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Effects of Prenatal Care on Child Health at Age 5

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Abstract The broad goal of contemporary prenatal care is to promote the health of the mother, child, and family through the pregnancy, delivery, and the child's development. Although the vast majority of mothers giving birth in developed countries receive prenatal care, past research has not found compelling evidence that early or adequate prenatal care has favorable effects on birth outcomes. It is possible that prenatal care confers health benefits to the child that do not become apparent until after the perinatal period. Using data from a national urban birth cohort study in the US, we estimate the effects of prenatal care on four markers of child health at age 5—maternal-reported health status, asthma diagnosis, overweight, and height. Prenatal care, defined a number of different ways, does not appear to have any effect on the outcomes examined. The findings are robust and suggest that routine health care encounters during the prenatal period could potentially be used more effectively to enhance children's health trajectories. However, future research is needed to explore the effects of prenatal care on additional child health and developmental outcomes as well as the effects of preconceptional and maternal lifetime healthcare on child health.

Keywords Prenatal care timing · Prenatal care adequacy · Child health outcomes

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Introduction

Standard prenatal care involves a series of encounters during the gestational period, educates women about pregnancy, monitors medical conditions, tests for gestational health problems, and refers expectant mothers to services such as support groups and social services [1]. Although statistics on prenatal care use in developed countries other than the US are not routinely available, one study found that in the 1980s, rates of late and no prenatal care were much higher in the US than in France, Denmark, and one Belgian province, all of which had nearly-universal access to prenatal care [2]. Owing largely to expansions of Medicaid for pregnant women in the late 1980s and early 1990s, prenatal care has become quasi-universal in the US, with 92–96% of mothers giving birth in 2006 receiving at least some prenatal care [3]. However, there remains substantial variation in the timing of initiation and adequacy of care. For example, 17% of births in the US in 2006 were to mothers who initiated care after the first trimester [3] and about 25% of births in the US in 2003 were to mothers who had less than adequate prenatal care as defined by the adequacy of prenatal care utilization (APNCU) index [4].

Most research on the effectiveness of prenatal care in developed countries has focused on birth outcomes (generally birthweight or infant mortality) and has found small or no effects. For example, using econometric techniques to address potential omitted variables bias, Reichman et al. [5] found that first trimester care increases birthweight by only 20 g, and Evans and Lien [6] found that prenatal visits do not have a significant effect on birthweight overall but have positive effects early in the pregnancy. The finding of small effects of prenatal care on birthweight are consistent with a recent review in the medical literature indicating that few features of prenatal care would be expected to increase birthweight at the aggregate level [7]. Reichman et al. [5] also found that prenatal care has no effects on a more direct measure of infant health—whether the child had any serious abnormal infant health condition, such as fetal alcohol syndrome, that was unlikely to be a random shock. Although studies indicate that prenatal care may improve birth outcomes in lesser-developed countries, [8–10] the evidence that early or adequate prenatal care improves aggregate birth outcomes in the developed world is less than compelling.

It is possible that prenatal care has no appreciable effect on birthweight, but that it benefits children's health in the longer-term. There are at least three reasons to think so. First, the prenatal environment affects the fetus in ways that may not be reflected in birthweight. Research on the fetal origins of adult disease has revealed associations between adverse intrauterine environments and subsequent disease in offspring. The hypothesized process, referred to as fetal programming, [11] is that fetuses starved in utero may develop more efficient metabolisms, placing them at increased risk for obesity, heart disease, and diabetes. Much research in this area has focused on the effects of undernutrition during pregnancy on cardiovascular disease in offspring, but fetal programming may represent a more general phenomenon. For example, recent studies have linked prenatal intake of Vitamin D to wheezing and asthma among offspring [12, 13].

Second, by educating mothers about their children's health and connecting them to the health care system (some for the first time), prenatal care may increase the use of pediatric health care or improve maternal health-related parenting practices and, ultimately, child health. For example, referrals to counseling or smoking cessation treatment and breastfeeding education have become typical features of contemporary prenatal care [14, 15]. Bradford [16] and Colman et al. [17] found that although most women who quit smoking during pregnancy resume postpartum, many do not. Prenatal smoking cessation interventions and breastfeeding education have been shown to confer favorable behavioral effects in the postnatal period (e.g., Fang et al. [18], Kistin et al. [19]), with some evidence coming from randomized controlled trials, and both behaviors are strongly linked to child health. Children exposed to second-hand tobacco smoke are at increased risk for acute respiratory infections, asthma, and ear infections [20], and human milk decreases the incidence and severity of infectious diseases and appears to be protective against diabetes, obesity, hypercholesterolemia, asthma, and neurodevelopmental delays [21].

Finally, prenatal care could improve maternal physical or mental health, which could affect the mother's ability to care for her child. There is some evidence that prenatal care improves mothers' health. Using two-stage models to address potential omitted variables bias, Conway and Kutinova [22] found that receiving early and adequate prenatal care leads mothers to maintain a healthy postpartum weight and may reduce lengthy maternal birth hospitalizations. Maternal health has also been linked to health-related parenting behavior. For example, one study found that maternal depression is associated with cigarette smoking, not administering vitamins to children, and not restraining children in appropriate car seats [23]. Another found that children living with a parent unable to provide his/her own personal care are less likely than children who live with a nondisabled parent to be immunized on time [24].

The broad goal of contemporary prenatal care is to promote the health of the mother, child, and family through the pregnancy, delivery, and the child's development [14]. However, links between prenatal care and relevant postnatal outcomes have been underexplored. Aside from the study referenced above that looked at effects on maternal health, the few existing population-based studies have examined well-child care, postpartum cigarette smoking, and breastfeeding. Significant (favorable) associations have been found for well-child visits [25–27]; immunizations [26]; and maternal postpartum smoking [25]. These behavioral changes may translate to better child health outcomes. To the best of our knowledge, no studies have investigated whether prenatal care is associated with child health beyond infancy.

We use survey data from a national urban birth cohort study in the US that have been augmented with both hospital medical record data and in-home child assessments at age 5 to estimate effects of prenatal care on a set of markers for child health at age 5—maternal-reported health status, asthma diagnosis, overweight, and height. We focus on first trimester prenatal care, but also define prenatal care other ways. We conduct a large number of specification checks to validate the findings. This study fills a critical gap in the literature and contributes to a more complete understanding of the effects of prenatal care.

Data

The Fragile Families and Child Wellbeing (FFCWB) study is an ongoing longitudinal birth cohort study. During 1998–2000, parents were interviewed in 75 hospitals in 20 large US cities shortly after their children were born. Non-marital births were oversampled (see Reichman et al. [28], for information on survey design). Mothers completed postpartum (baseline) interviews right after the birth, and again 1, 3, and 5 years later. The children's fathers were also interviewed at each survey wave. A total of 4,898 mothers (86% of those eligible) were interviewed at baseline; of those, 4,139 (85%) completed follow-up interviews 5 years later. Mothers interviewed at 5 years were asked to also participate in an in-home study, which included a child assessment. In-home assessments were conducted for 3,024 (62%) of the children enrolled in the study.

The survey records were merged with additional data which were collected as "add on" studies to the FFCWB: (1) information from medical records (from the birth hospitalization) of the mother and child, and (2) spatial (geographic) coordinates of the mother's address at the time of the birth and of the hospital in which she gave birth. The medical record data were collected using an instrument based largely on the US Standard Certificate of Live Birth. The availability of medical record data depended, for the most part, on administrative processes of hospitals rather than decisions on the part of survey respondents to make their records available. Medical record data, which were needed for the analyses, were available for 3,684 (75%) of the 4,898 births in the FFCWB sample.

Our analyses are restricted to cases for which medical record data are available. We use two different analysis samples. The first, to investigate overall health and asthma, consists of mothers who participated in the 5-year survey (which asked about those outcomes) and includes 2,552 births (3,137 of mothers with medical record data completed follow-up interviews at 5 years; of those, 585 had missing data on analysis variables). The second, to investigate children's overweight and height, consists of mothers who participated in the 5-year in-home module (in which weight and height were measured) and includes 1,395 cases (2,318 mothers with medical record data completed the in-home module; of those, 923 had missing data on analysis variables). Sampling weights are available for neither the medical records nor the in-home samples. Comparisons of the analysis samples to cases not included in those samples revealed no consistent patterns by socioeconomic status. For example, mothers included in the medical records sample were less educated than those who were not in the medical records sample. But, given inclusion in the medical records sample, mothers who completed the 5-year survey were less educated than those who did not complete the 5-year survey. Our specification checks, described later, explore whether patterns in missing data are likely to affect our findings.

Measures

Prenatal Care

Our key measure of prenatal care, based on information from the medical records, is a dichotomous indicator for first trimester prenatal care (before week 14 of the pregnancy). In supplemental analyses we consider other measures of prenatal care use. Almost half (42%) of the mothers in our sample started care after the first trimester, which is consistent with previous research indicating that rates of late, no, and inadequate care are higher among mothers who are young and poor [29, 30]. In the vast majority of the cases (95%), the week of pregnancy prenatal care began was indicated directly in the records. When that was not the case, we calculated the number of days between the date of the last menstrual period (LMP) and the date prenatal care began, and divided by 7. If both week care began and LMP were unavailable (<1% of cases), we imputed LMP by subtracting 280 from the estimated date of confinement.

Outcomes

There is a large and growing literature on the consequences of childhood health for educational attainment, income and wages, and morbidity and mortality into adulthood [31]. Drawing upon this literature, we consider four widely-used markers of child health at age 5: overall health status, asthma diagnosis, overweight, and height.

Overall Health Status

We use the standard survey question in which mothers are asked to rate their children's health on a 5-point scale to construct a dichotomous indicator for excellent or very good (vs. good, fair or poor) overall health status. Although this measure is subjective, it may capture subtle aspects of health that are not detected when considering specific (and often rare) conditions and it facilitates comparisons across studies since it is used widely in population-based surveys.

Asthma Diagnosis

Asthma, which is considered a worldwide epidemic, is a major cause of chronic illness and disability among children

[32, 33]. Prevalence rates have more than doubled in the US since the early 1990s, with 9% of children in 2005 having had a diagnosis of asthma [34]. Our main measure of asthma is whether the child had ever been diagnosed with asthma, based on a question at the 5-year survey asking the mother if a doctor or other health professional ever told her that the child has asthma. The child was characterized as having had an asthma diagnosis if the mother responded affirmatively to this question. Mothers of children with a diagnosis were further asked whether the child had an asthma attack and whether the child had visited an emergency room or other urgent care facility because of asthma in the past 12 months; information from those follow-up questions was used to create alternative measures that are used in supplemental analyses. The advantage of our asthma measures is that they are based on the set of survey questions used in the National Health Interview Surveys to derive national estimates and in numerous other surveys. The disadvantages include potentially imperfect maternal reports and inaccurate or missed diagnoses.

Overweight or Obese

Obesity is another escalating global epidemic that affects virtually all age and socioeconomic groups in both developed and developing countries [35]. In the US, the prevalence of childhood overweight and obesity has increased substantially in the past three decades. In 2007–2008, 21.2% of children between the ages of 2 and 5 years had a body mass index (BMI) $\geq$85th percentile for age [36]. Child overweight and obesity are significant concerns, both because they are associated with childhood morbidities including type 2 diabetes, cardiovascular disease, and sleep-disordered breathing [37] and because overweight/obese children are at elevated risk for becoming overweight adults who are at disproportionate risk for a number of health conditions [38]. The Centers for Disease Control (CDC) classifies children with BMI between the 85th and 95th percentiles of their age and sex to be overweight and above the 95th percentile to be obese [39]. For the FFCWB study, child weight and height were measured at the 5-year in-home assessment by trained interviewers following CDC guidelines. BMI is calculated as weight in kilograms divided by height in meters squared. Our primary measure is an indicator for >85th percentile. However, we assess the sensitivity of the findings to the 95th percentile cutoff and with continuous measures of BMI.

Height

Recent literature has pointed to childhood height as a marker of health, even in developed countries, and has found that suboptimal growth or short stature in childhood adversely affects health trajectories and other lifecourse outcomes. For example, Rees et al. [40] found that shorter children and teens are at increased risk for depression. Case and Paxson [41] summarized and presented new evidence on the relationship between height and adult earnings and found that taller adults earn more because they have higher cognitive ability. Although genes play an important role in determining height, a recent review suggests that environmental factors such as poor nutrition, stress, and illness can slow a child's growth and lead to reduced height in both childhood and adulthood [42]. According to Case and Paxson [41], height advantages or disadvantages are reached at a young age because environmental influences have their effects during the prenatal period or early childhood. The authors concluded that height is not only a determinant of future success, but that it is also a useful marker for childhood health [43]. Our main measure of height is the child's percentile of height for age and sex.

Covariates

Because both prenatal care use and child health are strongly associated with socioeconomic status, we include an extensive set of sociodemographic controls in our models, all from the mother's baseline survey. These include maternal age, relationship status, race/ethnicity, education, nativity, public health insurance (proxy for poverty), parity, family structure as a child, and religious attendance, as well as the father's education and age.

In certain models, we include whether the child was low birthweight (<2,500 g) (from medical record), maternal and paternal self-rated health (using the same 5-point scale and variable construction as for the child measure, from their baseline interviews), maternal pre-existing lung disease (from prenatal history in medical record), paternal medication for asthma (from his 3 or 5-year interview), maternal obesity (based on pre-pregnancy weight and height in her medical record), and father obesity (from his 3-year interview), as well as the child's birth length (from medical record), the mother's height (from medical record), and father's self-reported height (from his 3-year interview), all in centimeters. To minimize the potential for reverse causality, it would have been ideal if all of the parental health measures were measured at the time of, or just prior to, the pregnancy. However, there was no information in the data on the father's asthma, weight, or height until 3 years.

Sample Characteristics

Table 1 presents sample characteristics—overall, for mothers who received first trimester care, and for those who initiated care after the first trimester. The first

Table 1 Sample characteristics

	Full sample (N = 2,552)	1st trimester care (N = 1,474)	Late care (N = 1,078)
Markers of child health at 5 years			
Excellent or very good health	.88	.88	.88
Asthma diagnosis	.21	.20	.23*
Overweight (>85th percentile BMI)[a]	.34	.35	.33
Height percentile (mean)[a]	54.4	55.3	53.2
Sociodemographic measures			
Mother's age (years)			
<20	.19	.15	.23*
20–34	.72	.74	.70
Parents' Relationship			
Married	.25	.32	.16*
Cohabiting	.37	.35	.40
Mother's race/ethnicity			
Non-Hispanic black	.47	.43	.52*
Non-Hispanic white	.21	.27	.14
Hispanic	.28	.27	.29
Mother's education			
<high school graduate	.33	.28	.41
High school graduate	.30	.30	.30
Some college	.26	.27	.24
Mother foreign born	.15	.16	.15
Publicly insured birth	.63	.55	.73*
Mother's first birth	.38	.41	.34*
Father < high school graduate	.33	.30	.38*
Father's age (years)			
<20	.09	.07	.11*
20–34	.74	.74	.74
Mother lived with both parents at age 15	.43	.46	.39*
Mother attends religious services several times per month	.38	.41	.35*
Health measures			
Child			
Low birthweight	.09	.09	.09
Birth length (mean, in cm)	50.0	50.3	49.8*
Mother			
Excellent or very good health	.66	.67	.65
Pre-existing lung disease	.14	.14	.15
Obese	.24	.25	.22
Missing weight or height	.10	.08	.14*
Height (mean, in cm)	162.5	162.5	162.6
Father			
Excellent or very good health	.61	.64	.56*
Medication for asthma	.02	.02	.03
Missing asthma medication	.16	.14	.20*
Obese	.20	.21	.19
Missing obesity	.21	.18	.26*
Height (mean, in cm)	177.1	177.4	176.6*
Missing height	.21	.18	.25*

All figures are proportions unless indicated otherwise

* Statistically significant ($p < .05$) difference between first trimester and later care groups

[a] Child overweight and height percentile are based on the child's age and sex. These outcomes were collected in the 5-year in-home module, which had a lower response rate than the core 5-year survey; these analyses were based on a sample of 1,395, of which 808 had first trimester care and 587 had late care. The means for mother obese, father obese, child's birth length, mother's height, father's height, and missing on any of those are based on the smaller sample

trimester care group had a lower rate of asthma diagnosis and the difference was statistically significant. For the three other health markers, the differences between the prenatal care groups were small and statistically insignificant.

By design, only one quarter of the mothers were married at the time of the birth. Because non-marital fertility is highly associated with minority status and poverty in the US, the oversampling of non-marital births resulted in a sample that is largely minority and poor. About half of the mothers were non-Hispanic black and about one-third were Hispanic. Approximately one-third had not completed high school and another third had only a high school education. About two-thirds of the births were covered by public insurance, reflecting the fact that a large proportion of the sample is poor or near poor.

About two-thirds of both mothers and fathers reported very good or excellent health. Rates of obesity (defined according to CDC standards) were similar for mothers (24%) and fathers (20%). The rate of low birthweight (9%) in our largely disadvantaged sample is above the national average of 7.6% in 2000 [44], and the rates of children with poor health outcomes are higher than national figures cited earlier.

Compared to mothers who initiated care later, mothers who received first trimester care were less likely to be teenagers, more likely to have been married, and less likely to have had publicly insured births. That is, there is favorable selection into early care based on observed characteristics (those with the best expected outcomes initiate care earlier). However, consistent with previous research, mothers with earlier care were not less likely to have a low birthweight child.

Estimation Strategy

We apply a three-pronged approach with the goal of obtaining unbiased estimates of the effects of first trimester care on our markers of child health. First, we rely on rich, well-measured, longitudinal data. First trimester prenatal care was constructed from information in the mother's obstetrical records, which are designed to collect this information; our models are therefore not subject to biases stemming from the overreporting of early prenatal care by mothers themselves, as was found by Reichman et al. [5] Two of the outcomes (overweight and height) are based on in-home child assessments at age 5. From the medical records and surveys, we are able to control for corresponding measures (e.g., obesity, asthma) for both parents. Second, we estimate models that alternatively include state indicators, city indicators, and hospital indicators as well as models that include additional theoretically important variables that are often unobserved. Third, we conduct numerous specification checks to assess the sensitivity of our estimates.

Based on Table 1, we expect favorable selection based on unobserved characteristics, which would lead to upward-biased estimates of the effects of first trimester prenatal care in our models. However, we allow for the possibility of adverse selection into prenatal care (e.g., mothers at greater risk being more likely to initiate care early). By including birthweight, prenatal maternal health, and paternal health in our expanded models, we control for adverse selection (which would lead to downward-biased estimated effects of early prenatal care) reasonably well. These variables may be correlated with other covariates so their estimated effects should be interpreted with caution. However, Reichman et al. [5] found that including or excluding them did not change the estimated effects of prenatal care on birth outcomes.

Multivariate Results

Table 2 presents estimated effects of first trimester prenatal care on each of the markers of child health at age 5. The figures include probit marginal effects (for dichotomous outcomes) and ordinary least squares (OLS) coefficients (for child's height). Standard errors in all models were corrected for city clustering of observations using the Huber-White method. Each model includes all of the sociodemographic characteristics in Table 1, as well as birthweight and parental health measures that correspond to the specific outcome. Although past research has typically found no effects of prenatal care on birthweight in the US, as is the case in our data (not shown), controlling for low birthweight fully ensures that we are looking at potential pathways other than through that outcome. Similarly, when controlling for parental health variables, we are considering potential pathways other than through those measures. As discussed earlier, the parental health variables are all measured at the earliest time point available and are included to control for intergenerational (biological or social) patterns in the outcomes. For excellent or very good child health, we include both maternal and paternal reports of their own health. For asthma diagnosis, we include whether the mother had ever been diagnosed with lung disease prior to the birth and whether the father reported that he takes medication for asthma. For overweight, we include indicators for each parents' obesity. For height, we include the mother's height, father's height, and also the child's birth length which is associated with subsequent height [45]. Due to incomplete data on specific parental health measures (which are coded as negative when the relevant data are missing), we include separate indicators for missing data on each of the following: mother's obesity, father's asthma, father's obesity, and father's height.

Results from all models, including alternative models not shown that did not include low birthweight and the

Table 2 Effects of first trimester prenatal care on markers of child health at age 5

	Excellent or very good health N = 2,552	Asthma diagnosis	Overweight N = 1,395	Height percentile
	Marginal effect	Marginal effect	Marginal effect	Coefficient
First trimester prenatal care	−.01	−.01	.01	1.04
Sociodemographic measures				
Mother's age				
<20 years	.03	−.04	−.01	−8.84**
20–34 years	.03	−.02	−.05	−6.93**
Parents' relationship				
Married	−.00	−.06**	−.03	−3.10
Cohabiting	−.01	−.03	.03	−1.14
Mother's race/ethnicity				
Non-Hispanic black	−.03**	.06**	−.02	5.40**
Hispanic	−.02	.08*	.05	−1.09
Other non-white non-Hispanic	.05	.03	−.09	−6.51
Mother's education				
High school graduate	.02	−.02	−.03	−2.84
Some college	.04**	.00	−.00	−1.43
College graduate	.06**	.00	.05	−.20
Mother foreign born	−.10***	−.07***	.07	7.77*
Publicly insured birth	−.03**	.03	−.03	−.37
Mother's first birth	.04***	−.03	−.04*	1.58
Father < high school graduate	−.00	.02	.00	1.47
Father's age				
<20 years	−.01	.06	.01	2.50
20–34 years	.00	.04	.06	.71
Mother lived with both parents at age 15	.00	−.01	.02	−1.26
Mother attends religious services several times per month	−.01	.06***	.02	−.72
Health measures				
Child—low birthweight	−.06**	.13***	−.08	2.06
Excellent or very good health				
Mother	.08***			
Father	−.01			
Mother—pre-existing lung disease		.18***		
Father—medication for asthma		.20***		
Obese[a]				
Mother			.21***	
Father			.15***	
Child—birth length				1.88***
Height[a]				
Mother				1.00***
Father				.73***

In models that excluded the health measures, the marginal effects of prenatal care were −.01, −.01, and .02 for excellent or very good health, asthma diagnosis, and overweight, respectively, and the OLS coefficient for height percentile was 1.48 (none was statistically significant)

* $p < .10$; ** $p < .05$; *** $p < .01$

[a] Indicator for "missing" included

other child and parental health measures, suggest that early initiation of prenatal care does not significantly affect child health. The patterns of associations between sociodemographic factors and the markers of child health are consistent across models with and without the health variables (latter not shown) and are consistent with findings

from past research. As expected, the health covariates are very strong predictors of age 5 child health outcomes. Mothers are less likely to report that their child is in excellent or very good health if the child was low birthweight and more likely to do so if they rated their own health at baseline as excellent or very good. The probability of being diagnosed with asthma is significantly higher for children who were low birthweight, for children whose mothers have a history of lung disease, and for children whose fathers take medication for asthma. Children whose parents are obese are much more likely to be overweight at age 5. As expected, birth length, maternal height, and paternal height are strong positive predictors of the child's height at age 5.

To address the issue of omitted variables bias, we estimated supplementary models (not shown) that alternatively included state, city, or hospital indicators as well as models that included additional covariates that economic theory suggests are important determinants of both prenatal care use and child health but are not typically observed in population-based surveys. For the latter, we follow Reichman et al. [5] by including a proxy for wantedness (whether the mother reported at baseline that she had considered having an abortion), which may address potential favorable selection into prenatal care, and a measure of the mother's known health endowment (any pre-existing maternal physical or mental health condition, taken from the health history in the mother's prenatal record), which may address potential adverse selection. To capture aspects of socioeconomic status perhaps not accounted for by education, insurance status and the other covariates, we estimated additional models that included household income and proportion of households below the federal poverty line in the mother's residential census tract. In all cases, the estimated effects of prenatal care (no matter how characterized) on the child health outcomes (no matter how characterized) remained insignificant (results not shown).

Specification Checks

First, we estimated models using alternative measures of prenatal care—week of gestation prenatal care began, different cutoffs for early care (before week 16, before week 28), total number of prenatal visits, total number of prenatal visits conditional on any pre-existing maternal physical or mental health condition, the APNCU index, and the Graduated Index—Revised. The latter two measures take into consideration both the timing of prenatal care initiation and the number of prenatal visits given the gestational age of the infant at birth [46]. Regardless of prenatal care measure used, there were no significant effects of prenatal care on any of the markers of child health, with two exceptions—the APNCU index, for overweight and height. However, once the health measures were included, those estimates were no longer statistically significant.

Second, we used alternate measures of child health. Maternal assessment of child health was re-characterized as excellent, very good, or good (vs. fair or poor) and also as excellent (vs. less than excellent). For asthma, we positively coded only children who had a severe asthma attack in the last 12 months. For weight, we considered continuous measures of BMI and BMI percentile as well as a dichotomous measure for obesity (BMI $>$ 95th percentile). For height, we considered height in centimeters, dichotomous measures of height at less than the 10th and 5th percentiles, and the child's height percentile divided by the mother's height percentile. We also estimated ordered probit models for maternal assessment of child health as well as models with dichotomous variables for any negative health condition. In all cases, the estimated effects of prenatal care, no matter how measured, remained insignificant.

Third, we investigated the extent to which our null results may be due to selective sample attrition. We found that first trimester prenatal care had no association with the mother's report of child health status at 1 year, which had an 89% response rate; that children with fair or poor health at 1 year were as likely as those in excellent health at 1 year to remain in the sample at 5 years (73 vs. 74%); and that associations between prenatal care and birthweight and between prenatal care and maternal-reported child health at 1 year did not differ significantly for those who left and those who remained in the sample at 5 years. These findings suggest that the associations between prenatal care and child health are likely to be the same for the two groups.

Finally, we estimated numerous subsample and interactive models to assess whether there could be hidden effects for certain groups, including first births, immigrant mothers, non-Hispanic black mothers, publicly insured births, mothers with (and without) suboptimal self-rated health, mothers with (and without) pre-existing medical conditions, mothers who were obese, mothers with a previous low birthweight or small-for-gestational age infant, and healthy newborns (defined as having gestational age of at least 32 weeks and weighing over 1,500 g at birth). Out of 28 different subgroup models, first trimester care had a significant favorable association with child health in only 1 (for black women, those who had early prenatal care had children with a significantly higher mean height percentile), and out of 28 different interaction models, the interaction with prenatal care was significantly favorable in only 1 case (overall child health, for immigrant mothers). We thus found no compelling evidence that prenatal care has benefits for any clearly-defined group.

Conclusion

As far as we know, this is the first study to investigate the effects of prenatal care on child health beyond infancy. Studies have found that prenatal care confers favorable effects on maternal health-related parenting behaviors such as postpartum cigarette smoking and pediatric care. Such prenatal care-induced behavioral changes would be expected to lead to improved child health. However, using population-based data from a national urban birth cohort study from the US and implementing a number of different strategies to validate the findings, we found that prenatal care, measured a number of different ways, has no discernable effects on four key markers of child health—overall health status as reported by the mother, asthma diagnosis as reported by the mother, overweight, and height.

If prenatal care has effects on child health at age 5, we would have expected to find some evidence to this effect. We used extremely rich data with information on prenatal care from the mothers' prenatal records, data on child health from in-home assessments and surveys 5 years later, and detailed sociodemographic and health data on both parents. We found no effects for any obvious population subgroup. The findings are consistent with previous literature that has generally found small or no effects of prenatal care on infant health in developed countries. All of this said, however, we offer several caveats.

Health is a difficult construct to measure, especially for children, so it is possible that our four key markers of child health do not capture effects that might exist. Studies incorporating indicators of immune function or exposure to disease may be warranted [47], as may studies including cognitive and behavioral outcomes. It is possible that, despite our preliminary evidence to the contrary, lack of an observed relationship between prenatal care and child health reflects selective sample composition, the two key sources of which were participation in the in-home assessment at 5 years and availability of medical record data from the birth hospitalization. Prenatal care may help certain individuals a great deal but not translate to observed effects for identifiable population groups. We were not able to measure the quality of prenatal care received, which may be an important unobserved factor. Finally, the findings may not be representative of the US population as a whole. Our interaction and subsample models indicating no consistent evidence of significant favorable effects of prenatal care for any group, in concert with our analyses suggesting that the estimated effects of prenatal care are not biased due to attrition, suggest that our findings are representative of the FFCWB sampling frame—the US population in cities over 200,000 people, which accounts for 58% of the US population as a whole [48]. However, sampling weights were not available for these analyses and we cannot speak to the issue of whether our results would apply to populations in smaller cities in the US, rural or suburban areas in the US, or other developed countries.

This study broke new ground by being the first on the topic; as such, it is important that the findings be replicated and further explored. Importantly, the findings should not be interpreted as implying that prenatal care should be curtailed. Rather, the findings suggest that routine prenatal care could potentially be better capitalized upon to improve child health trajectories. The fact that studies have found favorable effects on maternal health-related parenting behaviors represents an important first step in this direction. Also, prenatal care has been shown to improve maternal health and could potentially affect prenatal health behaviors in subsequent pregnancies, both of which could affect the health of the mother's future children. A recent study found that late and inadequate prenatal care are associated with short subsequent birth intervals, which are associated with adverse perinatal outcomes, suggesting that early or adequate prenatal care could indeed have favorable effects on the health of the next child [49]. Finally, a related and important question is how mothers' lifetime medical care (as in countries with universal healthcare), or at the very least pre-conception care, affects their children's health.

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