the full population. Furthermore, from previous research we know that mothers who are immigrants, and mothers with low levels of education, even net of the overlap between the two groups, have worse birth outcomes, suffering from an increased risk of preterm birth and SGA (Gissler et al., 2003; Luo et al., 2006; Rasmussen et al., 1995), though it should be noted that the differences observed between native-born Swedish mothers and immigrant mothers are smaller than the differences

[1] Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, and the United Kingdom.

observed between native-borns and immigrants in many other countries[2] (Bollini et al., 2009).

Better educated mothers and those born in Sweden may have more resources to monitor their own health as well as that of their child both during pregnancy and afterward, and to adopt compensatory behaviors that reduce any potential negative effects of short interpregnancy intervals. Part of the explanation for these differences in birth outcomes is that mothers from immigrant groups and mothers with lower levels of education are more likely to suffer from general socioeconomic disadvantage and the concomitant negative health effects (Torssander & Erikson, 2009; Westerling & Rosén, 2002; Wiking et al., 2004). Research also suggests that mothers with lower levels of education and immigrant groups face more barriers in taking full advantage of the possibilities for prenatal care (Essén et al., 2002; Heaman et al., 2013), and for some immigrant groups there are also sociocultural differences in what are considered to be acceptable practices during pregnancy (Essén et al., 2002). For example, research has indicated that East African immigrants in Sweden are more likely to experience more delays in establishing contact with health care centers during pregnancy as well as face verbal miscommunication due to lack of interpreters at healthcare centers, amongst other suboptimal factors (Essén et al., 2002). Previous research also documents differences in the risk of vitamin deficiencies, which can be critical for the healthy development of the fetus (Sääaf et al., 2011). Furthermore, potential incompatibility between the diet in the country of origin with availability of food items in Sweden as well as ethnocultural dietary norms and practices related to pregnancy could potentially lead to food choices that have detrimental health effects (Ahlqvist et al., 2000; Higginbottom et al., 2014). Given that short interpregnancy intervals can lead to maternal nutrient depletion (Smits & Essed, 2001), disparities of this kind may magnify the potential negative effects of birth spacing between the children of mothers originating from different countries.

We also know from previous research that education attainment and country of origin is associated with health behaviours such smoking and alcohol consumption (Cnattingius

[2] Some earlier studies in Sweden have also reported negligible differences between immigrants and Swedes for severe birth outcomes such as perinatal death (Oldenburg et al., 1997; Smedby & Ericson, 1979), though this might be explained by the relative rarity of such cases.

et al., 1992; Moussa et al., 2010; Urquia et al., 2013), which greatly increases the risks for poor perinatal outcomes (Cnattingius, 2004) and health outcomes of children (Davidson et al., 2010; Wisborg et al., 1999). These differences in health behaviors also vary according to the region of origin of immigrants, which is part of the reason why we stratify our analyses.

Our second key contribution is that we examine a series of outcomes that have not been examined in the previous literature, which is whether the risk of hospitalization during several age windows during childhood is affected by the length of the birth interval between siblings. The risk of hospitalization for different causes should vary by the age of the child, and therefore we examine the risk of hospitalization in relation to birth interval length in the first year of life, from ages 1 to 3, from ages 4 to 6, and from ages 7 to 10. We argue that this broader focus on health beyond the first year of life is an important contribution for understanding whether and how birth intervals have long-term negative effects on individuals.

Data

In this study, we use data available at the Umeå SIMSAM Lab combining information from several administrative registers in Sweden (Lindgren et al., 2016), specifically, the Multigenerational Register, the Medical Birth Register, and the National Patient Register. The Multigenerational Register and the Medical Birth Register include information on demographic events, most importantly the births of siblings and the social background of children and their parents. The National Patient Register provides measures on all in-hospital care with respect to the date of admission and discharge. We select cohorts of children born in Sweden between 1980 and 2010. For these cohorts, we can access all the relevant maternal and child characteristics during pregnancy and birth. We exclude families with two children or less as well as first-born children. Our primary estimation strategy is based upon implementing a sibling fixed effects approach, which requires variance within the sibling group: one-child families do not have any interpregnancy interval, and there is only one interpregnancy interval in a two-child family. We also exclude families with multiple births, and children in blended families, whose parents repartnered before the conception. We excluded blended families because we wanted to ensure that parental attention and investment would be focused on their own biological children rather than any other children they might have, which might otherwise confound our results. Overall, we estimated sibling fixed effects models based on 499,339 siblings from 243,906 families.

Stratified Analyses

In this study we also examine how patterns vary across children born to mothers with different levels of education, and different countries of origin. Specifically, examine whether the patterns differ between mothers who have a tertiary education and mothers who have less than tertiary education, and whether the patterns differ between children born to: 1) native-born Swedish mothers (84% of the analytical population); 2) immigrant mothers from the EU-15 nations, Norway, Switzerland, and non-European OECD countries (4% of the analytical population); 3) immigrant mothers from Central and Eastern Europe (4% of the analytical population); and 4) immigrant mothers from the rest of the world (8% of the analytical population);

Interpregnancy intervals (IPI). We calculate the number of months between the date of birth of the earlier-born sibling and the date of conception of the next sibling. Date of conception is based on information on gestational age at birth available in the Medical Birth Register. It is assessed according to maternal reports on last menstrual period and clinical judgment by the attending pediatrician (Socialstyrelsen, 2003). Interpregnancy intervals are categorized as 0–6 months, 7–12 months, 13–18 months, 19–24 months (the reference category), 25–30 months, 31-36 months, 37-42 months, 43-48 months, 49-54 months, 55-60 months and more than 60 months.

We consider a wide range of outcome variables measuring health at birth and during the first 10 years of a child's life: preterm birth, low birth weight, being small for gestational age, as well as hospitalization during the first 10 years of life.

Preterm births.

Based on gestational age, following World Health Organization (2012), we distinguish the following categories of preterm birth: extremely preterm (less than 28 weeks), very preterm (28 to 31 weeks) and moderate preterm (32 to 36 weeks). Births after completed 37 weeks of pregnancy are considered as births at term.

Low birth weight (LBW).

Infants with birth weight less than 2500g are classified as children with low birth weight.

Hospitalisation.

Based on data on the dates of admission and discharge from the from the National Patient Register, which includes all in-patient care in Sweden (Ludvigsson et al., 2011) we created binary indicators of hospitalization at ages: 0, 1-3, 4-6 and 7-10. These indicators take zero if a child was not hospitalized for at least one day at a specific age and they take value one if a child was hospitalized at least once in a specific age range.

Methods

Our primary estimation strategy is based upon sibling fixed effects models, where biological children sharing the same mother and father are treated as repeated observations of the same family. The choice of methodological approach was motivated by the fact that biological siblings are more alike than a randomly selected pair of individuals. In addition, the same family-specific factors that determine interpregnancy intervals may affect the risk of adverse birth outcomes as well as children's health problems leading to hospitalization. By using fixed effects sibling models we control all shared family-specific factors, including unobserved factors, which might otherwise bias our estimates. This allows us to estimate the net effect of the length of the interpregnancy interval on the various outcome variables that we examine. For our analysis of the pooled population, we also contrast the results from the fixed effects models with the results from OLS models on binary outcomes (i.e. linear probability models), with the standard errors adjusted for clustering at the sibling group level. For our analyses of children born to mothers by country of origin and educational level, we only present the results from our fixed effects models. We also control for a number of factors that covary with the length of interpregnancy intervals and the various outcomes that we study, including sex, birth year, maternal age at the time of birth, birth order, and in the non-fixed effects models, sibling group size, at the family-level.

Results

Descriptives

Table 1 shows summary statistics for the seven main outcomes that we focus on in this paper: low birth weight, preterm birth, being small for gestational age, and hospitalization at ages 0-1, 1-3, 4-6, and 7-10. Highly detailed descriptives tables can be seen in the Online Supplement, in Tables S1-S6. As can be seen in Table 1, for LBW, preterm birth, hospitalization before age 1, and hospitalization at ages 4-6 and 7-10, the incidence is highest amongst interpregnancy intervals (IPIs) of less than 12 months, and particularly less than 7 months, while also elevated amongst children born after IPIs greater than 60 months. For hospitalizations between ages 1-3, the incidence is highest amongst children born after the shortest IPIs, but is not elevated for children born after the longest IPIs of longer than 5 years.

Table 1. Summary statistics for low birth weight (LBW), preterm birth, being small for gestational age (SGA), and hospitalization (Hospital) before age 1, and at ages 1-3, 4-6, and 7-10, by the length of the preceding interpregnancy interval.

Inter-pregnancy interval (months)	LBW (%)	Preterm (%)	% Hospital (Ages 0-1)	% Hospital (Ages 1-3)	% Hospital (Ages 4-6)	% Hospital (Ages 7-10)
0-6	2.9	5.8	12.1	19.2	10.1	9.0
7-12	2.9	3.8	10.3	18.0	9.8	8.6
13-18	1.9	3.1	10.2	17.5	9.8	8.3
19-24	1.5	3.1	10.1	17.6	9.7	8.4
25-30	1.7	3.1	10.0	17.3	9.5	8.2
31-36	1.7	3.4	10.0	18.1	9.3	7.9
37-42	2.0	3.3	10.6	18.0	8.8	7.7
43-48	1.9	3.4	10.6	18.1	8.6	7.5
49-54	1.8	3.4	10.7	18.4	8.2	7.4
55-60	2.0	3.8	10.9	18.4	8.6	7.1
60+	2.2	4.5	12.1	17.9	8.3	6.6
Total	1.9	3.5	10.5	17.8	9.3	8.0

Low Birth Weight

The estimates for the relationship between IPIs and the probability of low birth weight are shown in Figure 1. Please take care to note that the y-scale varies between Panels A, B, and C across Figures 1 to 7. Full results tables with detailed output for the results underlying Figure 1 can be found in the Online Supplement, in Tables S10 to S12. Panel A in Figure 1 contrasts the results from the within-family sibling comparison (i.e. fixed effects models), and the regular OLS models that do not adjust for unobserved factors that are correlated both with birth interval length and the risk of LBW.

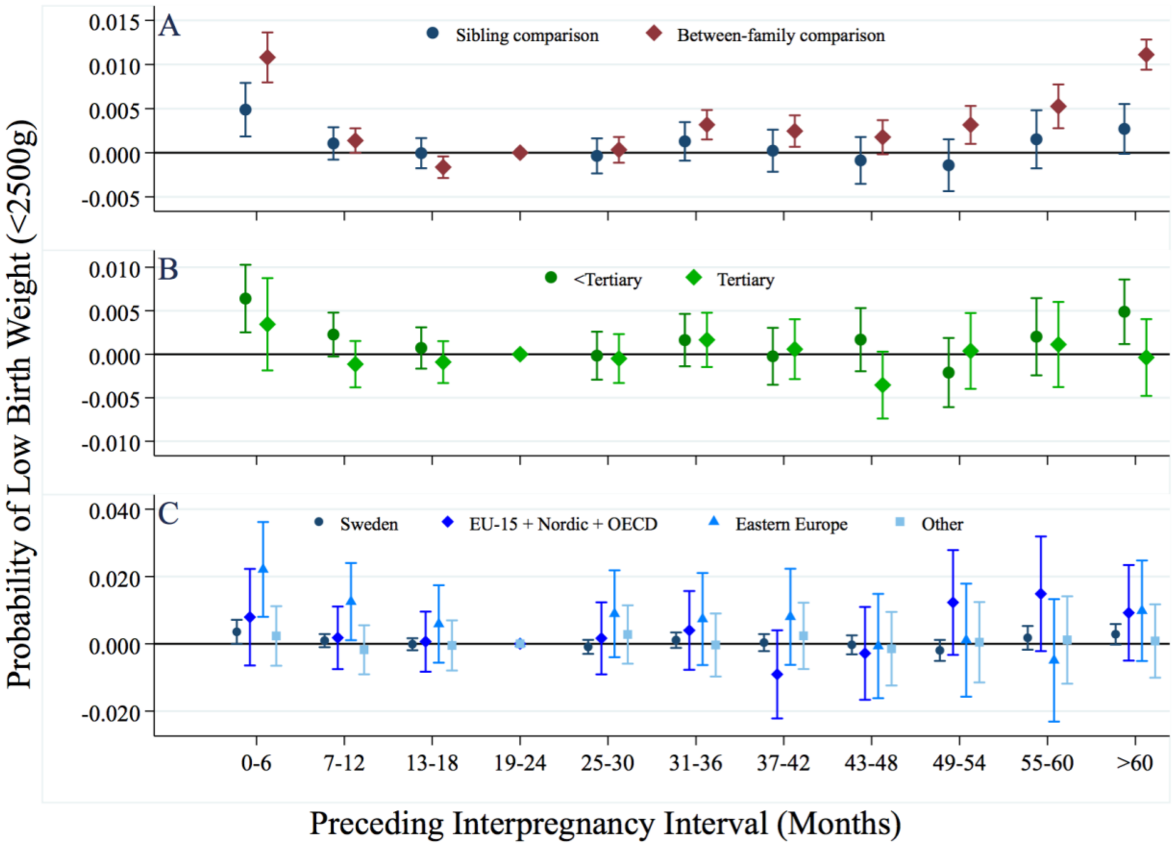

Figure 1. Relationship between the length of interpregnancy intervals and the probability of low birth weight in the pooled sample (Panel A - OLS + fixed effects models), by maternal educational level (Panel B - fixed effects models), and by maternal immigrant status (Panel C - fixed effects models) for children born in Sweden between 1980 and 2010. Reference category is interpregnancy interval of 19-24 months.

Panel A shows that both the sibling comparison and the OLS model indicate that the IPIs shorter than 7 months are associated with an increase in the probability of LBW. Indeed, the fixed effects models show that the probability is 0.005 higher relative to the reference category. Taking the baseline probability (0.019) into account, this is a relative increase in the probability of LBW of 25.2%. However, the sibling fixed effects models do not indicate that long birth intervals are associated with any significantly increased risk of LBW.

Panel B, which is based on fixed effects models, shows the results stratified by maternal educational level. Panel B shows that amongst mothers with less than a tertiary education, IPIs both shorter than 7 months, and longer than 60 months, are associated with an increased risk of LBW. Hence, our results indicate that the negative effects of very short and very long intervals shown in the fixed effects estimates in Panel A are in fact restricted to children with a more disadvantaged parental background. Although the baseline probability of LBW is lower for mothers with less than a tertiary education than for mothers with a tertiary education (0.015 vs 0.022 – see Table S1), the relative increase in the probability of LBW for children born after an IPI of less than 7 months relative to the reference category for mothers with less than a tertiary education is higher, at 41.9%.

Panel C shows the results stratified by the country of origin of the mothers. These results show that there are some significant within-immigrant-group differences in the effects of short birth intervals. For example, children born after especially short IPIs (i.e. less than 7 months) to mothers from Eastern Europe are significantly more likely to be born with LBW than other children born to mothers from Eastern Europe after longer birth intervals. However, given the overlapping confidence intervals, we cannot say that there are statistically significant between-immigrant-group differences in the negative effects of especially short or especially long birth intervals.

Preterm Birth

The results from our models examining the relationship between IPIs and the probability of preterm birth are shown in Figure 2. Full results tables with detailed output for the results underlying Figure 2 can be found in the Online Supplement, in Tables S13 to S15. Please take care to note that the y-scale varies between Panels A, B, and C. Panel A shows that estimates from both the OLS model and the fixed effects models indicate an increased risk of preterm birth for children born after IPIs of less than 13 months, and greater than 60 months relative to the reference category of 19-24 months. Relative to the baseline probability (0.037), the relative probability after an IPI of 0-6 months is 46.6% higher, and the relative probability after an IPI greater than 60 months is 17.0% higher.

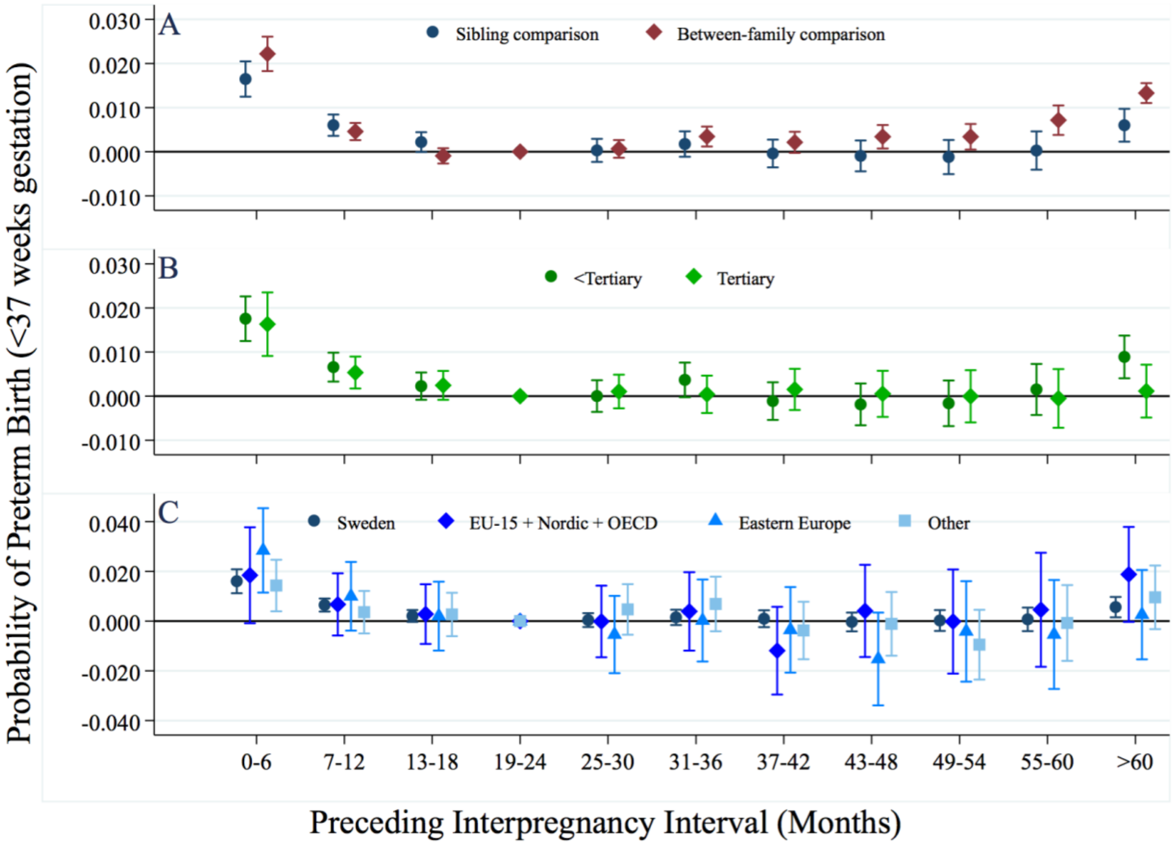

Figure 2. Relationship between the length of interpregnancy intervals and the probability of preterm birth in the pooled sample (Panel A - OLS + fixed effects models), by maternal educational level (Panel B - fixed effects models), and by maternal immigrant status (Panel C - fixed effects models) for children born in Sweden between 1980 and 2010. Reference category is interpregnancy interval of 19-24 months.

Panel B shows that the increased probability of preterm birth after short IPIs is similar regardless of the mothers educational level, but for long intervals is only observed amongst mothers with less than a tertiary education. Panel C of Figure 2 shows that the increased risk of preterm birth after an IPI of 0-6 months is observable amongst all mothers regardless of country of origin. The point estimates for the increased probability of preterm birth after an IPI of greater than 60 months seems to be higher amongst children born to all mothers with the exception of mothers originating from Eastern Europe.

Hospitalization Before Age 1

Figure 3 shows the results for our first analyses of health outcomes beyond those measured directly after birth, focusing on hospitalization during the first year of life. Full results tables with detailed output for the results underlying Figure 3 can be found in the Online Supplement, in Tables S16 to S18. Please take care to note that the y-scale varies between Panels A, B, and C. Panel A contrast the results from our fixed effects models to the regular OLS models on the same sample population. The between-family comparison shows an elevated probability of hospitalization before age 1 for those born after IPIs of less than 7 months relative to the reference category, but no other meaningful relative differences. The fixed effects model, however, show that short IPIs are barely related to the probability of hospitalization, but IPIs longer than 42 months *decrease* the risk of hospitalization. For example, relative to the baseline probability (0.105), the relative probability of hospitalization after an IPI greater than 60 months is 31.1% lower. The results shown in Panel B support the conclusion that this is consistent regardless of maternal educational level. Panel C, however, suggests that Swedish mothers primarily drive this pattern in the pooled data.

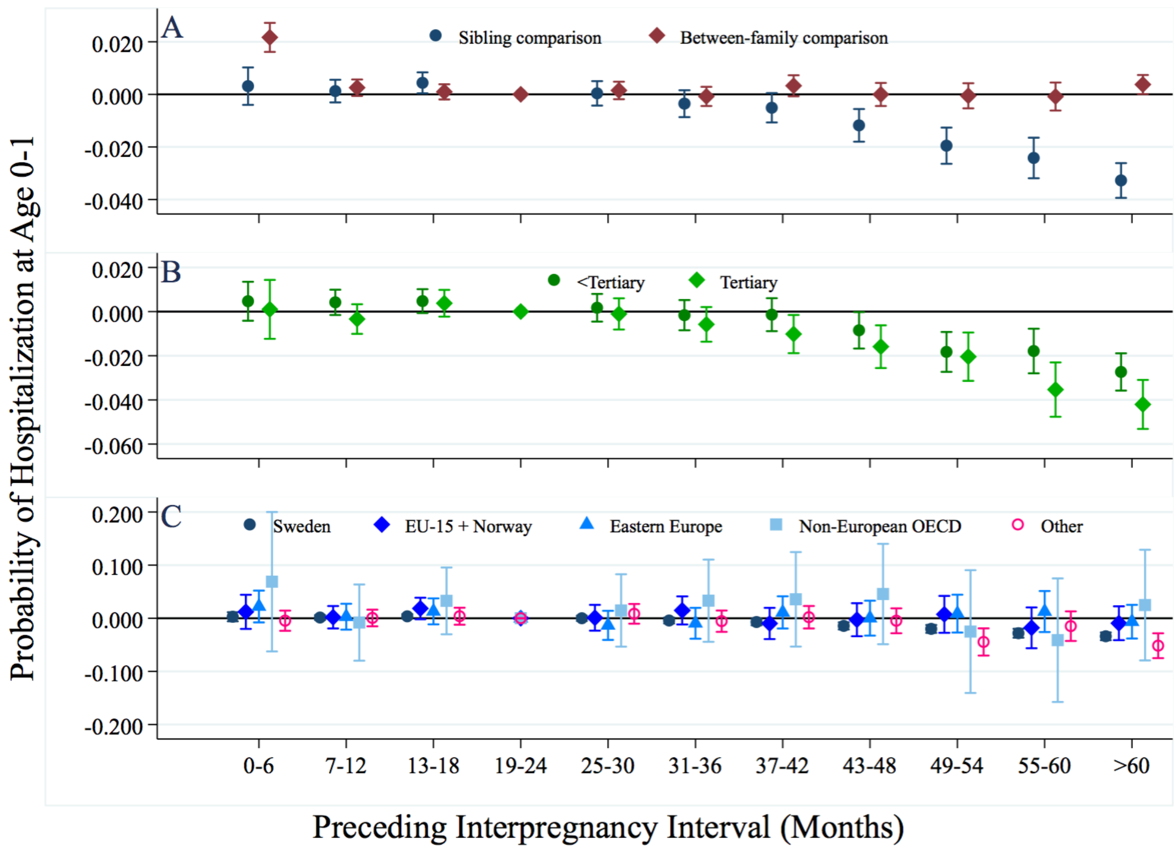

Figure 3. Relationship between the length of interpregnancy intervals and the probability of hospitalization before age 1 in the pooled sample (Panel A - OLS + fixed effects models), by maternal educational level (Panel B - fixed effects models), and by maternal immigrant status (Panel C - fixed effects models) for children born in Sweden between 1980 and 2010. Reference category is interpregnancy interval of 19-24 months.

Hospitalization at Ages 1-3

Figure 4 shows the results from models examining the relationship between the length of the preceding IPI and hospitalization between ages 1 to 3. Full results tables with detailed output for the results underlying Figure 4 can be found in the Online Supplement, in Tables S19 to S21. Please take care to note that the y-scale varies between Panels A, B, and C. Panel A contrast the results from our fixed effects models to the regular OLS models on the same sample population.

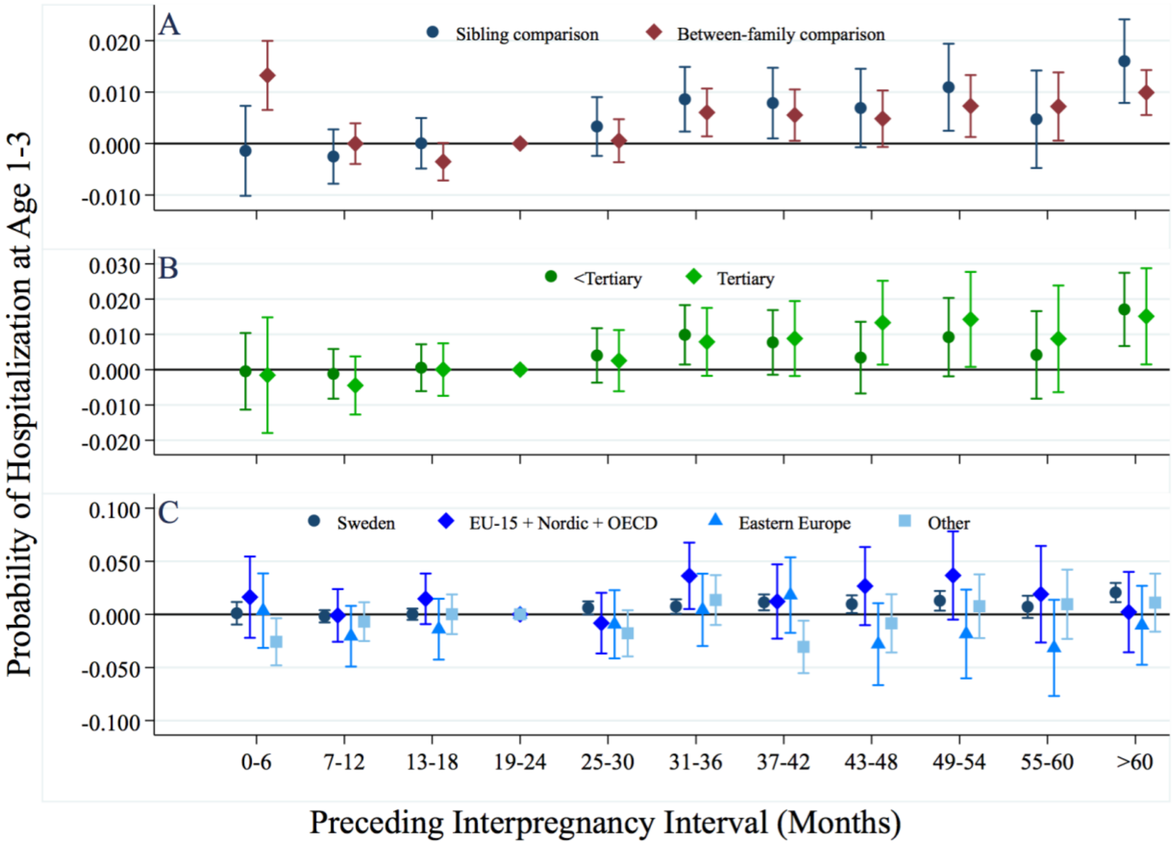

Figure 4. Relationship between the length of interpregnancy intervals and the probability of hospitalization at ages 1-3 in the pooled sample (Panel A - OLS + fixed effects models), by maternal educational level (Panel B - fixed effects models), and by maternal immigrant status (Panel C - fixed effects models) for children born in Sweden between 1980 and 2010. Reference category is interpregnancy interval of 19-24 months.

While the between-family comparisons show that both very short IPIs and longer IPIs are associated with an increased probability of hospitalization at ages 1-3, the fixed effects results show that it is only IPIs greater than 30 months that are associated with an increased probability of hospitalization at these ages. For example, relative to the baseline probability (0.178), the relative probability of hospitalization after an IPI greater than 60 months is 9.0% higher. Panel B shows that the pattern observed in the pooled sibling comparison analysis is consistent regardless of maternal educational level, while Panel C shows that this pattern is driven by Swedish mothers rather than mothers who were born outside of Sweden.

Hospitalization at Ages 4-6

The results from our analyses of the relationship between the IPI length and hospitalization at ages 4 to 6 are shown in Figure 5. Full results tables with detailed output for the results underlying Figure 5 can be found in the Online Supplement, in Tables S22 to S24. Please take care to note that the y-scale varies between Panels A, B, and C. Panel A in Figure 5 shows the results from the pooled analysis using the fixed effects model as well as the regular OLS model. Panel A shows that the association between IPI and the probability of hospitalization is weaker at ages 4-6 than at ages 1-3, though there is some evidence that shorter intervals, as well as IPIs longer than 60 months, increase the probability of hospitalization. For example, relative to the baseline probability (0.093), the relative probability of hospitalization after an IPI greater than 60 months is 7.8% higher. The results from models stratified by maternal educational level, shown in Panel B, show that amongst children born to mothers with less than a tertiary education, the probability of hospitalization is higher for those born after IPIs greater than 60 months. We do not observe those within-group differences amongst children born to mothers with a tertiary education. The results shown in Panel C do not allow us to infer that there are significant differences across immigrant groups in the effects of very long IPIs on the probability of hospitalization at ages 4-6, though we do observe significant within-group differences in the effects of long IPIs on hospitalization for children born to Swedish mothers.

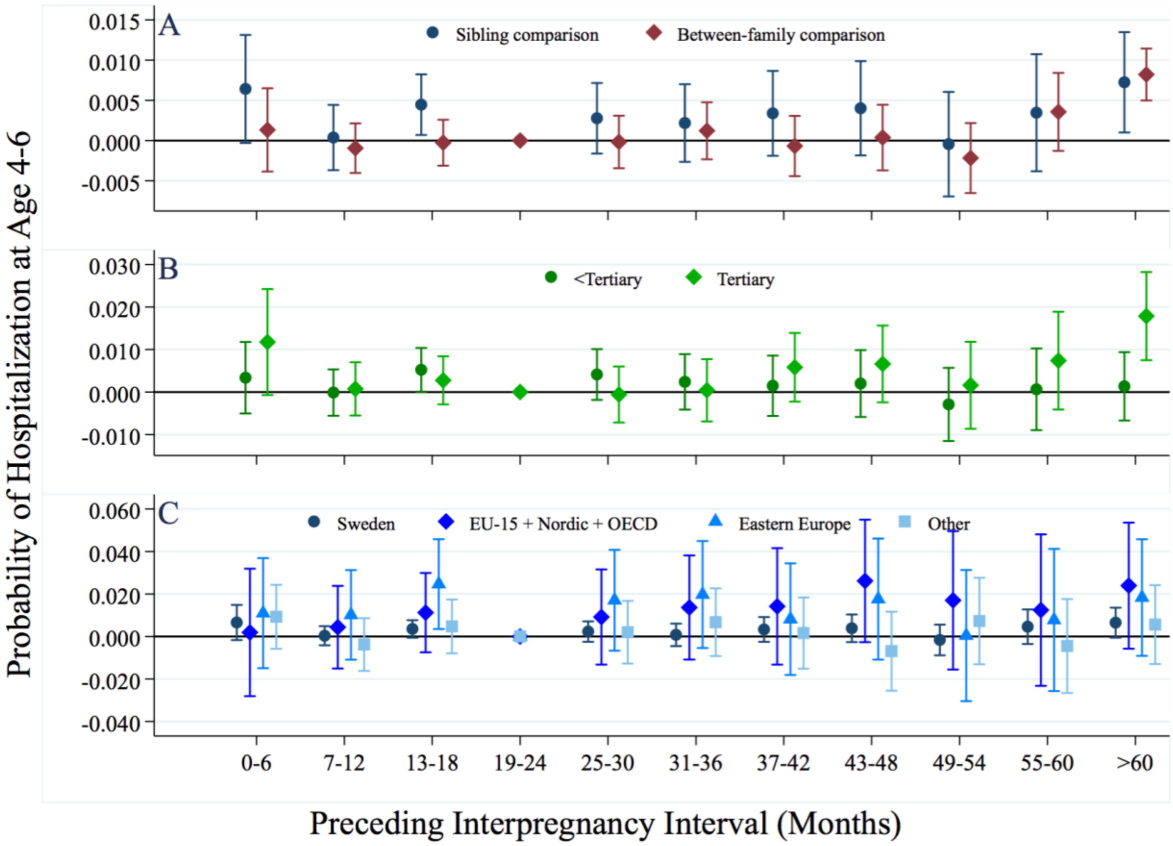

Figure 5. Relationship between the length of interpregnancy intervals and the probability of hospitalization at ages 4-6 in the pooled sample (Panel A - OLS + fixed effects models), by maternal educational level (Panel B - fixed effects models), and by maternal immigrant status (Panel C - fixed effects models) for children born in Sweden between 1980 and 2010. Reference category is interpregnancy interval of 19-24 months.

Hospitalization at Ages 7-10

The results for our analyses of hospitalization at later childhood ages are consistent with the weakening relationship between the length of IPIs and probability of hospitalization at ages 4-6. Please take care to note that the y-scale varies between Panels A, B, and C. Figure 6 shows that there are no clear patterns of hospitalization by the length of the IPI in either the pooled sample, by maternal educational level, or by the country of origin of the mother. Full results tables with detailed output for the results underlying Figure 6 can be found in the Online Supplement, in Tables S25 to S27

.

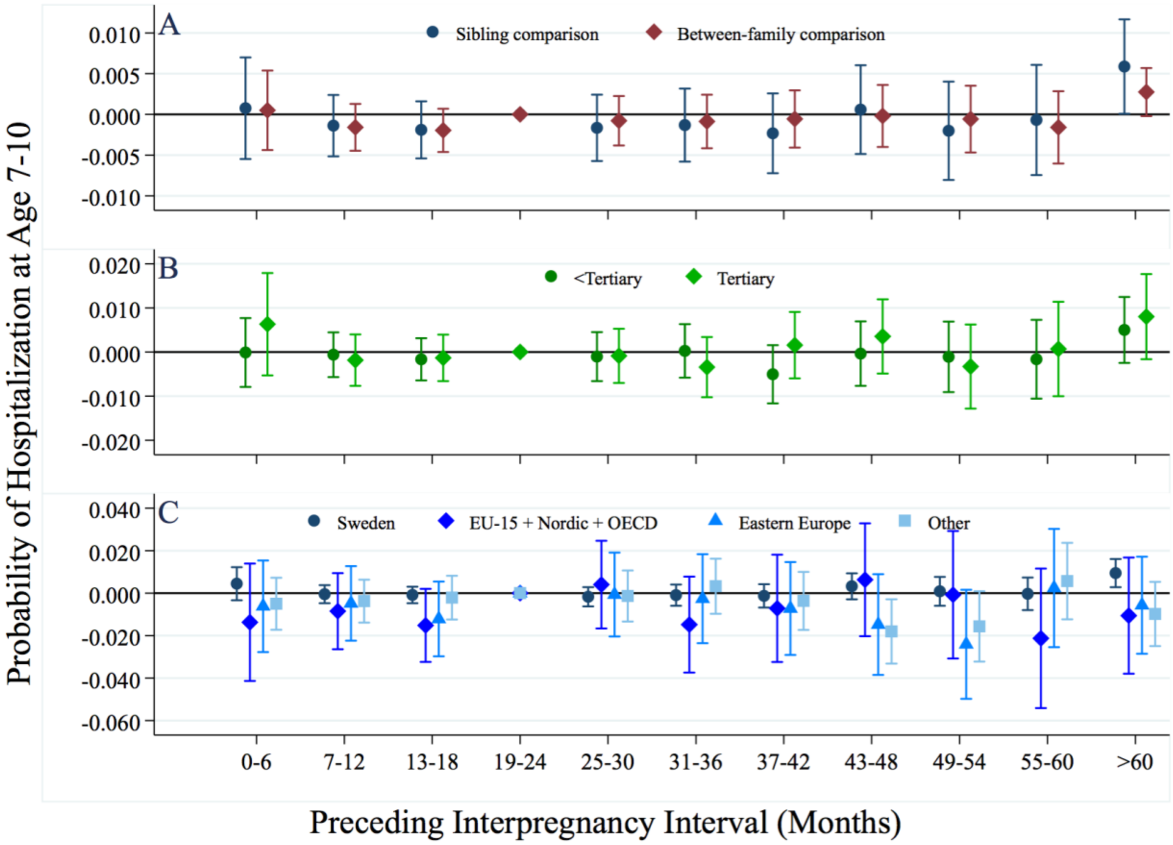

Figure 6. Relationship between the length of interpregnancy intervals and the probability of hospitalization at ages 7-10 in the pooled sample (Panel A - OLS + fixed effects models), by maternal educational level (Panel B - fixed effects models), and by maternal immigrant status (Panel C - fixed effects models) for children born in Sweden between 1980 and 2010. Reference category is interpregnancy interval of 19-24 months.

Discussion

In this study we have examined the effects of interpregnancy interval length on the probability of poor perinatal outcomes, as well as the risk of hospitalization during childhood, and how these patterns vary according to the mother's level of education and country of origin.

Overall we find that after controlling for shared factors within the sibling group, the length of IPIs does not generally influence the probability of the child suffering from poor perinatal outcomes. The exceptions to this are that very short and very long interpregnancy intervals do increase the probability of low birth weight and preterm birth. For example, the probability of LBW and preterm birth for children conceived after IPIs of less than 7 months is 25.2% and 46.6% higher, respectively, than the probability of LBW and preterm birth for children conceived after IPIs of 19-24 months. However, it should be said that these very short IPIs are relatively uncommon, accounting for only 3% of intervals in our analytical population. As a result, the overall population health impact of these short intervals is likely to be small.

These results speak to the recent series of studies that have raised questions about whether interpregnancy intervals matter for perinatal health in high-income countries. Recent studies have shown that very short interpregnancy intervals do not matter for the risk of low birth weight, preterm birth, and being small for gestational age in Australia (Ball et al., 2014) and Canada (Hanley et al., 2017) after adjusting for shared risk factors within the sibling group. However, our results support the findings of other recent studies using data from the United States (Mayo et al., 2017; Shachar et al., 2016) and the Netherlands (Koullali et al., 2017) that found that short intervals were associated with the risk of poor perinatal outcomes even after adjusting for shared maternal frailty. Based upon the results of this study we would like to echo the recent calls for more research on this topic (e.g. Copen et al., 2015; Klebanoff, 2017), and particularly to explain why birth intervals seem to matter for perinatal health in some high-income contexts but not others.

In this study we also extend the literature by examining health outcomes during childhood in relation to the length of interpregnancy intervals, which has not been done with sibling comparison models. We examined hospitalization during several different age windows during the first 10 years of childhood. The results from these analyses suggested that the length of interpregnancy intervals is more important for the probability of hospitalization before age 4, but particularly before age 7. Intriguingly, our estimates suggest that longer birth intervals are protective against hospitalization in the first year of life, but that they increase the risk of hospitalization at later ages, up to age 7. This pattern is difficult to explain, but may be related to medical practice norms regarding how sick infants are treated. In Sweden doctors typically prefer for a child to be at home with the parents if at all possible rather than being hospitalized. Furthermore, those infants who are identified with health problems at birth are more likely to be kept at the hospital until the problems are solved, meaning that this hospitalization would not be recorded as a separate event from the hospital birth itself. This might explain why children born after very short or very long intervals do have worse perinatal outcomes, but also have a lower risk of hospitalization in the first year of life.

We have also extended previous research on this topic by examining whether there are differences in the effects of IPIs on perinatal and child health by maternal educational level and maternal country of origin. Overall we do not find significant differences in the effects of maternal educational level or maternal country of origin on the probability of poor perinatal outcomes or hospitalization during childhood. Given known differences in factors such as health behaviours and possibilities to navigate the health care system by maternal educational level as well as maternal country of origin, it is interesting that we do not find any differences in the effects of IPI length on perinatal outcomes across these different social categories. This suggests either that these differences in behaviour across social groups are smaller than believed, or that they have relatively little impact on the risk of poor perinatal and child health outcomes after especially short or long IPIs in a high-income setting such as Sweden. It might also be the case that the medical and social system in Sweden is able to adequately moderate such differences in maternal health and maternal health behaviours through both prenatal and postnatal care.

In examining the effects of IPI length on childhood hospitalization this study has also allowed us to bridge the gap between recent research using a sibling comparison approach on perinatal health outcomes, and long-term educational, socioeconomic, and health outcomes in Sweden. Previous research has shown that even especially short and especially long birth intervals are not associated with poor long-term educational, socioeconomic, and health outcomes in Sweden (Barclay & Kolk, 2017; 2018), but it was not clear whether this previous finding was due to the fact that birth intervals did not matter for even perinatal health outcomes in contemporary Sweden, or whether the null finding for the long-term effects might be due to some kind of moderating effect of the Swedish welfare state in negating disadvantage early in life. Our results, largely confirm previous results on the small impact of birth intervals on outcomes of the children, though we find a substantial negative effect of extremely short interpregnancy intervals on perinatal outcomes. Given that previous literature shows that low birth weight and preterm birth can have serious long-term consequences for health and educational and socioeconomic attainment (Black et al., 2007; Conley & Bennett, 2000; Swamy et al., 2008) our study suggests that there may be an ameliorating moderating effect of medical, social, or environmental conditions in Sweden that breaks the link between the negative effects of extremely short IPIs on perinatal outcomes and poor long-term socioeconomic, educational, and health outcomes.

Although this study has many strengths, it is also important to acknowledge the limitations. Chief amongst these is that, in order to estimate our fixed effects models, we necessitate a focus on families with at least three children because we need to observe variance on the length of the interpregnancy interval within the sibling group. Although excluding one-child families is unavoidable as we do not observe any birth interval in such groups, we also exclude two-child families, which are the most common sibling group size in Sweden. There is an inevitable tradeoff between the generalizability of our findings to the full population, and the great benefit of being able to control for all unobserved factors shared amongst siblings which might be driving the relationship between IPI length and perinatal and child health. Given our chosen approach, we need to be careful about generalizing our findings to two-child sibling groups as it is possible that the effect of IPIs on perinatal and child health is quite different in two-child groups in comparison to groups with three or more children. Nevertheless, we feel that this is a relatively small problem. First, the mechanisms that could link IPI length to perinatal and child health, such as maternal nutrient depletion, or sibling competition for resources, should both be more severe in larger sibling groups than smaller ones. Second, by studying sibling groups with at least three children we do actually still study the majority of empirically observed interpregnancy intervals in the population, as larger sibling groups contribute far more intervals than do two-child sibling groups. For example, a four-child sibling group produces three times as many intervals as a two-child sibling group.

To conclude, we feel that the strengths of this study deserve further highlighting. We examine childhood health in a research area previously mainly concerned with perinatal outcomes. We also examine whether specific social groups drive the average pattern of association between the length of interpregnancy intervals and perinatal and child health in the general population, and we do so use high quality population registers and sophisticated statistical methods that allow us to adjust for all unobserved factors that are shared amongst siblings in our fixed effects approach. In doing so we contribute to an important and ongoing debate about the relative importance of the length of interpregnancy intervals for the health of children in high-income societies.

References

Ahlqvist, M., & Wirfält, E. (2000). Beliefs concerning dietary practices during pregnancy and lactation. *Scandinavian Journal of Caring Sciences*, 14, 105-111.

Ball, S.J., Pereira, G., Jacoby, P., de Klerk, N., & Stanley, F.J. (2014). Re-evaluation of link between interpregnancy interval and adverse birth outcomes: retrospective cohort study matching two intervals per mother. *BMJ,* 349, g4333.

Barclay, K.J., & Kolk, M. (2017). The long-term cognitive and socioeconomic consequences of birth intervals: a within-family sibling comparison using Swedish register data. *Demography,* 54, 459-484.

Barclay, K.J., & Kolk, M. (2018). Birth intervals and health in adulthood: a comparison of siblings using Swedish register data. *Demography,* 55, 929–955.

Black, S.E., Devereux, P.J., & Salvanes, K.G. (2007). From the cradle to the labor market? The effect of birth weight on adult outcomes. *The Quarterly Journal of Economics,* 122, 409-439.

Blake, J. (1981). Family size and the quality of children. *Demography,* 18, 421-442.

Bollini, P., Pampallona, S., Wanner, P., & Kupelnick, B. (2009). Pregnancy outcome of migrant women and integration policy: a systematic review of the international literature. *Social science & medicine,* 68, 452-461.

Class, Q.A., Rickert, M.E., Oberg, A.S., Sujan, A.C., Almqvist, C., Larsson, H., et al. (2017). Within-Family Analysis of Interpregnancy Interval and Adverse Birth Outcomes. *Obstetrics & Gynecology,* 130, 1304-1311.

Cnattingius, S. (2004). The epidemiology of smoking during pregnancy: smoking prevalence, maternal characteristics, and pregnancy outcomes. *Nicotine & tobacco research,* 6, S125-S140.

Cnattingius, S., Lindmark, G., & Meirik, O. (1992). Who continues to smoke while pregnant? *Journal of Epidemiology & Community Health,* 46, 218-221.

Conde-Agudelo, A., Rosas-Bermúdez, A., & Kafury-Goeta, A.C. (2006). Birth spacing and risk of adverse perinatal outcomes: a meta-analysis. *JAMA,* 295, 1809-1823.

Conde-Agudelo, A., Rosas-Bermúdez, A., & Kafury-Goeta, A.C. (2007). Effects of birth spacing on maternal health: a systematic review. *American Journal of Obstetrics & Gynecology,* 196, 297-308.

Conde-Agudelo, A., Rosas‐Bermudez, A., Castaño, F., & Norton, M.H. (2012). Effects of birth spacing on maternal, perinatal, infant, and child health: a systematic review of causal mechanisms. *Studies in family planning,* 43, 93-114.

Conley, D., & Bennett, N.G. (2000). Is biology destiny? Birth weight and life chances. *American Sociological Review*, 458-467.

Copen, C.E., Thoma, M.E., & Kirmeyer, S. (2015). Interpregnancy intervals in the United States: data from the birth certificate and the national survey of family growth. *National vital statistics reports: from the Centers for Disease Control and Prevention, National Center for Health Statistics, National Vital Statistics System,* 64, 1-10.

Essén, B., Bödker, B., Sjöberg, N.O., Langhoff‐Roos, J., Greisen, G., Gudmundsson, S., et al. (2002). Are some perinatal deaths in immigrant groups linked to suboptimal perinatal care services? *BJOG: An International Journal of Obstetrics & Gynaecology,* 109, 677-682.

Gemmill, A., & Lindberg, L.D. (2013). Short interpregnancy intervals in the United States. *Obstetrics and gynecology,* 122, 64.

Gissler, M., Pakkanen, M., & Olausson, P.O. (2003). Fertility and perinatal health among Finnish immigrants in Sweden. *Social science & medicine,* 57, 1443-1454.

Hanley, G.E., Hutcheon, J.A., Kinniburgh, B.A., & Lee, L. (2017). Interpregnancy interval and adverse pregnancy outcomes: an analysis of successive pregnancies. *Obstetrics & Gynecology,* 129, 408-415.

Heaman, M., Bayrampour, H., Kingston, D., Blondel, B., Gissler, M., Roth, C., et al. (2013). Migrant women's utilization of prenatal care: a systematic review. *Maternal and child health journal,* 17, 816-836.

Klebanoff, M.A. (2017). Interpregnancy interval and pregnancy outcomes: causal or not? *Obstetrics & Gynecology,* 129, 405-407.

Koullali, B., Kamphuis, E.I., Hof, M.H., Robertson, S.A., Pajkrt, E., de Groot, C.J., et al. (2017). The effect of interpregnancy interval on the recurrence rate of spontaneous preterm birth: a retrospective cohort study. *American Journal of Perinatology,* 34, 174-182.

Kramer, M.S. (1987). Determinants of low birth weight: methodological assessment and meta-analysis. *Bulletin of the world health organization,* 65, 663.

Lindgren, U., Nilsson, K., de Luna, X., & Ivarsson, A. (2016). Data resource profile: Swedish microdata research from childhood into lifelong health and welfare (Umeå SIMSAM Lab). *International journal of epidemiology,* 45, 1075-1075g.

Ludvigsson, J.F., Andersson, E., Ekbom, A., Feychting, M., Kim, J.-L., Reuterwall, C., et al. (2011). External review and validation of the Swedish national inpatient register. *BMC Public Health,* 11, 450.

Luo, Z.-C., Wilkins, R., & Kramer, M.S. (2006). Effect of neighbourhood income and maternal education on birth outcomes: a population-based study. *Canadian Medical Association Journal,* 174, 1415-1420.

Mayo, J.A., Shachar, B.Z., Stevenson, D.K., & Shaw, G.M. (2017). Interpregnancy Interval and Adverse Pregnancy Outcomes: An Analysis of Successive Pregnancies and: Interpregnancy Interval and Pregnancy Outcomes: Causal or Not? *Obstetrics & Gynecology,* 130, 463.

Molitoris, J. (2017). The effect of birth spacing on child mortality in Sweden, 1878–1926. *Population and Development Review,* 43, 61-82.

Molitoris, J., Barclay, K., & Kolk, M. (2018). When Birth Spacing Does and Does Not Matter for Child Survival: An International Comparison using the DHS. *Stockholm Research Reports in Demography,* 2018:21.

Moussa, K.M., Ostergren, P., Eek, F., & Kunst, A.E. (2010). Are time-trends of smoking among pregnant immigrant women in Sweden determined by cultural or socioeconomic factors? *BMC Public Health,* 10, 374.

Oldenburg, C.M., Rasmussen, F., & Cotten, N.U. (1997). Ethnic differences in rates of infant mortality and sudden infant death in Sweden, 1978–1990. *The European Journal of Public Health,* 7, 88-94.

Powell, B., & Steelman, L.C. (1990). Beyond sibship size: Sibling density, sex composition, and educational outcomes. *Social Forces,* 69, 181-206.

Powell, B., & Steelman, L.C. (1993). The educational benefits of being spaced out: Sibship density and educational progress. *American Sociological Review*, 367-381.

Rasmussen, F., Oldenburg, C.E.M., Ericson, A., & Gunnarskog, J. (1995). Preterm birth and low birthweight among children of Swedish and immigrant women between 1978 and 1990. *Paediatric and Perinatal Epidemiology,* 9, 441-454.

Shachar, B., Mayo, J., Lyell, D., Baer, R., Jeliffe‐Pawlowski, L., Stevenson, D., et al. (2016). Interpregnancy interval after live birth or pregnancy termination and estimated risk of preterm birth: a retrospective cohort study. *BJOG: An International Journal of Obstetrics & Gynaecology,* 123, 2009-2017.

Smedby, B., & Ericson, A. (1979). Perinatal mortality among children of immigrant mothers in Sweden. *Acta Paediatrica,* 68, 41-46.
Smits, L.J., & Essed, G.G. (2001). Short interpregnancy intervals and unfavourable pregnancy outcome: role of folate depletion. *The Lancet,* 358, 2074-2077.
Socialstyrelsen (2003). *The Swedish Medical Birth Register—a summary of content and quality.* : Swedish National Board of Health and Welfare.
Swamy, G.K., Østbye, T., & SkjŠrven, R. (2008). Association of preterm birth with long-term survival, reproduction, and next-generation preterm birth. *JAMA,* 299, 1429-1436.
Torssander, J., & Erikson, R. (2009). Stratification and mortality—A comparison of education, class, status, and income. *European Sociological Review,* 26, 465-474.
Urquia, M.L., Janevic, T., & Hjern, A. (2013). Smoking during pregnancy among immigrants to sweden, 1992–2008: The effects of secular trends and time since migration. *The European Journal of Public Health,* 24, 122-127.
Westerling, R., & Rosén, M. (2002). 'Avoidable'mortality among immigrants in Sweden. *The European Journal of Public Health,* 12, 279-286.
WHO. (2006). Report of a WHO technical consultation on birth spacing. Geneva: World Health Organization.
Wiking, E., Johansson, S.-E., & Sundquist, J. (2004). Ethnicity, acculturation, and self reported health. A population based study among immigrants from Poland, Turkey, and Iran in Sweden. *Journal of Epidemiology & Community Health,* 58, 574-582.
Zhu, B.-P., Rolfs, R.T., Nangle, B.E., & Horan, J.M. (1999). Effect of the interval between pregnancies on perinatal outcomes. *New England Journal of Medicine,* 340, 589-594.

Supplementary Materials

TABLE S1. Descriptive Statistics: Length of the Preceding Interpregnancy Interval in Relation to Low Birth Weight.

		Preceding Interpregnancy Interval											
		0-6	7-12	13-18	19-24	25-30	31-36	37-42	43-48	49-54	55-60	>60	Everyone
N		15,946	69,583	93,743	71,782	53,338	40,131	32,641	25,390	20,595	16,132	58,806	498,087
% Low Birth Weight		2.9	2.9	1.9	1.5	1.7	1.7	2.0	1.9	1.8	2.0	2.2	1.9
Female	%	51.0	52.1	51.9	52.1	52.1	52.0	51.6	51.6	51.2	51.7	51.6	51.9
Birth order	Mean	2.6	2.6	2.6	2.6	2.7	2.8	2.9	3.0	3.0	3.1	3.2	2.8
Maternal age	Mean	27.6	28.9	29.4	29.9	30.4	30.9	31.6	32.1	32.5	33.0	34.7	30.7
Birth year	Mean	1994.1	1994.2	1994.5	1994.7	1994.8	1995.2	1995.5	1995.9	1996.0	1996.4	1997.9	1995.2
Set Size	Mean	3.7	3.5	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.4
N by Immigrant Group	Sweden	10,407	56,339	80,928	62,207	46,086	34,452	27,786	21,528	17,444	13,563	48,936	419,676
	EU-15 + Nordic + OECD	881	3,349	3,819	2,811	2,020	1,565	1,206	1,030	799	654	2,448	20,582
	Eastern Europe	1,305	2,761	2,686	2,146	1,743	1,440	1,284	1,022	865	698	3,107	19,057
	Other	3,352	7,129	6,304	4,615	3,485	2,673	2,363	1,810	1,486	1,217	4,312	38,746
N by Maternal Education	<Tertiary	4,068	26,277	39,285	30,011	22,180	16,318	13,117	10,160	7,904	6,091	20,246	195,657
	Tertiary	11,009	41,022	52,292	40,221	30,056	23,042	18,871	14,735	12,287	9,722	37,602	290,859
% LBW by	Sweden	2.9	1.7	1.4	1.6	1.6	1.9	1.8	1.8	1.8	2.0	2.7	1.8
Immigrant Group	EU-15 + Nordic + OECD	3.2	2.1	1.8	1.7	1.7	3.0	1.8	1.5	2.6	3.8	3.1	2.2
	Eastern Europe	3.7	2.9	2.4	2.5	2.8	2.6	2.4	1.6	2.7	2.1	3.7	2.8
	Other	2.7	2.6	2.1	2.4	2.3	2.8	3.0	2.8	2.7	3.2	3.8	2.7
% LBW by	<Tertiary	2.4	1.4	1.2	1.4	1.4	1.7	1.6	1.3	1.6	1.8	2.2	1.5
Maternal Education	Tertiary	3.1	2.1	1.7	1.9	1.9	2.2	2.0	2.2	2.2	2.4	3.1	2.2

TABLE S2. Descriptive Statistics: Length of the Preceding Interpregnancy Interval in Relation to Preterm Birth.

		Preceding Interpregnancy Interval											
		0-6	7-12	13-18	19-24	25-30	31-36	37-42	43-48	49-54	55-60	>60	Everyone
N		15,993	69,773	93,979	72,002	53,490	40,232	32,708	25,441	20,635	16,161	58,925	499,339
% Preterm		5.8	3.8	3.1	3.1	3.1	3.4	3.3	3.4	3.4	3.8	4.5	3.5
Female	%	51.1	52.1	51.9	52.1	52.1	52.0	51.6	51.6	51.2	51.7	51.6	51.9
Birth order	Mean	2.6	2.6	2.6	2.6	2.7	2.8	2.9	3.0	3.0	3.1	3.2	2.8
Maternal age	Mean	27.6	28.9	29.4	29.9	30.4	30.9	31.6	32.1	32.5	33.0	34.7	30.7
Birth year	Mean	1994.1	1994.2	1994.5	1994.7	1994.8	1995.2	1995.5	1995.9	1996.0	1996.4	1997.9	1995.2
Set Size	Mean	3.7	3.5	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.4
N by Immigrant Group	Sweden	10,441	56,488	81,120	62,394	46,220	34,542	27,845	21,568	17,476	13,590	49,022	420,706
	EU-15 + Nordic + OECD	884	3,362	3,831	2,819	2,022	1,567	1,207	1,035	802	654	2,457	20,640
	Eastern Europe	1,308	2,773	2,693	2,156	1,748	1,442	1,284	1,024	868	699	3,120	19,115
	Other	3,359	7,145	6,329	4,629	3,496	2,680	2,370	1,814	1,488	1,218	4,323	38,851
N by Maternal Education	<Tertiary	4,083	26,345	39,391	30,097	22,247	16,358	13,146	10,180	7,920	6,103	20,284	196,154
	Tertiary	11,040	41,133	52,410	40,351	30,137	23,098	18,905	14,766	12,311	9,739	37,680	291,570
% Preterm by Immigrant Group	Sweden	6.0	3.7	3.0	3.0	3.1	3.3	3.3	3.4	3.4	3.7	4.3	3.5
	EU-15 + Nordic + OECD	6.4	4.6	3.5	3.1	3.3	4.3	3.8	4.3	4.1	4.9	5.0	4.1
	Eastern Europe	6.7	4.4	3.8	4.3	3.0	4.0	3.3	2.1	4.0	3.0	5.2	4.2
	Other	4.5	4.0	3.1	3.3	3.3	4.2	3.7	3.6	3.1	4.6	5.1	3.9
% Preterm by Maternal Education	<Tertiary	5.3	3.3	2.8	2.7	2.7	2.9	2.9	3.1	3.1	3.3	3.8	3.1
	Tertiary	6.0	4.1	3.3	3.3	3.4	3.8	3.6	3.5	3.5	4.1	4.8	3.8

TABLE S3. Descriptive Statistics: Length of the Preceding Interpregnancy Interval in Relation to Hospitalization at Ages 0-1.

		Preceding Interpregnancy Interval											
		0-6	7-12	13-18	19-24	25-30	31-36	37-42	43-48	49-54	55-60	>60	Everyone
N		15,993	69,773	93,979	72,002	53,490	40,232	32,708	25,441	20,635	16,161	58,925	499,339
% Hospitalized		12.1	10.3	10.2	10.1	10.0	10.0	10.6	10.6	10.7	10.9	12.1	10.5
Female	%	51.1	52.1	51.9	52.1	52.1	52.0	51.6	51.6	51.2	51.7	51.6	51.9
Birth order	Mean	2.6	2.6	2.6	2.6	2.7	2.8	2.9	3.0	3.0	3.1	3.2	2.8
Maternal age	Mean	27.6	28.9	29.4	29.9	30.4	30.9	31.6	32.1	32.5	33.0	34.7	30.7
Birth year	Mean	1994.1	1994.2	1994.5	1994.7	1994.8	1995.2	1995.5	1995.9	1996.0	1996.4	1997.9	1995.2
Set Size	Mean	3.7	3.5	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.4
N by Immigrant Group	Sweden	10,441	56,488	81,120	62,394	46,220	34,542	27,845	21,568	17,476	13,590	49,022	420,706
	EU-15 + Nordic + OECD	884	3,362	3,831	2,819	2,022	1,567	1,207	1,035	802	654	2,457	20,640
	Eastern Europe	1,308	2,773	2,693	2,156	1,748	1,442	1,284	1,024	868	699	3,120	19,115
	Other	3,359	7,145	6,329	4,629	3,496	2,680	2,370	1,814	1,488	1,218	4,323	38,851
N by Maternal Education	<Tertiary	4,083	26,345	39,391	30,097	22,247	16,358	13,146	10,180	7,920	6,103	20,284	196,154
	Tertiary	11,040	41,133	52,410	40,351	30,137	23,098	18,905	14,766	12,311	9,739	37,680	291,570
% Hospitalized by	Sweden	11.8	10.1	10.0	9.9	9.8	9.7	10.3	10.3	10.6	10.6	12.0	10.3
Immigrant Group	EU-15 + Nordic + OECD	10.9	8.5	9.2	8.7	8.5	10.3	8.9	9.9	9.0	10.4	12.1	9.5
	Eastern Europe	12.4	11.3	12.1	12.2	11.6	12.6	12.5	12.8	14.2	15.2	13.3	12.5
	Other	13.1	12.4	12.6	12.5	12.6	12.5	13.4	12.7	10.1	12.0	12.4	12.5
% Hospitalized by	<Tertiary	11.5	9.5	9.7	9.6	9.5	9.5	9.9	9.9	10.0	9.8	10.9	9.8
Maternal Education	Tertiary	12.2	10.8	10.6	10.4	10.4	10.4	11.0	11.0	11.1	11.5	12.7	11.0

TABLE S4. Descriptive Statistics: Length of the Preceding Interpregnancy Interval in Relation to Hospitalization at Ages 1-3.

		Preceding Interpregnancy Interval											
		0-6	7-12	13-18	19-24	25-30	31-36	37-42	43-48	49-54	55-60	>60	Everyone
N		15,993	69,773	93,979	72,002	53,490	40,232	32,708	25,441	20,635	16,161	58,925	499,339
% Hospitalized		19.2	18.0	17.5	17.6	17.3	18.1	18.0	18.1	18.4	18.4	17.9	17.8
Female	%	51.1	52.1	51.9	52.1	52.1	52.0	51.6	51.6	51.2	51.7	51.6	51.9
Birth order	Mean	2.6	2.6	2.6	2.6	2.7	2.8	2.9	3.0	3.0	3.1	3.2	2.8
Maternal age	Mean	27.6	28.9	29.4	29.9	30.4	30.9	31.6	32.1	32.5	33.0	34.7	30.7
Birth year	Mean	1994.1	1994.2	1994.5	1994.7	1994.8	1995.2	1995.5	1995.9	1996.0	1996.4	1997.9	1995.2
Set Size	Mean	3.7	3.5	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.4
N by Immigrant Group	Sweden	10,441	56,488	81,120	62,394	46,220	34,542	27,845	21,568	17,476	13,590	49,022	420,706
	EU-15 + Nordic + OECD	884	3,362	3,831	2,819	2,022	1,567	1,207	1,035	802	654	2,457	20,640
	Eastern Europe	1,308	2,773	2,693	2,156	1,748	1,442	1,284	1,024	868	699	3,120	19,115
	Other	3,359	7,145	6,329	4,629	3,496	2,680	2,370	1,814	1,488	1,218	4,323	38,851
N by Maternal Education	<Tertiary	4,083	26,345	39,391	30,097	22,247	16,358	13,146	10,180	7,920	6,103	20,284	196,154
	Tertiary	11,040	41,133	52,410	40,351	30,137	23,098	18,905	14,766	12,311	9,739	37,680	291,570
% Hospitalized by	Sweden	18.9	17.7	17.4	17.5	17.4	17.8	18.0	18.0	18.4	18.3	18.0	17.7
Immigrant Group	EU-15 + Nordic + OECD	17.9	15.9	15.2	14.6	14.0	17.7	17.3	17.1	19.3	18.5	17.5	16.2
	Eastern Europe	21.2	18.9	18.6	20.9	18.8	20.5	20.8	19.6	20.4	20.2	18.8	19.6
	Other	19.8	20.4	19.9	19.9	18.2	20.7	17.4	18.2	16.8	18.1	16.4	19.1
% Hospitalized by	<Tertiary	17.4	16.7	16.3	16.2	15.7	16.2	16.4	17.0	16.8	16.6	16.6	16.4
Maternal Education	Tertiary	20.1	18.8	18.4	18.7	18.6	19.5	19.1	18.9	19.5	19.5	18.6	18.9

TABLE S5. Descriptive Statistics: Length of the Preceding Interpregnancy Interval in Relation to Hospitalization at Ages 4-6.

		Preceding Interpregnancy Interval											
		0-6	7-12	13-18	19-24	25-30	31-36	37-42	43-48	49-54	55-60	>60	Everyone
N		15,993	69,773	93,979	72,002	53,490	40,232	32,708	25,441	20,635	16,161	58,925	499,339
% Hospitalized		10.1	9.8	9.8	9.7	9.5	9.3	8.8	8.6	8.2	8.6	8.3	9.3
Female	%	51.1	52.1	51.9	52.1	52.1	52.0	51.6	51.6	51.2	51.7	51.6	51.9
Birth order	Mean	2.6	2.6	2.6	2.6	2.7	2.8	2.9	3.0	3.0	3.1	3.2	2.8
Maternal age	Mean	27.6	28.9	29.4	29.9	30.4	30.9	31.6	32.1	32.5	33.0	34.7	30.7
Birth year	Mean	1994.1	1994.2	1994.5	1994.7	1994.8	1995.2	1995.5	1995.9	1996.0	1996.4	1997.9	1995.2
Set Size	Mean	3.7	3.5	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.4
N by Immigrant Group	Sweden	10,441	56,488	81,120	62,394	46,220	34,542	27,845	21,568	17,476	13,590	49,022	420,706
	EU-15 + Nordic + OECD	884	3,362	3,831	2,819	2,022	1,567	1,207	1,035	802	654	2,457	20,640
	Eastern Europe	1,308	2,773	2,693	2,156	1,748	1,442	1,284	1,024	868	699	3,120	19,115
	Other	3,359	7,145	6,329	4,629	3,496	2,680	2,370	1,814	1,488	1,218	4,323	38,851
N by Maternal Education	<Tertiary	4,083	26,345	39,391	30,097	22,247	16,358	13,146	10,180	7,920	6,103	20,284	196,154
	Tertiary	11,040	41,133	52,410	40,351	30,137	23,098	18,905	14,766	12,311	9,739	37,680	291,570
% Hospitalized by	Sweden	11.0	10.2	10.0	9.9	9.6	9.4	8.9	8.8	8.4	8.8	8.5	9.5
Immigrant Group	EU-15 + Nordic + OECD	8.8	8.8	9.1	8.7	10.2	9.1	10.0	9.0	8.5	8.7	8.8	9.1
	Eastern Europe	9.3	9.5	9.5	9.2	9.8	8.9	8.3	9.1	7.9	9.6	8.0	9.0
	Other	8.1	7.4	7.6	7.7	7.4	7.6	7.3	6.1	6.7	6.7	5.6	7.2
% Hospitalized by	<Tertiary	9.7	9.3	9.0	8.6	8.2	7.8	7.9	7.9	7.2	7.6	7.8	8.5
Maternal Education	Tertiary	10.4	10.3	10.4	10.5	10.4	10.3	9.4	9.1	9.0	9.3	8.6	10.0

TABLE S6. Descriptive Statistics: Length of the Preceding Interpregnancy Interval in Relation to Hospitalization at Ages 7-10.

		Preceding Interpregnancy Interval											
		0-6	7-12	13-18	19-24	25-30	31-36	37-42	43-48	49-54	55-60	>60	Everyone
N		15,993	69,773	93,979	72,002	53,490	40,232	32,708	25,441	20,635	16,161	58,925	499,339
% Hospitalized		9.0	8.6	8.3	8.4	8.2	7.9	7.7	7.5	7.4	7.1	6.6	8.0
Female	%	51.1	52.1	51.9	52.1	52.1	52.0	51.6	51.6	51.2	51.7	51.6	51.9
Birth order	Mean	2.6	2.6	2.6	2.6	2.7	2.8	2.9	3.0	3.0	3.1	3.2	2.8
Maternal age	Mean	27.6	28.9	29.4	29.9	30.4	30.9	31.6	32.1	32.5	33.0	34.7	30.7
Birth year	Mean	1994.1	1994.2	1994.5	1994.7	1994.8	1995.2	1995.5	1995.9	1996.0	1996.4	1997.9	1995.2
Set Size	Mean	3.7	3.5	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.4
N by Immigrant Group	Sweden	10,441	56,488	81,120	62,394	46,220	34,542	27,845	21,568	17,476	13,590	49,022	420,706
	EU-15 + Nordic + OECD	884	3,362	3,831	2,819	2,022	1,567	1,207	1,035	802	654	2,457	20,640
	Eastern Europe	1,308	2,773	2,693	2,156	1,748	1,442	1,284	1,024	868	699	3,120	19,115
	Other	3,359	7,145	6,329	4,629	3,496	2,680	2,370	1,814	1,488	1,218	4,323	38,851
N by Maternal Education	<Tertiary	4,083	26,345	39,391	30,097	22,247	16,358	13,146	10,180	7,920	6,103	20,284	196,154
	Tertiary	11,040	41,133	52,410	40,351	30,137	23,098	18,905	14,766	12,311	9,739	37,680	291,570
% Hospitalized by	Sweden	10.3	9.1	8.8	8.7	8.4	8.2	8.0	8.0	7.8	7.4	7.1	8.4
Immigrant Group	EU-15 + Nordic + OECD	8.5	8.1	6.5	7.8	8.5	7.8	8.8	7.3	6.9	6.1	7.0	7.5
	Eastern Europe	7.4	7.2	6.2	6.6	6.7	6.5	6.2	6.3	6.1	6.2	4.4	6.2
	Other	5.6	5.3	4.9	5.4	5.5	4.8	4.2	2.8	3.6	4.3	2.7	4.7
% Hospitalized by	<Tertiary	9.5	8.1	7.8	7.4	7.1	6.6	7.0	7.0	6.7	6.4	6.1	7.3
Maternal Education	Tertiary	9.1	9.1	8.9	9.2	9.0	8.8	8.1	8.0	7.9	7.6	6.9	8.5