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Kieron Barclay, Martin Kolk, Øystein Kravdal

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Kieron Barclay[1,2,3], Martin Kolk[1,4,5], Øystein Kravdal[6,7]

[1]Department of Sociology, Stockholm University, Stockholm, Sweden; [2]Swedish Collegium for Advanced Study, Uppsala, Sweden; [3]Max Planck Institute for Demographic Research, Rostock, Germany; [4]Institute for Futures Studies, Stockholm, Sweden; [5]Centre for Cultural Evolution, Stockholm University, Stockholm, Sweden; [6]Centre for Fertility and Health, Norwegian Institute of Public Health, Oslo, Norway; [7]Department of Economics, Oslo University, Oslo, Norway

Abstract

There is a large literature examining the relationship between birth spacing and subsequent health outcomes for parents, and particularly for mothers. However, research on this topic draws almost exclusively on observational research designs, and almost all studies have been limited to adjusting for observable factors that may confound the relationship between birth spacing and health outcomes. In this study we use Norwegian register data to examine the relationship between birth spacing and the number of general practitioner consultations for physical and mental health concerns for both mothers and fathers in both the period immediately after childbirth (1–5 and 6–11 months after the birth), as well as the long-term (10-11 years after the birth). To examine short-term health outcomes, we use individual-level fixed effects – examining only different births to the same parent – to hold constant factors that may influence the birth spacing behavior of mothers and fathers as well as their health. We apply sibling fixed effects in our analysis of long-term outcomes, holding constant the family background of the mothers and fathers that we study. The results from our analyses that do not apply individual or sibling fixed effects yield results consistent with much of the previous literature, where both shorter and longer birth intervals are associated with worse health outcomes than birth intervals approximately 2-3 years long. Estimates from individual fixed effects models suggest that particularly short intervals negatively affects maternal mental health in the short-term, with more ambiguous evidence that particularly short- or long-intervals may influence parental health outcomes in the short- and long-term, though some of these patterns may be consistent with selection processes.

Keywords: Birth intervals, Physical health, Mental health, Parents, Fixed effects, Norway

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Introduction

The consequences of fertility behavior for the health of parents have long been of interest to physicians, epidemiologists, and social scientists. To this end, researchers have investigated how factors such as parental age at the time of first birth, fertility quantum, and other related factors affect the subsequent health and mortality risks of mothers and fathers (K. Barclay et al., 2016; Hanson et al., 2015). A further dimension of fertility that has attracted much research interest is the extent to which the spacing between births may influence the health of mothers, and even fathers. Indeed, concerns about potentially adverse effects of short birth intervals on the health of mothers and children have been a strong motive for family planning programs in lower-income countries (Miller & Babiarz, 2016; Yeakey et al., 2009). However, less is known about how short intervals may affect mothers' health in high-income countries, where family sizes are smaller, parents have better access to health care and nutrition, and consequently, where the effects are likely weaker than in poorer settings. Furthermore, given that most of the existing work in this field relies upon observational data (Conde-Agudelo et al., 2007), the degree to which most previous studies have been able to reduce confounding and identify the net effect of spacing between births on the health of parents has been restricted. Developing a greater understanding of the impact of birth spacing on parental health is important for parents, children, as well as for the allocation of public health investment and other related resources (Ahrens et al., 2019). Furthermore, in parallel with fertility postponement and declining fertility quantum, birth spacing between first and second births has been decreasing in many western countries, including Sweden, since the 1970s (Miranda, 2020); these secular trends underscore the importance of understanding whether there are any consequences of spacing behavior for the health of parents and children.

There are at least two good reasons for assuming that birth interval length may affect the health of mothers and fathers. First, numerous studies already point towards a strong association between interval length and negative pregnancy outcomes for mothers (i.e. outcomes specifically related to the health of the mother), where the worst outcomes tend to be concentrated amongst women who had short birth intervals (e.g., <12 months), or long birth intervals (e.g., >60 months) (Conde-Agudelo et al., 2007). Second, the medical literature suggests several physiological mechanisms by which short birth intervals might be associated with the health of parents, and particularly mothers, such as maternal nutrient depletion, and physiological regression (Conde-Agudelo et al., 2012). Given this evidence, and empirical research that shows that birth intervals affect perinatal outcomes and infant mortality (Conde-Agudelo et al., 2006; Molitoris et al., 2019; Rutstein, 2005), the World Health Organization recommends that women wait at least 24 months between pregnancies (World Health Organization, 2007). Although this advice is primarily geared towards mothers in low- and middle-income countries, medical associations such as the American College of Obstetricians and Gynecologists (ACOG) also advise mothers to wait at least 6 months between pregnancies (American College of Obstetricians and Gynecologists, 2019).

Nevertheless, there are also reasons to believe that reported associations between interval length and parental outcomes may overstate the negative effects of particularly short and long intervals, because data suggests that births after particularly short and long intervals are concentrated amongst women with lower levels of education, from disadvantaged minority groups, and teenage mothers; furthermore, births after short intervals are more likely to be unplanned (Gemmill & Lindberg, 2013; Liu et al., 2021). Research suggests that the negative effects of short birth spacing on *children* are almost entirely explained by parental background factors in Sweden (K. J. Barclay & Kolk, 2017, 2018). In this study we use information on primary health care uptake from Norwegian register data to examine the link between birth interval lengths and maternal and paternal health. We add to the previous literature by using within-individual fixed effects (comparing post-birth outcomes among mothers/fathers after different births, following intervals of varying lengths, in a within-individual comparison), and sibling comparison analyses (e.g. comparing a mother to her sisters), to estimate the effect of birth spacing on parental health in the short- and long-term net of unobserved factors that are constant within the individual, or within the parent's own sibling group. We examine the extent to which birth intervals are associated with parental health outcomes, operationalized as the number of consultations for mental or physical diseases among mothers and fathers, in the periods 1-5, 6-11, and 120-143 months after the birth. To our knowledge only two studies have previously applied a within-individual comparison approach to address the association between birth spacing and physical health outcomes amongst mothers, but not fathers, while mental health outcomes have not been examined using this study design. Furthermore, our sibling comparison approach is novel for examining the association between birth intervals and both physical and mental health outcomes for both mothers and fathers. An important part of our analysis is to examine how sensitive the conclusions are to the choices of statistical approach and the time window for health measurement. We study two different 'short-term' periods in order to see whether the influence of birth spacing on parental health may differ between the immediate post-partum period and a period afterwards, while we examine the period 120-143 months after birth in order to see whether there are any protracted or persistent effects of birth spacing on parental health. Furthermore, studying both short- and long-term outcomes may allow us insight into the relative importance of the physiological and social mechanisms that may link birth spacing to later health outcomes.

Previous Empirical Research

Adverse Pregnancy Outcomes

Studies focusing on the potentially detrimental effects of short or long birth intervals in high-income countires have primarily focused on any potential detrimental effects on children (K. J. Barclay & Kolk, 2017, 2018; Buckles & Munnich, 2012; Conde-Agudelo et al., 2006; Molitoris et al., 2019). Considerably less attention has been paid to parental health. Most of the extant literature on the relationship between birth spacing and parental health is based on observational data, with various limitations in the extent to which the net effect of birth spacing can be distinguished from other potentially confounding factors. Most of this research is in the epidemiological and gynecological literature, and focuses on specific maternal health outcomes directly after birth, i.e. adverse pregnancy outcomes. A systematic review of 22 studies published between 1966 and 2006 indicated that short birth intervals are associated with an increased risk of uterine rupture amongst women attempting a vaginal birth after previous cesarean delivery, and an increased risk of uteroplacental bleeding disorders, while long birth intervals were associated with an increased risk of preeclampsia, and abnormally slow or protracted labor (Conde-Agudelo et al., 2007). A lack of clear or sufficient evidence has limited the extent to which conclusions can be drawn about the relationship between birth intervals and some other outcomes, such as the risk of maternal death, or anemia (Conde-Agudelo et al., 2007; Wendt et al., 2012). A more recent review, covering six new studies published between 2006 and 2018, reported that short interpregnancy intervals were associated with increased risk of obesity, gestational diabetes, precipitous labor, placental abruption, and labor dystocia, and a decreased risk of preeclampsia (Ahrens et al., 2019; Appareddy et al., 2017; Blumenfeld et al., 2014; Davis et al., 2014; Hanley et al., 2017; Sandström et al., 2012; Zhu et al., 2006). As mentioned earlier, only a handful of these studies have been conducted using data from high-income countries.

Although many of these studies have made some attempt to adjust for confounding in the relationship between birth spacing and maternal health outcomes, we are aware of only two studies that have specifically tried to adjust for both observed and *unobserved* characteristics that may drive an association between birth spacing and parental health. Studies by Hanley et al. (2017) and Liu et al. (2021) attempt to address unobserved confounding by using a within-mother comparison analysis, i.e. comparing pregnancy outcomes for mothers after birth intervals of different lengths (Hanley et al., 2017; Liu et al., 2021). Hanley et al. used perinatal register data from British Columbia, Canada, and examined gestational diabetes, preeclampsia, and beginning the following pregnancy obese. Short interpregnancy intervals (0-5 and/or 6-11 months) were associated with an increased risk of gestational diabetes and obesity, and this persisted even in the within-mother comparison analysis (Hanley et al., 2017). Hanley et al. discuss the possibility that short intervals mean that the mother has less time to lose weight before the following pregnancy, which may increase the risk of beginning the following pregnancy obese, while gestational diabetes is also associated with obesity (Hanley et al., 2017). Liu et al. used data from California perinatal registers over the period 1997-2012, and examined severe maternal morbidity using a within-mother comparison design. Severe maternal morbidity (SMM) was defined to include potentially life-threatening conditions such as eclampsia, or sepsis. Liu et al. found that, relative to interpregnancy intervals of 18-23 months, shorter intervals, including even intervals of 0-6 months, were associated with a lower risk of SMM in within-mother comparisons, while longer intervals, including not only >59 months but also 24-59 months, were associated with an increased risk of SMM (Liu et al., 2021).

Given previous research that indicates that almost all negative effects of short birth spacing on child outcomes seem to be explained by parental characteristics (K. J. Barclay & Kolk, 2017, 2018), it is clearly important to consider the potential role of observed and unobserved parental characteristics when estimating the influence of birth intervals on parental health outcomes, and particularly when previous research already indicates that individuals who are socioeconomically disadvantaged are overrepresented amongst parents who have children after short intervals (Gemmill & Lindberg, 2013).

Mental health outcomes

There is relatively little research on the relationship between birth spacing and parental mental health using large-scale quantitative data. However, with caution, we may also be able to draw inferences from the body of research that has examined how children affect the mental health of parents, and whether the parents of twins – arguably a special case of extremely short birth spacing in some respects – have different mental health outcomes from the parents of singletons. Research has suggested that the parents of closely spaced children are more likely to report symptoms of depression than parents of more widely spaced children, and parents of twins are even more likely to report symptoms of depression and anxiety than parents of closely spaced children (Thorpe et al., 1991; Wenze et al., 2015). Multiple births may be associated with an increased risk of postpartum depression (Choi et al., 2009). Research also suggests that raising closely spaced infants, whether they are twins or separated by a short birth interval, is more stressful for parents (Glazebrook et al., 2004), and that shorter birth intervals may even increase the risk of parental divorce (Berg et al., 2020).

As mentioned earlier, some research also shows that particularly short or long interpregnancy intervals can increase the probability of preterm birth and low birth weight (Conde-Agudelo et al., 2006), and the challenges of raising a child born preterm or with low birth weight may also increase the probability of suffering from depression (Poehlmann et al., 2009). However, this association is complicated by evidence that suggests that antenatal depression and anxiety may itself increase the probability of preterm delivery (Männistö et al., 2016; Staneva et al., 2015), and lower the probability of breastfeeding initiation (Grigoriadis et al., 2013); the absence of lactational amenorrhea would also increase the probability that any subsequent parity progression would follow a shorter birth interval. It should be noted, however, that other research indicates that lower parental wellbeing decreases the probability of parity progression (Margolis & Myrskylä, 2015). Adjusting for unobserved factors related to parental physical and mental health may be particularly important for trying to understand whether birth spacing has an independent effect on subsequent measures of parental health.

Long-term outcomes

Less research has examined longer-term outcomes in relation to birth spacing, though several of these studies distinguish themselves by examining fathers in addition to mothers. Grundy and Kravdal (2014) examined birth spacing history in relation to mortality in late adulthood for mothers and fathers using Norwegian register data (Grundy & Kravdal, 2014); they found that parents of two or three children had higher mortality if the intervening interval was 18 months or less relative to parents where the intervals were 30-41 months, while mortality was lower for parents of three or four children who experienced longer average birth intervals (Grundy & Kravdal, 2014). They also found that short birth intervals between the first and second birth were associated with increased medication use. Other research has also suggested that short birth intervals can increase mortality in later life for women (Grundy & Tomassini, 2005), and increase the likelihood of long-term health impairments for mothers and fathers (Read et al., 2011). Hanson et al. (2015) used data from the Utah Population Database to examine how various dimensions of reproductive history, including birth spacing, are associated with long-term morbidity. They found that having at least one long birth interval was associated with a lower likelihood of morbidity for women, but there was no association for men (Hanson et al., 2015). Other work has also suggested that both short- and long-birth intervals are associated with increased risk of cardiovascular disease (Ngo et al., 2016), cardiovascular-related mortality, and all-cause mortality (Weisband et al., 2020). A study examining China's 'later, longer, fewer' fertility campaign of the 1970s, which encouraged parents to wait until an older age for childbearing, increase spacing between births, and have fewer children, reported that this had a negative effect on long-term parental physical and mental wellbeing (Chen & Fang, 2018); however, the authors largely attribute this finding to having fewer children with whom to interact in older age rather than any negative effect of longer birth spacing (Chen & Fang, 2018). The findings may also differ as the delayed spacing was externally enforced which may have different mental health consequences than childbearing in a context where it is deliberately planned. A further literature suggests that higher parity is associated with elevated mortality for both mothers and fathers (Högnäs et al., 2017; Zeng et al., 2016); although this pattern does not necessarily reflect any effects of birth spacing, a larger family size does imply shorter spacing, and spacing behavior may be a contributory factor to the observed mortality pattern by completed parity.

Theoretical Mechanisms

In this section we review potential mechanisms that could link birth interval length to parental health outcomes, including physiological pathways directly related to pregnancy, as well as post-birth social and family conditions that might mediate the relationship between birth intervals and later health. We also consider potential selection processes that may drive an association between birth spacing and parental health.

Health consequences of pregnancy and childbirth

A review of the literature on potential mechanisms has suggested that there are a small number of, non-exclusive, physiological processes that might connect birth interval length with maternal health outcomes, which include maternal nutrient depletion, incomplete healing of the uterine scar, an abnormal process in terms of remodeling of endometrial blood vessels, and physiological regression (Conde-Agudelo et al., 2012). Maternal nutrient depletion may result from excessively short birth intervals, which may lead to negative anthropometric effects on the mother, such as loss of fat stores, deficiencies of key nutrients, and a decrease in body mass index (Khan et al., 1998; Winkvist et al., 1992), but the body of evidence is not overwhelmingly clear (Conde-Agudelo et al., 2012). In populations where malnutrition is a public health problem, admittedly uncommon in the Norwegian context that we study, maternal nutrient depletion may lead to an imbalanced nutrient distribution between the mother and the fetus (King, 2003). Incomplete healing of a uterine scar may lead to uterine rupture if a cesarean delivery is followed by a short interpregnancy interval, or by an attempt at vaginal delivery (Bujold & Gauthier, 2010; Conde-Agudelo et al., 2007). Abnormal remodeling of endometrial blood vessels can lead to uteroplacental bleeding disorders, and the risk of this outcome is increased if interpregnancy intervals are short (Conde-Agudelo et al., 2006). Physiological regression is the only hypothesis that suggests a link between long birth intervals and maternal health outcomes; this hypothesis suggests that women experience numerous physiological adaptations that optimize the body for pregnancy and child delivery, but that these adaptations revert slowly over time to the extent that after long birth intervals, the physical state of mothers is similar to that of women who have never been pregnant (Zhu et al., 1999). Although this mechanism is not well understood, the risks of preeclampsia are similar for both first-time mothers and women conceiving after a long interpregnancy interval, such as five years or more (Conde-Agudelo et al., 2005, 2007). There are no direct physiological pathways that link birth spacing to health outcomes among men.

Stress of childcare

The spacing between children may influence resource distribution in the family, caring conditions, and other related factors. Parents with closely spaced children, and particularly when those children are young in age, may experience greater demands on their time and attention, experience greater stress and anxiety, and have fewer opportunities to rest and recover (Glazebrook et al., 2004; Hagen et al., 2013; Wenze et al., 2015). All else equal, a sparser birth schedule will spread out parental time commitments and stress over a large number of years, reducing the intensity of parenting over that time period. In theory these demands can be similar for both mothers and fathers, but in most societies, women still assume a significantly greater share of childcare responsibilities than men (Sayer, 2005). For parents who combine childcare responsibilities with employment, particularly full-time employment, the corresponding stresses may be greater still (Hochschild & Machung, 2012). Although Norway is characterized by relatively gender-egalitarian parenting, with generous parental leave, and heavily subsidized childcare, women still take more responsibility for childcare than men (Bernhardt et al., 2008; Kitterød & Lappegård, 2012; Sayer, 2005). Given high-levels of female labor force participation (Nilsen, 2018), this may be stressful. Research shows that parents tend to gain weight and to do less exercise (Kravdal et al., 2020; Nomaguchi & Bianchi, 2004; Reczek et al., 2014; Umberson et al., 2011). Extended periods of stress and insufficient rest can lead to deterioration in both physical and mental health, and this may be exacerbated by a less healthy lifestyle in terms of diet and exercise. For these reasons, parents who raise closely spaced children may be more likely to have poor health than parents whose children are spaced further apart. If there are negative physiological health consequences of short intervals, these may also continue to contribute both to worse health, more stress and worse mental health many years after the birth itself.<

Selection processes

The above sections illustrate that there are a number of plausible mechanisms by which birth spacing may affect parental health. Nevertheless, birth spacing behavior is not randomly distributed, and parents who have children after particularly short or long birth intervals may differ in terms of socioeconomic status, health, or other demographic characteristics from parents who do not have particularly short or long birth intervals. To wit, systematic differences between parents who have short birth intervals versus those who do not could confound the relationship between birth spacing and parental health outcomes if those parental characteristics are associated with parental health in the short- or long-term. Data from the United States shows that short birth intervals are more common amongst socioeconomically disadvantaged mothers, teenage mothers, and mothers from racial/ethnic minorities; however, they are also more common amongst socioeconomically advantaged parents in their late 30s, who are presumably pursuing an accelerated fertility schedule following a delayed first birth (Gemmill & Lindberg, 2013; Thagard et al., 2018). On the other hand, long birth intervals may partly be a result of partner change. Note that while factors such as parental age at childbearing, socioeconomic status, partnership histories, and ethnicity are often measured in observational data, they may not be perfectly measured. There may also be unobserved factors that drive an association between birth spacing and parental health outcomes. For example, if an underlying health condition affects both fecundity and later health outcomes, women who have longer birth intervals may have worse health outcomes. The literature on birth spacing and long-term child outcomes, as mentioned earlier, largely find that negative effects of short-birth intervals disappear once you control for parental characteristics, suggestion that short intervals are much more common in negatively selected families, and that this may produce misleading associations between short birth intervals and poor outcomes. As will be outlined in greater detail below, we estimate models that variously implement individual- and sibling-level fixed effects analyses in an attempt to adjust for factors that may drive any association between birth spacing and parental health outcomes. We also expect that selection processes may differ between men and women, and for physical and mental health outcomes, and our modeling strategy should allow us to partially distinguish the relative importance of selection versus direct effects of spacing behavior on health.

Data and Methods

Data Sources

The data sources for this study are the Norwegian Population Register, the Educational Database, and the Health Reimbursement register (*Kontroll og utbetaling av helserefusjoner register*, KUHR), the latter with information about GP consultations from 2006[i]. The data extractions made for this analysis cover the period up to 1 January 2019.

All persons who have ever lived in Norway after 1964 are included in the Population Register and assigned a personal identification number (PIN) that allows linkage to other registers. The Population Register includes information about the person's year and month of birth and death (if any), as well as marital and cohabitation status on January 1st each year from 2005 to 2019 (Falnes-Dalheim 2009). Over the period 1975-2004, the register includes full information about marital status, but not cohabitation. PINs of spouses and cohabiting partners are also included. Additionally, PINs of parents are included for almost everyone born in Norway after 1953, which means that there are almost full histories of live births for women and men born after 1935, with very high coverage of biological fatherhood. Furthermore, there is annual information on whether the person lived in Norway on January 1st, and the municipality of residence. Additionally, annual information on educational achievements and school enrolments has been extracted from the Educational Database in Statistics Norway.

The outcome variable in this study is the annual number of face-to-face GP consultations for two main types of disease: mental diseases and physical diseases (excluding the pregnancy-related)[ii]. Note that, although GPs do not themselves treat the most severe diseases, the use of specialized health care is usually contingent on referral from GPs. Thus, the indicators reflect a combination of severe and less severe conditions.

Statistical Analysis

Data on all women and men who were born in 1935 or later and who had at least one live birth over the period 1996–2017 were extracted from the data. The following description of the statistical analysis refers to mothers, but the same steps were taken for fathers – with corresponding variables defined, such as for example paternal age rather than maternal age. Mothers with one or more twin deliveries were excluded.

For every childbirth of parity 2 to parity 5, born to a mother in the period 1996-2017, the birth interval between the index parity and directly preceding parity was calculated (e.g. the interval between a birth at parity 2 – the index birth in this example from where we start our health follow-up – and parity 1). This birth interval is represented by a categorical variable (6-11, 12-17, 18-23, 24-29, 30-35, 36-47, 48-59, 60-83, 84-119, or 120+ months). Various models were estimated to learn about the relationship between birth intervals and the number of primary care consultations within a specified time interval (e.g. 6–11 months after the birth). The analysis was restricted to mothers and fathers who were resident in Norway each calendar year that includes at least one of the months during the specified time interval. Being resident in a calendar year was defined as being resident on January 1st of that year and the subsequent year; this apparently clumsy definition reflects that the data do not include more detailed residence histories. The very small number of birth intervals shorter than 6 months (which implies a new pregnancy immediately after birth, where the new pregnancy also ends in a premature birth) were excluded from the analysis.

Models

To examine the relationship between birth intervals and primary care consultations for mental and physical health we estimate a series of linear regression models, some of which include individual fixed effects, others of which include sibling fixed effects. Our core research question, whether birth spacing affects parental health, consists of two sub-questions: whether birth spacing affects parental health in the short-term, and whether birth spacing affects parental health in the long-term. We use individual fixed effects models to try to isolate the net effect of birth spacing on short-term outcomes for mother and fathers. To study long-term physical and mental health we apply sibling fixed effects in order to adjust for family background factors that may influence both birth spacing behavior as well as health. In all our models we model the health outcomes of mothers and fathers, which we refer to as either mothers/fathers or parents. When we refer to sibling models, we refer to the siblings of the mother's and father's that we study. The individual fixed effects models hold constant factors across births to the same mother or father, and the sibling level fixed effect models hold constant family origin factors of mothers and fathers. Their sibling group of origin is defined by a shared mother ID.

Short-term outcomes

In the first step we examine all births at parities 2-5 within the years 2006-2017 and the number of consultations by the mother or father in the period 1-5 months after the birth. Three models were estimated:

Model 1a, which included $\boldsymbol{X}_{ij}$ (parental age and birth parity) using the full sample of births during this period.

Model 1b, which includes the same covariates as Model 1a but is based on the sample of parents for whom we have data on at least two births at parities 2-5 in the time window of our study, i.e. the within-individual FE sample, but without individual fixed effects being applied.
Model 1c, which was like Model 1b, but with individual fixed effects applied, i.e. comparing a mother's outcomes following birth intervals at different parities, and further includes $\boldsymbol{Z}_{ij}$ (mother's educational level, mother's marital/cohabitation status, and whether the co-parent is the same as at the previous parity).

In the second step we continue our examination of all births at parities 2-5 within the years 2006-2017, but shift the focus to the number of consultations 6-11 months after the birth. Again, three models were estimated:
Model 2a, which included $\boldsymbol{X}_{ij}$ as defined above, using the full sample.
Model 2b, which includes the same covariates as Model 2a but is based on the sample of parents for whom we have data on at least two births at parities 2-5 in the time window of our study, i.e. the within-individual FE sample, but without individual fixed effects being applied.
Model 2c, which was like Model 2b, but with individual fixed effects added, i.e. comparing a mother's ((or father's)) outcomes following birth intervals at different parities, and including $\boldsymbol{Z}_{ij}$ as defined above.

We note that a so-called "carry-over problem" (Sjölander et al. 2016) in principle may arise because the outcome (maternal health) may affect the exposure for the earlier born child (interval up to the birth of that child). In particular, mothers who have relatively poor health after a birth may be less likely to have another child quickly (Margolis & Myrskylä, 2015). However, the sibling-model estimates of the effects of birth intervals on maternal health will only be substantially biased if this effect of health on subsequent fertility is extremely strong, which is not likely to be the case (Kravdal 2020).

Long-term outcomes

In the final step, to look at long-term health outcomes, defined as the number of consultations for mental or physical diseases among mothers and fathers 120-143 months (10-11 years) after the final birth. We examine all mothers (and fathers) with at least 1 child of birth order 2+ aged 120-143 months during the period 2006-2018, focusing on the average birth interval across all (previous) births. Three types of models were estimated:

Model 3a, which included variables $\boldsymbol{X}_{ij}$ (birth parity, and age at time of the last birth for the index person, i.e. the mothers and fathers).

Model 3b, which includes the same covariates as Model 3a, but is based on the sample that we use for the sibling fixed effects analysis, but without sibling fixed effects being applied, i.e. a sample that includes parents whose own mother's PIN is observed, and who has at least one same-sex sibling who also had at least 1 child of birth order 2+ aged 120-143 months during the period 2006-2018.

Model 3c, based on the same sample as Model 3b, but applying sibling fixed effects analysis, i.e. we compare a mother to her sisters, and a father to his brothers. The variables Z defined above are also added.

We conduct each of these analyses for both mothers and fathers, and separately for physical and mental health consultations.

Results

Descriptives

Table 1 shows the mean number of consultations, where a mental and physical ailment is reported as a diagnosis, by birth interval length for men and women for each of the specific time windows that we study. Notable patterns include the fact that seeking care for mental health is much less common than seeking care for physical health, but that care seeking for both mental and physical care is much more common in the long-term compared to short-term – though this likely reflects parental age effects. Across all study periods, and for both men and women, it is clear that mothers and fathers who experience extremely short birth intervals of 6-11 months have the highest probability of seeking care, while care seeking is also relatively more common amongst mothers and fathers who experience a long birth interval of 120+ months. Further descriptive information on the distribution of each of the covariates is available in Supplementary Tables S1-S3.

Table 1. Descriptive statistics for the mean number of consultations for mental and physical ailments for men and women in Norway in specific periods (1-5 months, 6-11 months, and 120-143 months) after birth.

		Average number of consultations for mental diseases				Average number of consultations for physical ailments			
		Full sample		Fixed effects sample		Full sample		Fixed effects sample	
Period	Interval	Mother	Father	Mother	Father	Mother	Father	Mother	Father
1-5 months after birth	6-11	0.088	0.096	0.094	0.099	0.701	0.608	0.716	0.611
	12-17	0.049	0.064	0.052	0.067	0.589	0.515	0.581	0.521
	18-23	0.039	0.048	0.038	0.054	0.550	0.460	0.544	0.574
	24-29	0.033	0.038	0.033	0.041	0.535	0.435	0.511	0.448
	30-35	0.033	0.041	0.033	0.039	0.545	0.425	0.533	0.438
	36-47	0.039	0.043	0.036	0.044	0.550	0.441	0.534	0.458
	48-59	0.044	0.049	0.038	0.054	0.555	0.460	0.553	0.467
	60-83	0.054	0.058	0.054	0.060	0.561	0.483	0.561	0.492
	84-119	0.063	0.069	0.061	0.065	0.571	0.508	0.564	0.511
	120+	0.070	0.085	0.057	0.070	0.594	0.561	0.551	0.519
	Total	0.044	0.051	0.041	0.051	0.555	0.463	0.543	0.471
6-11 months after birth	6-11	0.190	0.139	0.193	0.144	0.921	0.696	0.927	0.702
	12-17	0.098	0.074	0.102	0.078	0.740	0.617	0.739	0.633
	18-23	0.070	0.053	0.073	0.060	0.660	0.553	0.654	0.563
	24-29	0.059	0.048	0.057	0.054	0.625	0.525	0.607	0.538
	30-35	0.062	0.048	0.064	0.046	0.627	0.511	0.611	0.514
	36-47	0.065	0.053	0.065	0.057	0.621	0.523	0.622	0.547
	48-59	0.073	0.059	0.070	0.064	0.640	0.544	0.631	0.554
	60-83	0.090	0.073	0.090	0.073	0.647	0.574	0.662	0.581
	84-119	0.112	0.079	0.114	0.083	0.668	0.608	0.669	0.608
	120+	0.124	0.105	0.101	0.102	0.706	0.684	0.644	0.633
	Total	0.076	0.061	0.075	0.063	0.647	0.555	0.641	0.562
120-143 months after birth	6-11	1.013	0.555	0.192	0.169	3.982	2.858	4.308	3.153
	12-17	0.704	0.398	0.621	0.321	3.460	2.544	3.422	2.485
	18-23	0.539	0.309	0.513	0.296	3.061	2.369	2.823	2.212
	24-29	0.475	0.305	0.458	0.239	3.007	2.242	2.856	2.066
	30-35	0.465	0.263	0.421	0.218	3.048	2.256	2.915	2.063
	36-47	0.501	0.281	0.468	0.232	3.222	2.396	3.104	2.228
	48-59	0.604	0.317	0.570	0.255	3.538	2.594	3.360	2.386
	60-83	0.684	0.387	0.665	0.353	3.815	2.908	3.729	2.675
	84-119	0.788	0.444	0.799	0.389	4.131	3.304	4.195	3.093
	120+	0.867	0.476	0.924	0.472	4.441	3.731	4.282	3.282
	Total	0.578	0.327	0.548	0.276	3.413	2.581	3.282	2.367

Health 1-5 months after birth

Figure 1 shows the results from models examining the relationship between birth spacing and the number of mental and physical health consultations 1–5 months after birth for mothers and fathers. In order to emphasize the magnitude and substantive significance of the results, we present figures where we scale the estimated coefficients by the baseline probability of the outcome within each sample. This is important given that care seeking for mental health remains much less common than care seeking for physical ailments. The unscaled regression coefficients are presented in Table 2. According to Model 1a, based on the full sample and adjusting for maternal age and parity, both short and long intervals are associated with more consultations for mental diseases among mothers and fathers. The shortest (6-11 months) or longest (120+ months) birth intervals are associated with an increase of approximately 0.05 consultations. Although this appears low in absolute terms, relative to the baseline probability of 0.044, this is a very large association. The curvilinear pattern is also clear for consultations related to physical health; relative to birth intervals of 24-29 months, parents who had a birth interval shorter or longer were more likely to seek medical care for a physical ailment. For physical ailments, the magnitude was much smaller when scaled by the baseline probability: the shortest (6-11 months) birth intervals are associated with an increase of approximately 0.15 consultations, while the longest (120+ months) birth intervals are associated with an increase of approximately 0.05 consultations. Figure 1 also shows the results from Model 1b, which are very similar to Model 1a, except for being based on a different sample: the sample of mothers and fathers for whom we have data on at least two births at parities 2+, i.e. the within-individual fixed effects sample.

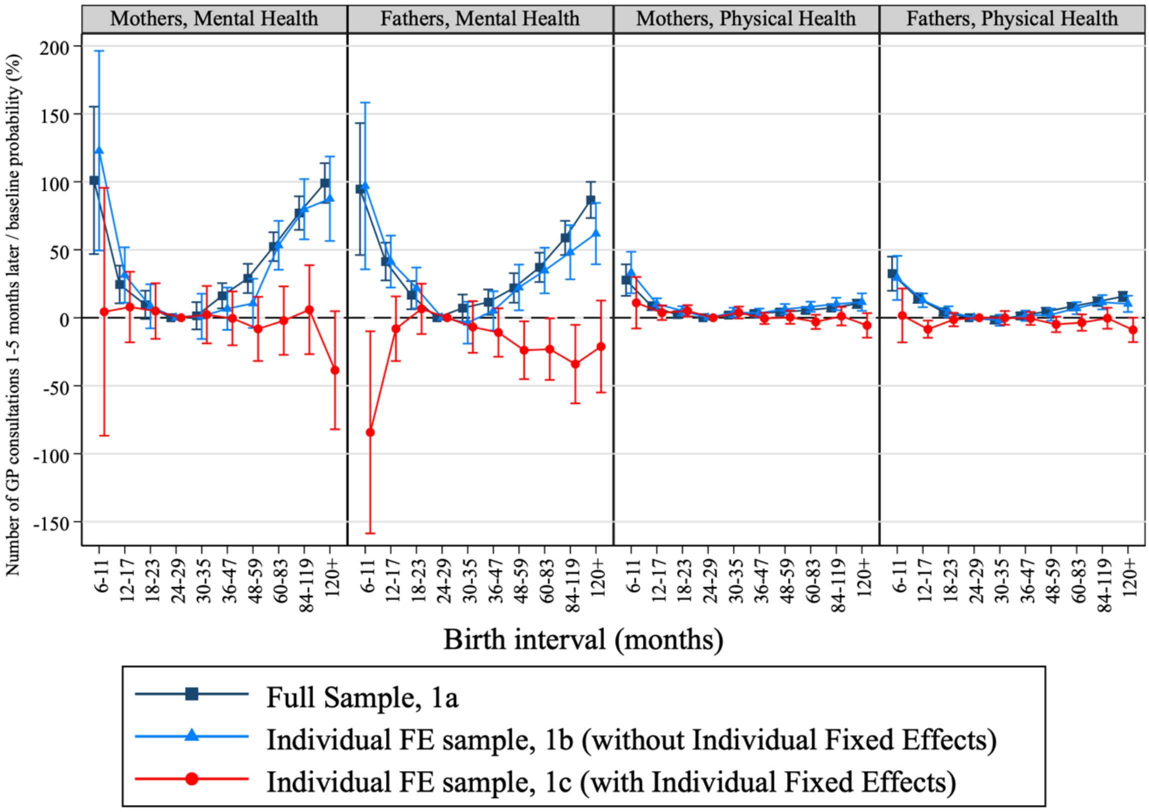

Figure 1. The relationship between birth intervals and number of general practitioner consultations for mental and physical health 1-5 months after birth for mothers and fathers in Norway. Please note that the coefficients are scaled by the baseline probability of the outcome within the analytical sample.

Finally, Model 1c introduces individual fixed effects and a few additional control variables. In Model 1c there are no statistically significant differences in the number of general practitioner consultations for mental health by birth interval length for women, with the point estimates close to zero for all birth interval categories except 120+ months. The results for mental health for fathers suggest that longer intervals are protective for mental health outcomes; intervals in the range 48-119 months are associated with fewer mental health consultations, these differences are generally statistically significant, and when scaled by the baseline hazard in the fixed effects sample (0.051), are approximately 20-30% lower in comparison to the reference category of 24-29 months. We also find that birth intervals of 6-11 months are substantially and significantly associated with fewer consultations. Regarding physical ailments, Model 1c shows little in the way of meaningful differences in GP consultations by birth interval length for either men or women: the differences are not statistically significant, and the magnitude of the association generally remains relatively small even when scaled by the baseline probability.

Table 2. The relationship between birth intervals and number of general practitioner consultations for mental and physical health 1-5 months after birth for mothers and fathers in Norway.

		Mental health						Physical health					
		Model						Model					
		1a		1b		1c		1a		1b		1c	
Sex	Interval	b	95% CI	b	95% CI	b	95% CI	b	95% CI	b	95% CI	b	95% CI
Male	6-11	0.048	.024, .073	0.049	.018, .081	-0.043	-.080, -.005	0.150	.092, .208	0.138	.062 .214	0.008	-.085, .101
	12-17	0.021	.014, .028	0.021	.011, .031	-0.004	-.016, .008	0.067	.051, .084	0.060	.037, .084	-0.040	-.069, -.009
	18-23	0.008	.003, .014	0.011	.003, .019	0.003	-.006, .018	0.020	.007, .032	0.021	.002, .040	-0.006	-.029, .017
	24-29 (ref)	0.000		0.000		0.000		0.000		0.000		0.000	
	30-35	0.004	-.001, .009	-0.002	-.009, .006	-0.003	-.013, .006	-0.008	-.019, .004	-0.009	-.027, .010	-0.001	-.024, .023
	36-47	0.006	.001, .011	0.003	-.004, .010	-0.006	-.014, .004	0.006	-.004, .017	0.007	-.010, .025	-0.002	-.024, .020
	48-59	0.011	.006, .017	0.011	.003, .020	-0.012	-.023, -.001	0.021	.008, .034	0.011	-.010, .038	-0.023	-.049, .004
	60-83	0.019	.013, .024	0.018	.009, .026	-0.012	-.023, -.000	0.038	.025, .051	0.033	.012, .054	-0.017	-.045, .012
	84-119	0.030	.024, .036	0.025	.014, .035	-0.017	-.032, -.002	0.055	.040, .070	0.054	.029, .079	-0.002	-.037, .035
	120+	0.044	.037, .051	0.032	.020, .043	-0.011	-.028, .006	0.072	.057, .088	0.048	.020, .076	-0.042	-.084, .000
	N	390,003		155,772		155,772		390,003		155,772		155,772	
Female	6-11	0.044	.021, .068	0.050	.020, .080	0.002	-.035, .039	0.154	.090, .218	0.181	.098, .263	0.060	-.042, .162
	12-17	0.011	.005, .017	0.013	.005, .021	0.003	-.007, .014	0.047	.031, .064	0.055	.032, .078	0.020	-.009, .049
	18-23	0.004	-.000, .009	0.003	-.003, .010	0.002	-.006, .010	0.012	.000, .025	0.028	.010, .046	0.027	.004, .050
	24-29 (ref)	0.000		0.000		0.000		0.000		0.000		0.000	
	30-35	0.001	-.003, .005	0.000	-.006, .007	0.001	-.007, .010	0.011	-.000, .023	0.021	.003, .040	0.021	-.003, .044
	36-47	0.007	.003, .011	0.003	-.003, .009	0.000	-.008, .008	0.018	.007, .029	0.019	.001, .036	-0.003	-.025, .019
	48-59	0.013	.008, .017	0.004	-.003, .012	-0.003	-.013, .006	0.023	.010, .036	0.034	.014, .055	0.002	-.024, .029
	60-83	0.023	.018, .028	0.022	.014, .029	-0.001	-.011, .009	0.030	.017, .043	0.044	.024, .064	-0.017	-.044, .012
	84-119	0.034	.028, .039	0.033	.027, .042	0.002	-.010, .016	0.040	.026, .055	0.055	.030, .080	0.006	-.030, .043
	120+	0.044	.037, .050	0.036	.023, .049	-0.016	-.033, .002	0.057	.040, .074	0.062	.027, .097	-0.030	-.079, .018
	N	396,502		151,374		151,374		396,502		151,374		151,374	

Health 6-11 months after birth

We now turn to our examination of health outcomes amongst mothers and fathers 6-11 months after birth. The results from these analyses, shown in Figure 2, are relatively similar to those seen for our analyses of outcomes 1-5 months after birth, illustrated in Figure 1. The unscaled regression coefficients are presented in Table 3. The results from Model 2a are based on the full sample, and show a curvilinear relationship between birth interval length and general practitioner consultations for mental and physical health, where intervals both shorter and longer than the reference category of 24-29 months are associated with an increase in medical care-seeking. For mental health outcomes, the shortest (6-11 months) and longest (120+ months) intervals are associated with an absolute increase of approximately 0.05 to 0.10 consultations for both mothers and fathers. For physical health outcomes the magnitude is smaller relative to the baseline probability, with the shortest intervals associated with an increase of approximately 0.25 GP consultations for women, and 0.15 for men. The results from Model 2b, which also controls for parental age at the time of birth and parity but based on the individual fixed effects sample, are very similar to the results from Model 2a.

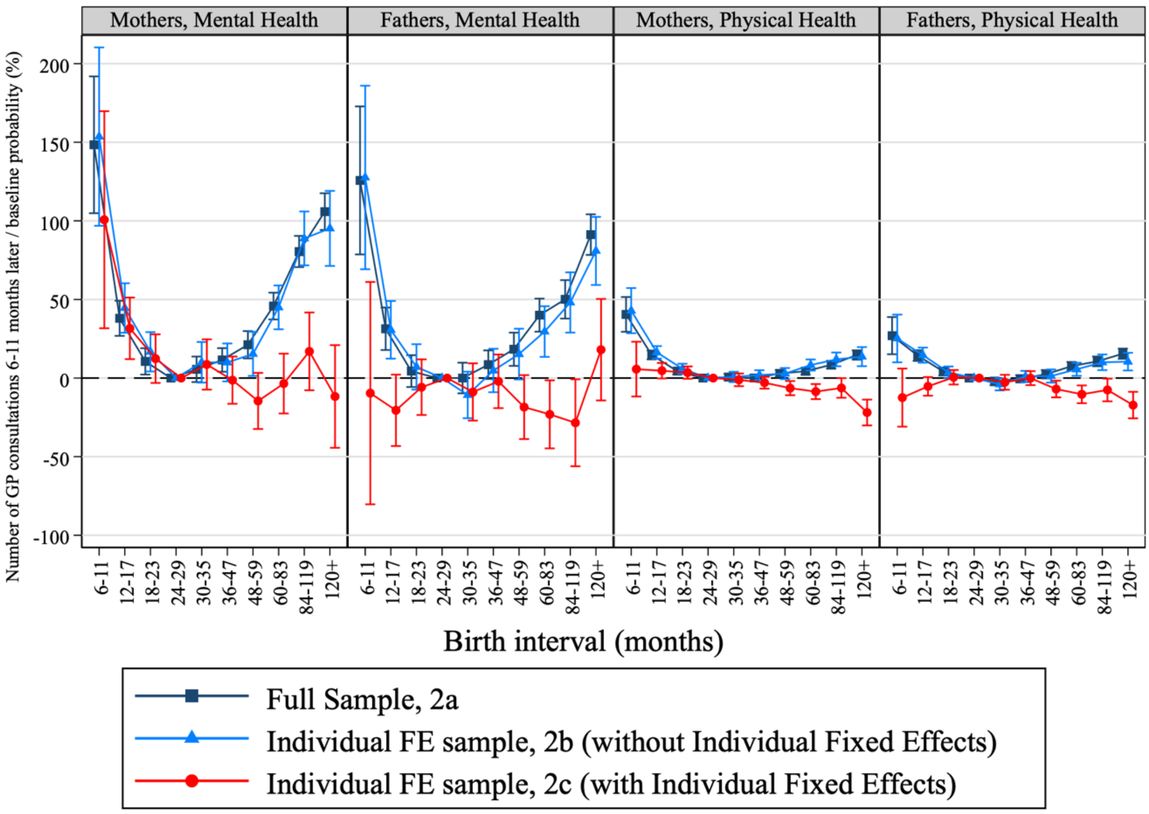

Figure 2. The relationship between birth intervals and number of general practitioner consultations for mental and physical health 6-11 months after birth for mothers and fathers in Norway. Please note that the coefficients are scaled by the baseline probability of the outcome within the analytical sample.

Table 3. The relationship between birth intervals and number of general practitioner consultations for mental and physical health 6-11 months after birth for mothers and fathers in Norway.

		Mental health						Physical health					
		Model						Model					
		2a		2b		2c		2a		2b		2c	
Sex	Interval	b	95% CI	b	95% CI	b	95% CI	b	95% CI	b	95% CI	b	95% CI
Male	6-11	0.077	.048, .105	0.080	.044, .117	-0.006	-.050, .039	0.150	.084, .215	0.142	.056, .227	-0.070	-.173, .034
	12-17	0.019	.011, .027	0.019	.008, .031	-0.013	-.027, .001	0.079	.061, .098	0.082	.055, .109	-0.030	-.063, .004
	18-23	0.003	-.003, .009	0.004	-.004, .014	-0.004	-.014, .007	0.023	.009, .037	0.020	-.000, .041	0.003	-.023, .029
	24-29 (ref)	0.000		0.000		0.000		0.000		0.000		0.000	
	30-35	0.000	-.005, .006	-0.007	-.016, .003	-0.006	-.017, .006	-0.012	-.025, .002	-0.022	-.044, -.000	-0.015	-.041, .012
	36-47	0.005	-.000, .011	0.003	-.005, .018	-0.001	-.012, .009	-0.002	-.015, .010	0.006	-.014, .026	0.000	-.025, .025
	48-59	0.011	.005, .018	0.010	-.000, .020	-0.012	-.024, .001	0.014	-.001, .028	0.007	-.016, .031	-0.039	-.069, -.009
	60-83	0.024	.018, .031	0.019	.008, .029	-0.015	-.028, -.000	0.042	.028, .057	0.031	.008, .055	-0.058	-.089, -.026
	84-119	0.031	.023, .038	0.030	.018, .042	-0.018	-.035, -.000	0.059	.042, .076	0.056	.028, .084	-0.043	-.083, -.001
	120+	0.056	.048, .064	0.051	.037, .065	0.011	-.008, .032	0.086	.068, .104	0.059	.027, .090	-0.097	-.143, -.049
	N	388,653		156,021		156,021		388,653		156,021		156,021	
Female	6-11	0.113	.080, .146	0.115	.073, .158	0.076	.024, .127	0.262	.190, .334	0.275	.183, .367	0.036	-.075, .148
	12-17	0.029	.020, .037	0.033	.022, .045	0.024	.009, .038	0.095	.077, .113	0.105	.079, .130	0.030	-.001, .062
	18-23	0.008	.002, .014	0.013	.003, .022	0.009	-.002, .021	0.029	.015, .042	0.038	.018, .058	0.022	-.002, .047
	24-29 (ref)	0.000		0.000		0.000		0.000		0.000		0.000	
	30-35	0.004	-.001, .010	0.008	-.002, .017	0.006	-.005, .018	0.004	-.009, .017	0.005	-.016, .026	-0.007	-.033, .019
	36-47	0.009	.003, .014	0.007	-.001, .016	-0.001	-.012, .010	0.000	-.011, .013	0.012	-.007, .032	-0.019	-.043, .005
	48-59	0.016	.010, .023	0.012	.001, .022	-0.011	-.024, .002	0.019	.005, .033	0.018	-.004, .041	-0.041	-.069, -.012
	60-83	0.035	.028, .041	0.034	.023, .044	-0.003	-.016, .012	0.028	.014, .042	0.053	.031, .076	-0.055	-.085, -.024
	84-119	0.061	.054, .069	0.067	.054, .079	0.013	-.005, .031	0.055	.038, .071	0.076	.048, .104	-0.040	-.080, -.000
	120+	0.080	.072, .089	0.071	.054, .089	-0.009	-.033, .016	0.095	.076, .114	0.087	.049, .126	-0.140	-.193, -.087
	N	395,175		151,672		151,672		395,175		151,672		151,672	

The results from Model 2c are based on the same analytical sample as Model 2b, but implement individual fixed effects and control for additional sociodemographic variables. For mental health outcomes, mothers who had a birth interval of 6-11 months seem to be more likely to seek care for mental health, with an average of 0.08 more consultations than mothers who had a birth interval of 24-29 months – a large difference relative to the baseline probability of 0.075 in this sample. Mothers who experienced a birth interval of 12-17 months are also marginally more likely to seek care for mental health, but there are no meaningful differences at longer birth intervals. For men, there are no differences in care-seeking behavior for mental health by birth interval length. For physical health outcomes, there is a relatively clear overall negative relationship between birth interval length and seeking health care among mothers, though the overall difference in the point estimates between those who experienced the shortest versus the longest intervals is only approximately 0.15 consultations. As with the results for outcomes measured in the period 1-5 months after birth (shown in Figure 1), the overall magnitude of the differences remains small even when the differences are statistically significant.

Health 10-11 years after birth

Finally, we use a different set of models where we study the outcomes more distant from the birth, once again examining it separately for mental health and physical health. We now examine how the average birth interval experienced by parents is associated with health outcomes 10–11 years after the birth of the last-born child. In Model 3c we introduce sibling fixed effects to control for family background factors that the mothers and fathers that we study share with their own siblings.

Table 4. The relationship between birth intervals and number of general practitioner consultations for mental and physical health 10-11 years after birth for mothers and fathers in Norway.

		Mental health						Physical health					
		Model						Model					
		3a		3b		3c		3a		3b		3c	
Sex	Interval	b	95% CI	b	95% CI	b	95% CI	b	95% CI	b	95% CI	b	95% CI
Male	6-11	0.201	-.009, .411	-0.100	-.553, .352	-0.188	-.801, .425	0.657	.212, 1.101	1.061	.129, 1.993	1.167	-.064, 2.397
	12-17	0.076	.023, .129	0.054	-.058, .167	-0.032	-.184, .120	0.329	.216, .442	0.402	.170, .634	0.210	-.095, .517
	18-23	0.001	-.035, .037	0.049	-.022, .121	0.065	-.032, .163	0.142	.066, .217	0.139	-.008, .287	0.168	-.028, .364
	24-29 (ref)	0.000		0.000		0.000		0.000		0.000		0.000	
	30-35	-0.041	-.070, -.010	-0.016	-.075, .044	-0.017	-.097, .064	-0.001	-.065, .063	-0.009	-.131, .114	0.008	-.153, .171
	36-47	-0.023	-.050, .004	0.003	-.050, .057	-0.011	-.084, .063	0.109	.051, .167	0.148	.038, .259	0.027	-.120, .175
	48-59	0.015	-.014, .045	0.032	-.027, .091	0.056	-.025, .139	0.248	.183, .312	0.272	.150, .394	0.002	-.162, .167
	60-83	0.094	.063, .124	0.140	.080, .200	0.024	-.061, .109	0.479	.414, .543	0.519	.395, .643	0.122	-.048, .293
	84-119	0.171	.133, .208	0.196	.119, .273	0.036	-.075, .147	0.746	.666, .826	0.863	.705, 1.021	0.253	.030, .477
	120+	0.239	.192, .287	0.299	.198, .400	0.011	-.141, .164	1.036	.936, 1.136	0.972	.765, 1.180	0.309	.003, .616
	N	233,842		52,487		52,487		233,842		52,487		52,487	
Female	6-11	0.421	.092, .749	-0.431	-1.37, .510	-0.381	-1.65, .888	0.836	.264, 1.41	1.310	-.316, 2.94	1.673	-.468, 3.813
	12-17	0.178	.107, .249	0.106	-.046, .258	0.004	-.205, .212	0.404	.281, .528	0.515	.2515, .778	0.177	-.175, .529
	18-23	0.054	.008, .101	0.039	-.056, .135	-0.111	-.241, .019	0.051	-.029, .132	-0.041	-.206, .125	-0.140	-.359, .080
	24-29 (ref)	0.000		0.000		0.000		0.000		0.000		0.000	
	30-35	-0.002	-.041, .037	-0.034	-.112, .045	-0.059	-.165, .047	0.045	-.022, .113	0.056	-.080, .191	0.059	-.119, .239
	36-47	0.041	.006, .076	0.028	-.043, .099	-0.060	-.157, .037	0.219	.158, .280	0.259	.137, .382	0.101	-.062, .264
	48-59	0.157	.119, .196	0.144	.066, .221	-0.022	-.129, .086	0.542	.475, .609	0.526	.392, .660	0.137	-.045, .318
	60-83	0.274	.235, .313	0.277	.199, .355	-0.023	-.135, .090	0.875	.808, .943	0.961	.827, 1.096	0.289	.100, .479
	84-119	0.434	.386, .481	0.455	.358, .552	-0.046	-.190, .098	1.286	1.203, 1.368	1.519	1.350, 1.687	0.489	.245, .732
	120+	0.589	.527, .651	0.642	.512, .773	0.032	-.163, .227	1.699	1.590, 1.806	1.707	1.480, 1.932	0.507	.177, .836
	N	247,410		58,512		58,512		247,410		58,512		58,512	

Figure 3 shows the results from models examining the relationship between birth spacing and mental and physical health consultations 10-11 years after the last birth for mothers and fathers, once again scaled by the baseline probability of the outcome within each sample. The unscaled regression coefficients are presented in Table 4. Model 3a shows the results from analyses based on the full sample of mothers and fathers. The results for mental health amongst women show that, relative to women who had an average birth interval of 24-29 months, women who had shorter or longer intervals had slightly higher care-seeking behavior: women with an average interval of 6-11 months had 0.42 more consultations, while women with an average interval of 84-119 months had 0.43 more consultations. The results for fathers were similar, but of a smaller magnitude. The results for care-seeking for physical health issues also show a curvilinear relationship between average interval length and medical consultations. For women, for example, an average interval of 6-11 months is associated with an increase of 0.84 consultations, while an average interval of 120+ months is associated with an increase of 1.70 consultations relative to the reference category. Men with an average interval of 6-11 months had 0.66 more consultations, and those with an average interval of 120+ months had 1.04 more consultations than men in the reference category of 24-29 months. The results from Models 3b, based on the sibling comparison sample but without applying the sibling fixed effects, are very similar to the results from Model 3a for both the physical and mental health outcomes, and for both men and women.

The results from Model 3c, based on the sibling comparison sample and applying sibling fixed effects and adding the three sociodemographic variables, show that care-seeking for mental health for mothers and fathers does not vary significantly by the length of the average birth interval in the period 10-11 years after the final birth, and nor do the point estimates suggest a clear pattern of results. The point estimates for physical health outcomes indicate that average birth intervals may influence medical consultations for women and men; for example, the point estimates for an average interval of 6-11 months seem to increase consultations by approximately 50% relative to the reference category even if the difference is not statistically significant. Longer intervals may also increase consultations for physical ailments. For example, average intervals of 120+ months increased consultations by 0.31 and 0.51 for women and men, respectively, compared to the reference category of 24-29 months. Further analyses (not shown), where we use the interval preceding the last-born child as the exposure variable rather than the average birth interval across all births, are qualitatively consistent with the findings presented in Figure 3.

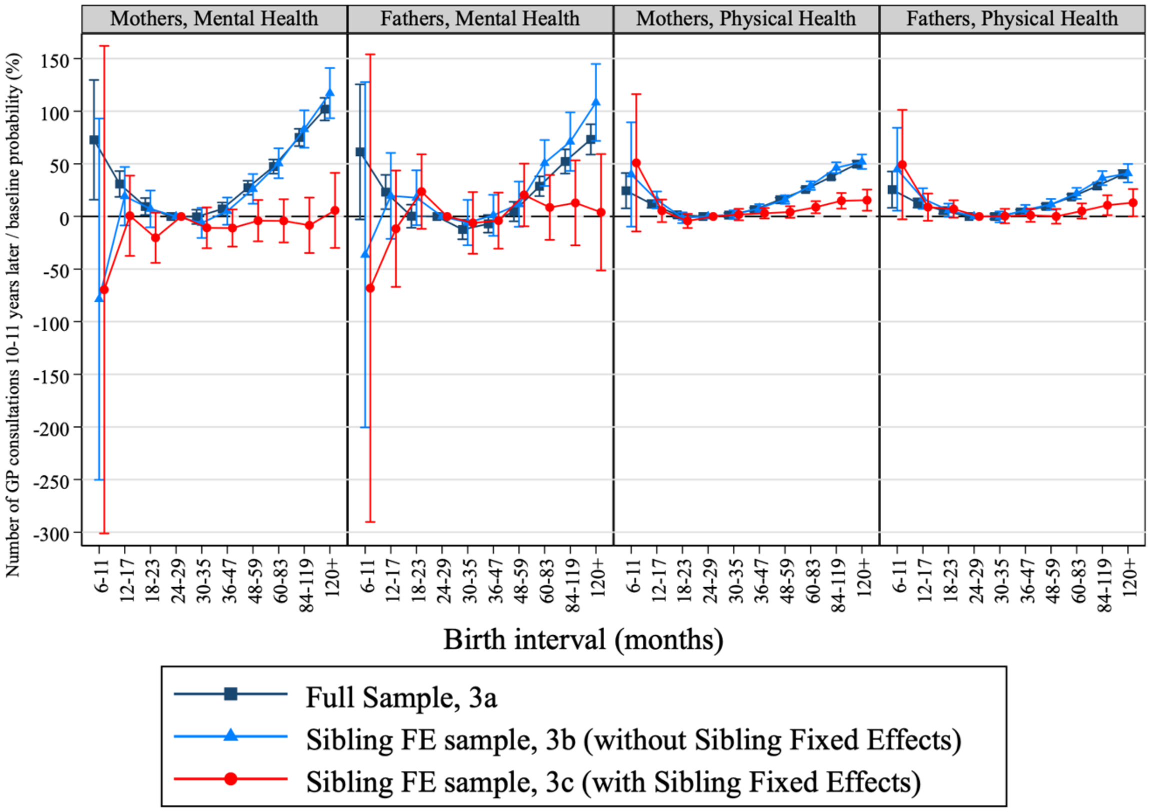

Figure 3. The relationship between birth intervals and number of general practitioner consultations for mental and physical health 10-11 years after birth for mothers and fathers in Norway. Please note that the coefficients are scaled by the baseline probability of the outcome within the analytical sample.

Discussion

In this study we add to the growing literature that attempts to develop our understanding of how birth spacing affects the health and wellbeing of both parents and children. To our knowledge this is one of the first studies to use a fixed effects approach to try to adjust for unobserved characteristics that may be related to both birth spacing behavior as well as later health outcomes in order to try to isolate the net effect of birth spacing. Furthermore, we extend the literature by applying this approach towards both physical and mental health outcomes, by examining these outcomes in both the short- and long-term, by addressing this research question for both men and women, and by applying two different study designs to adjust for shared family background factors as well as unobservable factors that are constant at the individual-level. The results from our associational analyses, not holding constant individual-level of sibling group-level factors, are broadly in line with previous research on this topic (which has been mostly restricted to controlling for only observed characteristics), showing that both women and men seem to have worse health outcomes if they experience either short or long intervals between births.

The results from our various fixed effects analyses are more ambiguous: when we estimate models that hold constant either individual-level or family background characteristics, we find that the negative effects of both short and long birth intervals are much smaller than those estimated in our naïve models, but not zero. The strongest pattern that we observe suggests support for a plausibly negative causal effect of very short intervals on mental health for women, perhaps related to increased stress with two tightly spaced children. We also find some suggestive evidence that longer birth intervals may be protective for mental health for both men and women in the short-term period after birth, but the lack of consistency in the findings for the separate analyses of the periods 1-5 and 6-11 months after birth suggests that we should be cautious about overinterpreting these results. The similar findings for men and for women, in both fixed-effects models and non-fixed effects models are worth highlighting, particularly given that the hypothesized mechanisms linking spacing to later health outcomes gives us reason to expect very different impact by sex in regard to both physiological effects, as well as the day-to-day wear and tear of childrearing.

In our analysis of long-term outcomes, we find that both very short, but also longer average birth intervals, increase the probability of care-seeking for physical health problems. The similarity of the patterns for men and women suggest either that the results may be driven by the stress of raising closely spaced children, rather than negative consequences related to perinatal outcomes directly associated with the pregnancy, or that similar selection processes for men and women produce similar results for the relationship between birth spacing and long-term health. That is to say, the sibling-comparison models are both consistent with explanations focusing on selection as an explanation and explanations based on a direct negative causal impact of a short interval. The negative effect of long birth intervals in these analyses is also plausibly related to the fact that sibling fixed effects are less effective at controlling for unobserved factors related to spacing behavior and health than individual-level fixed effects. These sibling comparison models should arguably be seen as providing a more effective control for family background factors, in contrast to the individual fixed effects models that adjust for all stable individual-level factors.

Unlike the literature using sibling fixed effects to estimate the influence of birth spacing on medium- and long-term child outcomes, where the negative effects of birth spacing seem to be largely explained by various forms of confounding (K. J. Barclay & Kolk, 2017, 2018; K. Barclay & Smith, 2022), we find some evidence that particularly short and long birth intervals may negatively impact parental health, even after holding unobserved factors at the individual-level and in the family of origin constant – although we suggest caution and advise against any over interpretation of the findings. Our results are somewhat consistent with previous research by Hanley et al. (2017), but not Liu et al. (2021), both of whom also used within-mother estimators to examine the relationship between birth spacing and several specific health outcomes, including gestational diabetes, preeclampsia, beginning the following pregnancy obese (Hanley et al., 2017), and severe maternal morbidity (Liu et al., 2021). Hanley et al. reported that short interpregnancy intervals (0-5 and/or 6-11 months) were associated with an increased risk of gestational diabetes and obesity even when holding unobserved factors at the mother-level constant. Liu et al. found that, relative to interpregnancy intervals of 18-23 months, shorter intervals, including even intervals of 0-6 months, were associated with a lower risk of severe maternal morbidity in within-mother comparisons, while intervals 24 months or longer were associated with an increased risk of severe maternal morbidity (Liu et al., 2021). We note that we study very different outcomes from either Hanley et al. or Liu et al. Both Hanley et al. and Liu et al. consider acute health outcomes, such as preeclampsia, or a composite measure of acute health problems (i.e. the severe maternal morbidity measure used by Liu et al.). In contrast, our health measure reflects mental and physical diseases diagnosed by a GP, with the exception of those judged to be pregnancy complications or pregnancy related (i.e. chapter W in the International Classification of Primary Care [ICPC-2][3]). We also note that the findings from Hanley et al. (2017) and Liu et al. (2021) are somewhat inconsistent with each other – Hanley et al. finding that short intervals are detrimental and long intervals harmless, and Liu et al. finding that short intervals are protective and long intervals harmful. In this study we find that short intervals have, depending on the outcome and time horizon, either a detrimental or negligible influence on health outcomes for mothers and fathers. Further work on this topic, examining different outcomes, in different periods after birth, and across different countries, is needed. Overall, this growing body of evidence suggests that especially short or long birth intervals may influence the likelihood of health outcomes of varying degrees of severity for mothers, and perhaps even for fathers, though less evidence is available for men and evidence is more ambiguous.

A potential problem with our models examining health outcomes in the period 6-11 months after childbirth is that there may already be a new pregnancy (this is much less likely when studying outcomes in the period 1-5 months after delivery). The chance of such a pregnancy may not only be affected by the mother's health (leading to the aforementioned "carry-over problem" in a sibling analysis), but a pregnancy may also *affect* the mother's health within the 6-11 observation period (even if pregnancy-related diseases are not counted), i.e. causality may run both ways. If there is such an effect of an ongoing pregnancy on the mother's health, and if there is also an effect of a short previous interval on the chance of getting pregnant again as quickly as within 6-11 months, the ongoing pregnancy would be mediating the effect of the previous birth interval length on mother's health. One might then, in principle, want to control for the ongoing pregnancy to account for that pathway and be left with a more direct effect. Alternatively, there may be a non-causal link between the previous birth interval length and the chance an ongoing pregnancy (produced by joint determinants), in which case a control for the latter may appear as even more important. However, one should be careful about controlling for the ongoing pregnancy in this situation with a possible two-way causality between pregnancy and mother's health, as this may result in so-called collider bias. More specifically, if both mother's health and the previous interval or its determinants affect the chance of an ongoing pregnancy, controlling for the latter produces an additional 'link' between the previous birth interval and the mother's health, which constitutes the collider bias.

An important point for reflection is the relative degree to which our outcome measure captures health, and the relative degree to which it captures differences in health-seeking behavior. Although this is a legitimate concern, and perhaps particularly in relation to mental health, the individual-level fixed effects should be an effective tool for holding the inclination to seek professional help for a health problem constant. The sibling comparison models may achieve this as well, but to lesser extent. Although our individual fixed effects models do not implicitly adjust for factors that vary over time, we do explicitly adjust for parity, education, marital status, and change of co-parent to the extent that those factors vary between births.

Despite some limitations, we believe that this study makes an important contribution to the existing literature. We provide 'more causal' estimates that better adjust for more non-observables than previous research on this topic. Our results generally suggest that the parents who have particularly short or long intervals between births may have more health issues than parents who have birth intervals in the approximate range of 18-30 months, but principally indicate that the strongest effects are concentrated around the negative effects of short intervals on the mental health of mothers. Any generalization of these findings beyond the Norwegian context should always be done with caution. Norway has an exceptionally generous welfare state, including excellent prenatal care as well as highly subsidized childcare, that is likely to moderate various adverse effects of very short or long birth intervals. Nevertheless, the fact that we observe any negative effects of birth spacing in a context that provides a substantial degree of support for parents suggests that the negative effects of more extreme birth spacing may be worse in less generous contexts. It is important to note that although we contend that we address the effect of birth spacing on general health following a pregnancy, including long-term effects of pregnancy complications, our results are less appropriate for understanding whether birth intervals directly affect pregnancy complications, a topic that should be addressed further in future work. We believe that further work, and particularly additional analyses of high-quality population-level data using methods that can adjust for unobserved heterogeneity, is essential for further developing our understanding of how spacing behavior may affect parental health.

ENDNOTES

[i] Primary health care personnel report consultations to KUHR in order to be reimbursed by the state. Additionally, KUHR includes some consultations with specialists. In the data extracted for the present analysis, 99.4% of the consultations are with physicians whom it may be reasonable to refer to as general practitioners. The few general practitioners who do not have a contract with the health authorities, and therefore do not benefit from public subsidies, do not report to KUHR.

[ii] Up to two diagnoses, in the ICPC-2 system, are given for each consultation. (In 0.8% of the consultations, three or more diagnosis are given, in which case only the first two were considered in this study). If there was at least one mental diagnosis (P70-P99), the consultation was considered as due to a mental disease. If there was at least one diagnosis where the digits were 70-99, and the chapter was not P (mental diseases) or W (pregnancy related diseases), the consultation was considered as due to a physical disease.

[3] W70:Puerperal infection/sepsis; W71 Infection complicating pregnancy; W72 Malignant neoplasm relate to pregnancy; W73 Benign/unspec. neoplasm/pregnancy; W75 Injury complicating pregnancy; W76 Congenital anomaly complicate pregnancy; W78 Pregnancy; W79 Unwanted pregnancy; W80 Ectopic pregnancy; W81 Toxaemia of pregnancy; W82 Abortion spontaneous; W83 Abortion induced; W84 Pregnancy high risk; W85 Gestational diabetes; W90 Uncomplicate labour/delivery live; W91 Uncomplicate labour/delivery still; W92 Complicate labour/ delivery livebirth; W93 Complicate labour/delivery stillbirth; W94 Puerperal mastitis; W95 Breast disorder in pregnancy other; W96 Complications of puerperium other.

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Supplementary Materials

Table S1. Descriptive statistics for the mean number of consultations for mental and physical ailments for men and women in Norway in the period 1-5 months after birth.

		Full sample				Individual FE sample			
		Mothers		Fathers		Mothers		Fathers	
Variable	Category	N	%	N	%	N	%	N	%
Interval (months)	6-11	989	0.2	1,218	0.3	588	0.4	735	0.5
	12-17	20,119	5.1	19,562	5.0	10,940	7.2	10,500	6.7
	18-23	48,356	12.2	47,405	12.2	23,020	15.2	22,897	14.7
	24-29	58,442	14.7	57,280	14.7	24,117	15.9	24,499	15.7
	30-35	55,217	13.9	54,144	13.9	20,758	13.7	20,968	13.5
	36-47	76,260	19.2	74,261	19.0	27,538	18.2	27,858	17.9
	48-59	43,037	10.9	41,024	10.5	15,801	10.4	15,652	10.0
	60-83	46,282	11.7	42,622	10.9	16,107	10.6	15,878	10.2
	84-119	28,728	7.2	26,693	6.8	8,678	5.7	9,487	6.1
	≥ 120	19,072	4.8	25,794	6.6	3,827	2.5	7,298	4.7
Birth order	2	265,789	67.0	252,399	64.7	63,484	41.9	62,548	40.2
	3	102,934	26.0	103,607	26.6	69,907	46.2	70,971	45.6
	4	22,929	5.8	27,388	7.0	15,018	9.9	18,113	11.6
	5	4,850	1.2	6,609	1.7	2,965	2.0	4,090	2.6
Age at birth	≤ 17	8	0.0	2	0.0	5	0.0	1	0.0
	18-20	1,146	0.3	202	0.1	604	0.4	81	0.1
	21-23	11,831	3.0	3,227	0.8	5,658	3.7	1,461	0.9
	24-26	37,604	9.5	15,329	3.9	16,361	10.8	6,653	4.3
	27-29	70,583	17.8	40,658	10.4	29,246	19.3	16,947	10.9
	30-32	95,005	24.0	71,960	18.5	36,965	24.4	28,919	18.6
	33-35	89,629	22.6	86,149	22.1	32,693	21.6	33,699	21.6
	36-38	57,490	14.5	72,989	18.7	20,106	13.3	28,870	18.5
	39-41	25,369	6.4	47,622	12.2	7,800	5.2	18,815	12.1
	42-44	6,695	1.7	26,178	6.7	1,709	1.1	10,453	6.7
	≥ 45	1,142	0.3	25,687	6.6	227	0.1	9,873	6.3
Coparent same as	Yes	355,251	89.6	341,952	87.7	135,658	89.6	134,438	86.3
previous parity	No	41,251	10.4	48,051	12.3	15,716	10.4	21,334	13.7
Educational level	Primary	86,328	21.8	82,460	21.1	36,738	24.3	34,631	22.2
	Lower secondary	5,079	1.3	10,572	2.7	1,329	0.9	4,054	2.6
	Higher secondary	101,782	25.7	148,435	38.1	37,402	24.7	58,483	37.5
	Lower tertiary	149,588	37.7	92,804	23.8	56,725	37.5	36,437	23.4
	Higher tertiary	53,725	13.5	55,732	14.3	19,180	12.7	22,167	14.2
Marital/cohabitation status	Never-married, not cohabiting	26,265	6.6	20,704	5.3	10,921	7.2	9,123	5.9
	Married	207,443	52.3	209,817	53.8	85,039	56.2	89,509	57.5
	Widowed, not cohabiting	344	0.1	198	0.1	163	0.1	89	0.1
	Divorced, not cohabiting	6,243	1.6	6,519	1.7	2,534	1.7	2,803	1.8
	Separated, not cohabiting	3,216	0.8	3,022	0.8	1,505	1.0	1,424	0.9
	Non-married, cohabiting	152,838	38.5	149,630	38.4	51,170	33.8	52,795	33.9
	Other	153	0.0	77	0.0	42	0.0	29	0.0
N		396,502	100.0	390,003	100.0	151374	100.0	155,772	100.0

Table S2. Descriptive statistics for the mean number of consultations for mental and physical ailments for men and women in Norway in the period 6-11 months after birth.

		Full sample				Individual FE sample			
		Mothers		Fathers		Mothers		Fathers	
Variable	Category	N	%	N	%	N	%	N	%
Interval (months)	6-11	995	0.3	1,223	0.3	592	0.4	749	0.5
	12-17	20,185	5.1	19,642	5.1	11,041	7.3	10,575	6.8
	18-23	48,252	12.2	47,336	12.2	23,835	15.7	23,064	14.8
	24-29	58,022	14.7	56,909	14.6	24,087	15.9	24,405	15.6
	30-35	54,557	13.8	53,521	13.8	20,689	13.6	20,929	13.4
	36-47	75,680	19.2	73,770	19.0	27,471	18.1	27,885	17.9
	48-59	42,907	10.9	40,925	10.5	15,784	10.4	15,683	10.1
	60-83	46,293	11.7	42,645	11.0	16,132	10.6	15,906	10.2
	84-119	28,858	7.3	26,739	6.9	8,733	5.8	9,484	6.1
	≥ 120	19,426	4.9	25,943	6.7	3,908	2.6	7,341	4.7
Birth order	2	264,355	66.9	250,894	64.6	63,594	41.9	62,634	40.1
	3	103,037	26.1	103,703	26.7	70,076	46.2	71,111	45.6
	4	22,974	5.8	27,476	7.1	15,073	9.9	18,212	11.7
	5	4,809	1.2	6,580	1.7	2,929	1.9	4,064	2.6
Age at birth	≤ 17	9	0.0	2	0.0	5	0.0	1	0.0
	18-20	1,211	0.3	207	0.1	627	0.4	84	0.1
	21-23	12,177	3.1	3,278	0.8	5,780	3.8	1,464	0.9
	24-26	38,017	9.6	15,510	4.0	16,536	10.9	6,689	4.3
	27-29	70,509	17.8	40,659	10.5	29,331	19.3	17,028	10.9
	30-32	94,486	23.9	71,882	18.5	36,964	24.4	28,997	18.6
	33-35	89,051	22.5	85,865	22.1	32,694	21.6	33,780	21.7
	36-38	56,958	14.4	72,714	18.7	20,062	13.2	28,989	18.6
	39-41	25,057	6.3	47,299	12.2	7,767	5.1	18,860	12.1
	42-44	6,601	1.7	25,946	6.7	1,680	1.1	10,444	6.7
	≥ 45	1,099	0.3	25,291	6.5	226	0.1	9,685	6.2
Coparent same as	Yes	353,600	89.5	340,406	87.6	135,854	89.6	134,578	86.3
previous parity	No	41,575	10.5	48,247	12.4	15,818	10.4	21,443	13.7
Educational level	Primary	85,885	21.7	81,322	20.9	36,715	24.2	34,271	22.0
	Lower secondary	5,589	1.4	11,164	2.9	1,499	1.0	4,344	2.8
	Higher secondary	102,326	25.9	148,378	38.2	37,635	24.8	58,673	37.6
	Lower tertiary	148,974	37.7	92,688	23.8	56,899	37.5	36,631	23.5
	Higher tertiary	52,401	13.3	55,101	14.2	18,924	12.5	22,102	14.2
Marital/cohabitation status	Never-married, not cohabiting	20,559	5.2	15,723	4.0	8,436	5.6	6,717	4.3
	Married	211,319	53.5	213,782	55.0	87,170	57.5	91,577	58.7
	Widowed, not cohabiting	301	0.1	158	0.0	135	0.1	68	0.0
	Divorced, not cohabiting	5,048	1.3	4,930	1.3	2,093	1.4	2,088	1.3
	Separated, not cohabiting	2,760	0.7	2,493	0.6	1,297	0.9	1,200	0.8
	Non-married, cohabiting	155,049	39.2	151,495	39.0	52,500	34.6	54,343	34.8
	Other	139	0.0	72	0.0	41	0.0	28	0.0
N		395,175	100.0	388,653	100.0	151,672	100.0	156,021	100.0

Table S3. Descriptive statistics for the mean number of consultations for mental and physical ailments for men and women in Norway in the period 120-143 months after birth.

		Full sample				Sibling FE sample			
		Mothers		Fathers		Mothers		Fathers	
Variable	Category	N	%	N	%	N	%	N	%
Interval (months)	6-11	223	0.1	317	0.1	26	0.0	59	0.1
	12-17	5,782	2.3	5,976	2.6	1,170	2.0	1,127	2.1
	18-23	18,051	7.3	17,580	7.5	3,975	6.8	3,755	7.2
	24-29	28,721	11.6	27,625	11.8	6,695	11.4	6,131	11.7
	30-35	34,224	13.8	32,590	13.9	8,346	14.3	7,554	14.4
	36-47	59,117	23.9	55,599	23.8	14,484	24.8	13,253	25.3
	48-59	37,621	15.2	34,540	14.8	9,073	15.5	8,029	15.3
	60-83	37,329	15.1	33,891	14.5	9,013	15.4	7,658	14.6
	84-119	17,757	7.2	16,484	7.0	3,942	6.7	3,310	6.3
	≥ 120	8,585	3.5	9,240	4.0	1,788	3.1	1,611	3.1
Birth order	2	142,484	57.6	130,373	55.8	31,115	53.2	27,477	52.4
	3	80,513	32.5	75,795	32.4	21,066	36.0	18,709	35.6
	4	19,808	8.0	21,739	9.3	5,237	9.0	5,135	9.8
	5	4,605	1.9	5,935	2.5	1,094	1.9	1,166	2.2
Age at birth	≤ 17	11	0.0	2	0.0	1	0.0	0	0.0
	18-20	550	0.2	93	0.0	66	0.1	2	0.0
	21-23	5,335	2.2	1,258	0.5	947	1.6	178	0.3
	24-26	19,017	7.7	7,223	3.1	4,042	6.9	1,270	2.4
	27-29	42,887	17.3	22,618	9.7	10,466	17.9	4,798	9.1
	30-32	63,010	25.5	45,724	19.6	15,962	27.3	10,734	20.5
	33-35	59,475	24.0	55,155	23.6	14,751	25.2	13,747	26.2
	36-38	36,792	14.9	45,315	19.4	8,448	14.4	11,060	21.1
	39-41	15,562	6.3	28,209	12.1	3,068	5.2	6,312	12.0
	42-44	4,108	1.7	14,787	6.3	681	1.2	2,798	5.3
	≥ 45	663	0.3	13,458	5.8	80	0.1	1,588	3.0
Coparent same as	Yes	219,654	88.8	211,086	90.3	51,653	88.3	47,811	91.1
previous parity	No	27,756	11.2	22,756	9.7	6,859	11.7	4,676	8.9
Educational level	Primary	46,642	18.9	43,620	18.7	9,545	16.3	8,846	16.9
	Lower secondary	18,456	7.5	16,944	7.2	4,788	8.2	3,548	6.8
	Higher secondary	76,914	31.1	95,110	40.7	19,098	32.6	22,861	43.6
	Lower tertiary	85,892	34.7	52,115	22.3	20,963	35.8	11,522	22.0
	Higher tertiary	19,505	7.9	26,053	11.1	4,118	7.0	5,710	10.9
Marital/cohabitation status	Never-married, not cohabiting	16,379	6.6	13,439	5.7	3,907	6.7	2,861	5.5
	Married	156,572	63.3	153,644	65.7	36,932	63.1	35,031	66.7
	Widowed, not cohabiting	1,391	0.6	490	0.2	252	0.4	104	0.2
	Divorced, not cohabiting	20,270	8.2	17,656	7.6	4,490	7.7	3,580	6.8
	Separated, not cohabiting	8,987	3.6	8,322	3.6	2,016	3.4	1,792	3.4
	Non-married, cohabiting	43,770	17.7	40,268	17.2	10,909	18.6	9,114	17.4
	Other	41	0.0	23	0.0	6	0.0	5	0.0
N		247,410	100.0	233,842	100.0	58,512	100.0	52,487	100.0

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