HSR Health Services Research

DOI: 10.1111/1475-6773.12742
RESEARCH ARTICLE

Does Maternity Care Coordination Influence Perinatal Health Care Utilization? Evidence from North Carolina

Marianne M. Hillemeier, Marisa E. Domino, Rebecca Wells, Ravi K. Goyal, Hye-Chung Kum, Dorothy Cilenti, and Anirban Basu

Objective. To examine effects of maternity care coordination (MCC) on perinatal health care utilization among low-income women.

Data Sources. North Carolina Center for Health Statistics Baby Love files that include birth certificates, maternity care coordination records, WIC records, and Medicaid claims.

Study Design. Causal effects of MCC participation on health care outcomes were estimated in a sample of 7,124 singleton Medicaid-covered births using multiple linear regressions with inverse probability of treatment weighting (IPTW).

Principal Findings. Maternity care coordination recipients were more likely to receive first-trimester prenatal care ($p < .01$) and averaged three more prenatal visits and two additional primary care visits during pregnancy; they were also more likely to participate in WIC and to receive postpartum family planning services ($p < .01$). Medicaid expenditures were greater among mothers receiving MCC.

Conclusions. Maternity care coordination facilitates access to health care and supportive services among Medicaid-covered women. Increased maternal service utilization may increase expenditures in the short run; however, improved newborn health may reduce the need for costly neonatal care, and by implication the need for early intervention and other supports for at-risk children.

Key Words. Maternal and perinatal care and outcomes, Medicaid, utilization of services, health care costs

Provision of care coordination services during pregnancy has often been suggested as a policy approach to reducing disparities in birth outcomes by increasing at-risk women's access to health care and other supportive services and improving communication with providers (Buescher et al. 1991; Alexander and Korenbrot 1995; Agency for Healthcare Research and Quality 2010;

Berry et al. 2010). Empirical evidence to date on the effects of such services on health care utilization, however, is sparse and contradictory. Participants in a maternity case management program in Tennessee were found to be more likely than other women to take prenatal vitamins in the first trimester of pregnancy and less likely to have inadequate prenatal care utilization (Piper, Mitchel, and Ray 1996). A more recent study by Meghea et al. (2013) also found that women receiving care coordination services through a home visiting program had higher odds of receiving adequate prenatal care as well as an appropriately timed postnatal visit. On the other hand, a case management initiative in South Carolina had no effect on rates of adequate prenatal care receipt (Newman et al. 2008), and Medicaid recipients in Iowa enrolled in primary care case management were actually less likely than women with traditional care arrangements to initiate prenatal care in the first trimester and to receive pregnancy-related services such as nutritional counseling (Schulman, Sheriff, and Momany 1997).

Inconsistent findings regarding the effects of care coordination are likely related to limitations of prior research on this topic with regard to selection effects. It is quite possible that women receiving care coordination differ from women who do not in ways that can either increase or decrease their chances of utilizing health services. While previous analyses have included some controls for maternal attributes, failure to adequately account for a wide range of underlying factors that may lead women to choose whether to sign up for case management services can introduce bias when attempting to quantify effects specifically attributable to care coordination receipt.

The goal of this study was to examine effects of the Baby Love maternity care coordination program in North Carolina on health care utilization in the perinatal period, using propensity score methods to reduce the influence of selection bias on baseline risk factors. The Baby Love program originated out of

---

Address correspondence to Marianne M. Hillemeier, Ph.D., M.P.H., Department of Health Policy and Administration, The Pennsylvania State University, 604 Ford Building, University Park, PA 16802; e-mail: mmh18@psu.edu. Marisa E. Domino, Ph.D., is with the Gillings School of Global Public Health, The University of North Carolina at Chapel Hill, Chapel Hill, NC. Rebecca Wells, Ph.D., M.H.S.A., is with the Department of Management, Policy & Community Health, University of Texas, Houston, TX. Ravi K. Goyal, M.S., B.Pharm., is with RTI Health Solutions, Research Triangle Park, NC. Hye-Chung Kum, Ph.D., is with the Department of Health Policy & Management, Texas A & M University, College Station, TX. Dorothy Cilenti, Dr.P.H., M.P.H., M.S.W., is with the Gillings School of Global Public Health, The University of North Carolina at Chapel Hill, Chapel Hill, NC. Anirban Basu, Ph.D., is with the Departments of Health Services, Pharmacy, and Economics, Magnuson Health Sciences Center, University of Washington, Seattle, WA.

concern about high rates of infant mortality in North Carolina (Buescher et al. 1991). Baby Love used professionally trained care coordinators as case managers for low-income pregnant women at risk for poor pregnancy outcomes. Components of the care coordination program included assessment for high-risk social and medical needs, case planning and follow-up, assistance with basic needs such as housing and transportation, and supportive counseling and referral to treatment services as appropriate. The number of care coordination encounters varied widely, according to maternal needs and preferences, with an average for the study sample of 1 hour of Medicaid-billed services, with a range of 0–15 hours. Prior research has found maternity care coordination associated with lower probability of preterm birth (Hillemeier et al. 2015).

With the exception of the work of Meghea et al. (2013) and Hillemeier et al. (2015), other papers in this area have not employed rigorous analytic approaches such as propensity score methods. In this study, data were analyzed from women giving birth in North Carolina between 2008 and 2010, a period when the state's Baby Love initiative mandated that eligibility for maternity care coordination (MCC) during pregnancy be offered to all pregnant women enrolled in Medicaid during pregnancy and 60 days postpartum. We hypothesized that receipt of care coordination services would be associated with increased use of prenatal care and other beneficial health care and supportive services among the low-income women in this population, as care coordinators increased the ability of pregnant women to make connections with the formal health care system.

METHODS

A random sample of 8,000 live singleton births was selected from Medicaid-funded deliveries in North Carolina during the period from October 1, 2008, through September 30, 2010. Data were drawn from the Baby Love composite file produced by the North Carolina Center for Health Statistics that included birth certificates, maternity care coordination records, WIC records, and Medicaid claims. We excluded birth records that could not be matched to the other data sources (n = 13) and deliveries covered by emergency Medicaid (n = 863), thus requiring mothers to be covered by either full Medicaid or the Medicaid pregnancy waiver program for at least some of their pregnancy. This resulted in an analytic sample of 7,124 deliveries.

The key exposure of interest is the receipt of MCC services. We identified 2,255 mothers who had at least one encounter with a maternity care

coordinator during their pregnancy, leaving 4,869 women as potential controls who were Medicaid or waiver enrollees, had Medicaid-funded deliveries, but did not receive Medicaid-paid MCC services during their pregnancy.

A number of health-related services outcomes were considered in the analyses. Three measures of prenatal care were analyzed as follows:

First-trimester initiation of prenatal care: A dichotomous variable was coded 1 for women whose first observed OB visit (see definition below) occurred in the first trimester of pregnancy, conditional on Medicaid enrollment during the first trimester.

Number of obstetric visits: The total number of obstetric visits completed during each woman's pregnancy was summed and included as a count variable. Obstetric visits were defined broadly and include visits to OB/GYNs, visits to any provider that include OB procedure codes, or visits to primary care that include a diagnosis of pregnancy on the claims files.

Adequacy of prenatal care receipt: The Kotelchuck Adequacy of Prenatal Care Utilization Index (APNCU) (Kotelchuck 1994) was used to characterize prenatal care receipt as either inadequate or adequate, with the adequate category encompassing adequate, and adequate plus levels of the APNCU.

Other types of services received during pregnancy and the postpartum period were also of interest:

Number of primary care visits during pregnancy: The total number of visits for primary care made during the course of the pregnancy was summed as a count variable. Primary care was defined as visits to providers coded as primary care providers (e.g., family or internal medicine).

Number of emergency department visits during pregnancy: The total number of visits made to the emergency department during the course of the pregnancy was also included as a count variable.

Receipt of WIC during pregnancy: Because the WIC program can facilitate and encourage access to health care, a dichotomous variable indicates whether the mother received WIC services or not.

We also analyzed types of Medicaid expenditures:

Maternal Medicaid expenditures during pregnancy: Total Medicaid expenditures during pregnancy were summed, which were obtained from claims data.

Maternal Medicaid expenditures in first 3 months postpartum: Total Medicaid expenditures in the first 3 months postpartum summed from claims data.

High infant Medicaid expenditures (>$5,000) in first 2 months: A dichotomous variable indicated whether infants incurred high Medicaid expenditures in the first 2 months of life, conditioned on infant Medicaid enrollment after birth.

Characteristics of mothers and the local health departments (LHDs) in their residential areas were incorporated in the analyses, drawn from a survey sent to the 85 LHDs in North Carolina that was conducted by one of the authors and from the Area Resource File. The LHD survey ($n = 75$ LHDs, for an 89 percent participation rate) included questions about how Baby Love was provided, staffing, and caseloads.

Variables included in the analyses were as follows:

Maternal Age: In view of evidence that the risk of adverse health outcomes is increased among very young as well as older mothers (Cavazos-Rehg et al. 2015), the age of the mother at the infant's birth was categorized as less than 18 years, 18–34 years, or 35 or more years.

Maternal Education: Educational level of mothers from birth certificate records was dichotomized as either less than high school completion or high school completion or greater.

Race/Ethnicity: Mothers' race/ethnicity as reported on birth certificates was characterized as non-Hispanic white, non-Hispanic black, Hispanic, or other race/ethnicity.

Maternal Health: Medicaid claims and birth certificate data were used to identify mothers who had a history of *Diabetes, Hypertension, Mental Health Problems (*schizophrenia, depression, bipolar disorder, trauma, and anxiety), or *Substance Use*.

Childbearing History: Variables were included that identified the number of *Prior Births* and *Prior Infant Deaths* from the birth certificate.

Maternal Program Eligibility and Participation: We controlled for mothers' access to services via the *Pregnancy Waiver,* in contrast to *Full Medicaid Benefits,* as *waiver* benefits are more restricted and may result in fewer visits and lower expenditures. This variable also controls for the lower income implied by full Medicaid's more stringent eligibility requirements. We also control for participation in *Healthy Start* (*Baby Love Plus*), a separate initiative that includes funding for outreach, transportation, depression screening and referral, prenatal and interconceptional case management, and health care for mothers in 14 North Carolina counties with the greatest birth outcome disparities.

Local Health Department Characteristics: Aspects of the local health department were characterized, including *Funding Per Capita,* availability of *WIC,* the presence of a *High Risk Maternity Clinic,* and *Number of Maternity Care Coordination Staff.*

Because of the potential for self-selection into the MCC program, we used inverse probability of treatment weighting (IPTW) to balance the observable baseline risk factors between women who did and did not receive MCC

services. We used a number of characteristics selected a priori to be associated with the service-use outcomes, described above as risk factors, including mothers' age (under 18, 18–34 years, or 35 and older), less than high school education, race/ethnicity, mothers' observed health history from Medicaid claims and birth certificate, including mental health or substance use status, prior live births or infant deaths, eligibility for full Medicaid benefits, or pregnancy waiver benefits, local health department characteristics such as funding per capita, the presence of a high-risk maternity clinic, and the number of maternal care coordination staff (Meghea et al. 2013; Hillemeier et al. 2015). Observations for women whose values fell outside the support of the propensity distribution for MCC participants ($n = 24$; <1 percent of the sample) were removed. Variable means by MCC status are reported in Table 1 for control variables and in Table 2 for outcome variables for the weighted and unweighted samples.

All outcomes were modeled using multiple linear regressions with IPTW and without weighting (OLS). Models with outcomes derived from claims were adjusted by the proportion of Medicaid enrollment during the relevant time period (e.g., number of OB visits during pregnancy controls for the proportion of the prenatal period covered by Medicaid). Covariates were added to linear regression models in blocks to determine the extent of selection into the MCC program. That is, the unadjusted OLS model gives the mean difference in outcomes without controlling for selection. As covariates are added to the model, changes from the unadjusted difference indicate selection bias. We then use IPTW linear regression models to estimate the causal effect of MCC participation on each outcome. The last column in the IPTW row gives results from doubly robust models, which both control for baseline covariates and use IPTW. All models use robust standard errors to account for potential heteroskedasticity.

Results

The first two columns of Table 1 display the unadjusted mean/proportion for each of the covariates in the analyses by MCC status. Women who received MCC services generally exhibited greater risk than other women. They were more likely to be under the age of 18 at the infant's birth and to be first-time mothers and were more likely to be African American and less likely to be Hispanic. Those receiving MCC had lower educational attainment and lower income, as indicated by higher rates of full Medicaid enrollment during

Table 1: Baseline Variable Means for Full and Propensity-Matched Samples

	Unweighted Means		*Propensity-Weighted (IPTW) Means*	
Baseline Variables	*MCC Recipients (n = 2,255)*	*Potential Controls (n = 4,869)*	*MCC Recipients (n = 2,255)*	*Control Sample (n = 4,455)*
Younger than 18 at delivery*	9.1%	5.1%	6.6%	6.6%
Age 35 or older at delivery*	4.4%	7.4%	6.5%	6.4%
Less than high school education*	22.1%	17.4%	19.2%	19.0%
Education not available*	35.7%	37.7%	36.7%	37.0%
Mother Hispanic ethnicity*	8.8%	17.1%	15.0%	14.2%
Mother African American*	45.7%	31.4%	35.8%	35.9%
Prior history of diabetes*,†	1.6%	2.2%	2.2%	2.0%
Prior history of hypertension†	1.0%	0.9%	0.9%	0.9%
Prior history of schizophrenia†	0.7%	0.4%	0.5%	0.5%
Prior history of bipolar disorder†	5.8%	3.3%	4.1%	4.2%
Prior history of other depression†	16.5%	13.0%	14.1%	14.1%
Prior history of trauma†	2.5%	1.5%	1.8%	1.8%
Prior history of anxiety†	10.0%	8.7%	9.1%	9.1%
Prior history of substance use treatment†	9.8%	7.5%	8.5%	8.3%
One or more prior live births*	42.7%	62.5%	56.4%	56.1%
Prior infant death*	1.8%	1.9%	2.0%	1.9%
Participation in Baby Love Plus‡	19.5%	14.3%	15.8%	16.0%
Receipt of full Medicaid in pregnancy†	40.2%	32.8%	35.8%	35.5%
Organizational factors				
Receipt of services from an LHD with a high-risk maternity clinic§	19.4%	22.3%	20.8%	20.8%
LHD in region not offering WIC¶	7.1%	6.8%	6.5%	6.8%
MCC staffing per 100,000 population in LHD service area§,**	3.86	3.28	3.54	3.54
LHD revenue per capita§	6.71	6.10	6.45	6.38
LHD revenue information missing§	3.1%	3.5%	3.2%	3.4%

Data Sources:
*Birth certificates.
†Medicaid claims and eligibility.
‡BabyLove Plus program records.
§Local Health Department (LHD) Survey.
¶WIC.
**Area Resource File.

pregnancy. These women were also more likely to have experienced health problems and to be enrolled in Baby Love Plus, which is targeted toward at-risk pregnant women. However, those receiving MCC were also less likely to be served by a health department that has high-risk maternity clinic services.

Table 2: Outcome Variable Means for Full and Propensity-Weighted Samples

	Unweighted Means		*Propensity-Weighted (IPTW) Means*	
Outcome variables	*MCC Recipients (n = 2,255)*	*Potential Controls (n = 4,869)*	*MCC Recipients (n = 2,255)*	*Control Sample (n = 4,455)*
Prenatal care				
First-trimester initiation of prenatal care*,†	85.6%	80.6%	85.2%	80.8%
Number of prenatal care visits*,†	15.5 (10.5)	11.1 (9.7)	14.9 (0.2)	11.5 (0.2)
Adequate prenatal care*,†	80.8%	78.5%	80.6%	78.3%
Other medical care services received in pregnancy and postpartum				
Number of primary care visits during pregnancy†	4.8 (5.1)	2.0 (3.6)	5.3 (0.2)	2.4 (0.1)
Number of emergency department visits during pregnancy†	0.5 (0.6)	0.4 (0.6)	0.5 (0.01)	0.4 (0.01)
Receipt of WIC during pregnancy‡	84.7%	67.5%	83.6%	68.5%
Family planning received in first 3 months after delivery†	46.6%	32.1%	45.5%	32.3%
Medicaid expenditures				
Maternal prenatal Medicaid expenditures†	$868 (614)	$577 (594)	$856 (14)	$583 (9)
Maternal Medicaid expenditures in 3-month postpartum period†	$3,700 (5,347)	$3,241 (2,358)	$3,708 (147)	$3,253 (36)
Infant Medicaid expenditures >$5,000 in first two months†	7.2%	8.0%	7.0%	8.2%

Data Sources:
*Birth certificates.
†Medicaid claims.
‡WIC.

The third and fourth columns of Table 1 show the means/proportions for the MCC and control samples after propensity weighting. Means for each covariate were very similar between the two groups, and in no case did the standardized difference exceed 0.02.

Mean values of outcomes are reported in Table 2, while estimates from regression analyses modeling the effects of MCC on health services outcomes are shown in Table 3. For each outcome, there are two rows of results in Table 3. The top row provides results from a series of ordinary least squares

Table 3: Effects of Maternity Care Coordination on Health Services Outcomes

			Covariates in OLS Model / IPTW Model				
Outcome Variable	*Unadjusted Effect*	*Adjusted Effects from*	*Model 1: Controlling for Demographic Characteristics*	*Model 2: Model 1 Controls + Maternal Health*	*Model 3: Model 2 Controls + Previous Births*	*Model 4: Model 3 Controls + Insurance*	*Model 5: Model 4 Controls + Health Department Characteristics*
Prenatal care							
First-trimester initiation of prenatal care	0.046*** (0.011)	OLS	0.054*** (0.011)	0.052*** (0.011)	0.048*** (0.011)	0.048*** (0.011)	0.048*** (0.011)
	0.045*** (0.012)	IPTW	0.046*** (0.012)	0.046*** (0.012)	0.046*** (0.012)	0.046*** (0.011)	0.047*** (0.011)
Number of prenatal care visits	3.36*** (0.26)	OLS	3.10*** (0.25)	3.02*** (0.25)	3.04*** (0.26)	3.04*** (0.26)	3.07*** (0.26)
	2.96*** (0.26)	IPTW	3.04*** (0.25)	3.06*** (0.25)	3.05*** (0.25)	3.08*** (0.25)	3.07*** (0.25)
Adequate prenatal care	0.023* (0.013)	OLS	0.032** (0.013)	0.033** (0.013)	0.025* (0.013)	0.023* (0.013)	0.020 (0.013)
	0.023* (0.014)	IPTW	0.020 (0.014)	0.020 (0.014)	0.020 (0.014)	0.020 (0.014)	0.019 (0.014)
Other medical care and services receipt in pregnancy and postpartum							
Number of primary care visits during pregnancy	2.72*** (0.20)	OLS	2.71*** (0.20)	2.70*** (0.20)	2.71*** (0.21)	2.72*** (0.21)	2.80*** (0.20)
	2.81*** (0.22)	IPTW	2.81*** (0.22)	2.82*** (0.22)	2.82*** (0.22)	2.81*** (0.22)	2.77*** (0.21)
Number of emergency department visits during pregnancy	0.099*** (0.016)	OLS	0.081*** (0.016)	0.074*** (0.016)	0.075*** (0.016)	0.074*** (0.016)	0.068*** (0.016)
	0.064*** (0.016)	IPTW	0.067*** (0.016)	0.068*** (0.016)	0.068*** (0.016)	0.069*** (0.016)	0.069*** (0.016)
Receipt of WIC during pregnancy	0.172*** (0.010)	OLS	0.163*** (0.010)	0.163*** (0.010)	0.151*** (0.010)	0.151*** (0.010)	0.146*** (0.011)
	0.151*** (0.011)	IPTW	0.151*** (0.011)	0.151*** (0.011)	0.151*** (0.011)	0.150*** (0.011)	0.150*** (0.011)

Continued

Table 3. *Continued*

			Covariates in OLS Model / IPTW Model				
Outcome Variable	*Unadjusted Effect*	*Adjusted Effects from*	*Model 1: Controlling for Demographic Characteristics*	*Model 2: Model 1 Controls + Maternal Health*	*Model 3: Model 2 Controls + Previous Births*	*Model 4: Model 3 Controls + Insurance*	*Model 5: Model 4 Controls + Health Department Characteristics*
Family planning received in first 3 months after delivery	0.115*** (0.012) 0.129*** (0.013)	OLS IPTW	0.119*** (0.012) 0.130*** (0.013)	0.118*** (0.012) 0.130*** (0.012)	0.118*** (0.012) 0.130*** (0.012)	0.131*** (0.012) 0.130*** (0.012)	0.131*** (0.013) 0.129*** (0.012)
Medicaid expenditures							
Maternal prenatal Medicaid expenditures	235*** (15) 247*** (16)	OLS IPTW	241*** (15) 248*** (15)	238*** (15) 248*** (15)	238*** (15) 248*** (15)	239*** (15) 247*** (15)	246*** (15) 246*** (15)
Maternal Medicaid expenditures in 3-month postpartum period	332*** (114) 437*** (150)	OLS IPTW	358*** (111) 436*** (149)	303*** (111) 439*** (149)	303*** (111) 439*** (149)	420*** (120) 438*** (146)	439*** (133) 443*** (149)
Infant Medicaid expenditures >$5,000 in first 2 months	−0.0079 (0.0069) −0.0121 (0.0074)	OLS IPTW	−0.0099 (0.0070) −0.0120 (0.0074)	−0.0114 (0.0071) −0.0121 (0.0073)	−0.0144** (0.0071) −0.0119 (0.0073)	−0.0147** (0.0072) −0.0119 (0.0073)	−0.0140* (0.0072) −0.0119 (0.0073)

Notes. All models control for the percent of each period (prenatal, postpartum) covered by full Medicaid or pregnancy waiver.
*$p < .10$; **$p < .05$; ***$p < .01$.

regression models beginning with unadjusted models and then adding covariates sequentially, with results from the full models shown at the far right. The second row shows the results from the analogous propensity-weighted analyses, which, as described above, more effectively control for selection effects than the OLS results. In all specifications, women who received MCC services were significantly more likely than otherwise similar women to begin prenatal care in the first trimester of pregnancy, and received an average of three more obstetric visits during their pregnancies. The estimates for the adequacy of prenatal care utilization variable were positive but were not significant at conventional levels in the full models.

Receipt of care coordination services was also associated with receipt of other health care and services. Women receiving MCC averaged over two additional visits for primary care during their pregnancy compared to controls, but also had a significantly greater number of visits to the emergency department. The chances of receiving WIC in pregnancy and family planning services in the first 3 months postpartum were also significantly greater among women in the MCC group. Consistent with results indicating that more services were received by mothers who received MCC services, their Medicaid expenditures during pregnancy and the postpartum period were also significantly greater. On the other hand, fewer infants had high (>$5,000) Medicaid expenditures in the first two months of life among mothers who received MCC services, suggesting that these infants had comparatively fewer health problems at birth on average, although this result became insignificant ($p = .11$) in the IPTW models.

Many of the control variables in the multivariate models are insignificant or do not have consistent patterns (results not shown). Mother's Hispanic ethnicity and having education missing from the birth certificate are negatively correlated with half of the models on services use, while mother's depression or anxiety status tends to be positively associated with services (results not shown). Participation in Baby Love Plus is negatively associated with services use, while having greater LHD revenue per capita is positively associated with services use (results not shown).

DISCUSSION

Improving low-income women's access to health care and other supportive services is a widely recommended strategy for addressing their elevated risk of adverse pregnancy outcomes (e.g., IOM 2007; Agency for Healthcare

Research and Quality 2010). Findings from the present study suggest that MCC services can be very successful in helping high-risk women to strengthen their connections to the health care system. Women who received MCC were significantly more likely to initiate prenatal care in the first trimester and to have more prenatal visits, as well as receive more primary care during pregnancy than women not receiving MCC services. Receipt of MCC was also associated with a higher likelihood of participation in WIC, a program which has been associated with more optimal infant health (Reichman and Teitler 2003; Bitler and Currie 2005; Figlio, Hamersma, and Roth 2009; Gueorguieva, Morse, and Roth 2009; Khanani et al. 2010; Hoynes, Page, and Stevens 2011).

In addition to facilitating use of preventive and primary care, MCC receipt was also associated with a higher likelihood of having emergency department visits during pregnancy. This result could plausibly be attributed to heightened monitoring and referral by care coordinators and other health care personnel. While seeking care in emergency departments is not generally considered to be an efficient use of health care resources, among underserved pregnant women, it may be an appropriate venue for dealing with emerging health problems before they progress (Heisler and Tyler 2014).

Consistent with increased health care utilization, Medicaid expenditures both pre- and postnatally were found to be greater among women receiving MCC services. This indicates that the investment in MCC services did not pay for itself from a Medicaid program perspective in terms of offsetting reductions in services such as ED use when only the Medicaid expenditures on mothers were considered. Provision of MCC could be cost-effective overall, however, if health outcomes for women and their infants are improved. Prior analyses did find lower rates of preterm birth among women receiving MCC (Hillemeier et al. 2015). However, the associations between MCC use and elevated infant expenditures (>$5,000) are slightly smaller in magnitude but lose statistical significance in the IPTW models, suggesting that the stronger OLS findings may have been due in part to selection bias.

Baby Love was a relatively low resource-intensive maternity care coordination initiative, with Baby Love care coordinators reporting an average caseload of 107 in a 2010 statewide survey (Wells, Cilenti, and Issel 2015), relative to a maximum of 25 for the nurse-family partnership model (http://www.nursefamilypartnership.org/Communities/Model-elements) and an average of 13 for prenatal cases among nine Medicaid maternity care coordination providers in one study (Kane and Issel 2005). The average Medicaid-billed

cost of maternity care coordination for the current study sample was $87, although Kane and Issel estimated that Medicaid costs represented only about 60 percent of the total costs of care coordination incurred by providers. More broadly, at the time the study data were collected, expenditures for all pregnancy-related services combined (excluding delivery) for typical pregnancies were around 30 percent lower among U.S. women covered by Medicaid compared to those with private insurance (Rohde and Machlin 2012).

Our findings also indicate that adequately controlling for selection bias in some manner can have large relative effects on estimates. The change in direction of these effects is not always clear a priori—simple OLS regression models that do not control for selection, underestimate some outcomes, and overestimate others. Consistent with other work (e.g., Rosenbaum and Rubin 1983; Austin 2011), including the covariates in OLS models yielded very similar findings to either simple IPTW models or doubly robust models. With the exception of Meghea et al. (2013) and Hillemeier et al. (2015), research on the effects of care coordination in pregnancy has not employed propensity score methods.

These results should be interpreted in light of several limitations. Outcome variables on services use only report those services paid through the Medicaid program and may suffer from measurement error if services are used and not billed to Medicaid. We cannot plausibly argue that such measurement error is correlated with MCC receipt, however, and likely does not bias our estimates. The IPTW and multivariate OLS models are only as effective as the covariates included. Factors disproportionately present in the MCC population that are not included in these models may bias the estimated effect of MCC, and the results are not necessarily causal. For example, it could be that, controlling for baseline covariates, women who receive early prenatal care are more likely to be referred to MCC, rather than that MCC is linking women to early prenatal care. An additional data limitation is that the vital statistics data available for these analyses did not include pregnancy losses and stillbirths. It is the case, however, that a large proportion of pregnancy losses occur in early pregnancy and before MCC would be initiated. Also, omission of pregnancy losses and stillbirths is not problematic for the primary purpose of our study, which was to identify the effects of MCC on pregnancies that result in live births.

In summary, findings from this study provide evidence that care coordination during pregnancy is effective in facilitating access to health care and supportive services among women covered by Medicaid. Although increased utilization of health care services may increase expenditures in the short run,

our results also suggest that the resultant improvement in infant health at birth may reduce the need for costly neonatal care, and by implication also reduce subsequent needs for early intervention and other supportive services for at-risk children, although this result was somewhat sensitive to specification. Additional research is needed to comprehensively assess the costs and benefits of maternity care coordination services in relation to long-term outcomes for women and their children.

ACKNOWLEDGMENTS

Joint Acknowledgment/Disclosure Statement: The authors greatly appreciate the data shared by the NC Division of Public Health. Funding to support this research was provided by the Robert Wood Johnson Foundation Public Health Practice-Based Research Network, and Maternal and Child Health Bureau, grant R40 MC21519.

Disclosures: None.

Disclaimer: None.

REFERENCES

Agency for Healthcare Research and Quality. "Findings on Children's Health Care Quality and Disparities." AHRQ Pub. No. 10-P006; 2010 [accessed on February 15, 2016]. Available at http://www.ahrq.gov/sites/default/files/wysiwyg/research/findings/nhqrdr/nhqrdr09/children.pdf

Alexander, G. R., and C. C. Korenbrot. 1995. "The Role of Prenatal Care in Preventing Low Birth Weight." *Future of Children* 5 (1): 103–20.

Austin, P. C. 2011. "An Introduction to Propensity Score Methods for Reducing the Effects of Confounding in Observational Studies." *Multivariate Behavioral Research* 46 (3): 399–424.

Berry, E., C. Brady, S. D. Cunningham, L. L. Derrick, M. Drummonds, B. Pettiford, A. Roberts, and S. E. Wilson. 2010. *National Healthy Start Initiative: A National Network for Effective Home Visitation and Family Support Services.* Washington, DC: National Healthy Start Association.

Bitler, M. P., and J. Currie. 2005. "Does WIC Work? The Effects of WIC on Pregnancy and Birth Outcomes." *Journal of Policy Analysis and Management* 24 (1): 73–91.

Buescher, P. A., M. S. Roth, D. Williams, and C. M. Goforth. 1991. "An Evaluation of the Impact of Maternity Care Coordination on Medicaid Birth Outcomes in North Carolina." *American Journal of Public Health* 81 (12): 1625–9.

Cavazos-Rehg, P. A., M. J. Krauss, E. L. Spitznagel, K. Bommarito, T. Madden, M. A. Olsen, H. Subramaniam, J. F. Peipert, and L. J. Bierut. 2015. "Maternal Age and

Risk of Labor and Delivery Complications." *Maternal Child Health Journal* 19: 1202–11.

Figlio, D., S. Hamersma, and J. Roth. 2009. "Does Prenatal WIC Participation Improve Birth Outcomes? New Evidence from Florida." *Journal of Public Economics* 93 (1–2): 235–45.

Gueorguieva, R., S. B. Morse, and J. Roth. 2009. "Length of Prenatal Participation in WIC and Risk of Delivering a Small for Gestational Age Infant: Florida, 1996–2004." *Maternal Child Health Journal* 13 (4): 479–88.

Heisler, E. J., and N. L. Tyler. 2014. "Hospital-Based Emergency Departments: Background and Policy Considerations." Congressional Research Services Report [accessed on February 15, 2016]. Available at https://www.fas.org/sgp/crs/misc/R43812.pdf

Hillemeier, M. M., M. E. Domino, R. Wells, R. K. Goyal, H.-C. Kum, D. Cilenti, J. T. Whitmire, and A. Basu. 2015. "Effects of Maternity Care Coordination on Pregnancy Outcomes: Propensity-Weighted Analyses." *Maternal Child Health Journal* 19: 121–7.

Hoynes, H., M. Page, and A. H. Stevens. 2011. "Can Targeted Transfers Improve Birth Outcomes? Evidence from the Introduction of the WIC Program." *Journal of Public Economics* 95: 813–27.

Institute of Medicine (IOM). 2007. *Preterm Birth: Causes, Consequences, and Prevention.* Washington, DC: National Academies Press.

Kane, D., and L. M. Issel. 2005. "Estimating Medicaid Prenatal Case Management Costs: The Provider's Perspective." *Nursing Economics* 23 (4): 181–8.

Khanani, I., J. Elam, R. Hearn, C. Jones, and N. Maseru. 2010. "The Impact of Prenatal WIC Participation on Infant Mortality and Racial Disparities." *American Journal of Public Health* 100 (Suppl 1): S204–9.

Kotelchuck, M. 1994. "An Evaluation of the Kessner Adequacy of Prenatal Care Index and a Proposed Adequacy of Prenatal Care Utilization Index." *American Journal of Public Health* 84 (9): 1414–20.

Meghea, C. I., J. E. Raffo, Q. Zhu, and L. Roman. 2013. "Medicaid Home Visitation and Maternal and Infant Healthcare Utilization." *American Journal of Preventive Medicine* 45 (4): 441–7.

Newman, R. B., S. A. Sullivan, M. K. Menard, C. S. Rittenberg, A. K. Rowland, J. E. Korte, and H. Kirby. 2008. "South Carolina Partners for Preterm Birth Prevention: A Regional Perinatal Initiative for the Reduction of Premature Birth in a Medicaid Population." *American Journal of Obstetrics and Gynecology* 199 (4): 393.e1–8.

Piper, J. M., E. F. Mitchel, and W. A. Ray. 1996. "Evaluation of a Program for Prenatal Care Case Management." *Family Planning Perspectives* 28 (2): 65–8.

Reichman, N. E., and J. O. Teitler. 2003. "Effects of Psychosocial Risk Factors and Prenatal Interventions on Birth Weight: Evidence from New Jersey's Health Start Program." *Perspectives in Sexual and Reproductive Health* 35 (3): 130–7.

Rohde, F., and S. Machlin. 2012. *Health Care Expenditures for Uncomplicated Pregnancies, 2009 Research Findings No. 32.* Rockville, MD: Agency for Healthcare Research

and Quality [accessed on August 14, 2016]. Available at http://www.meps.ahrq.gov/mepsweb/data_files/publications/rf32/rf32.pdf

Rosenbaum, P. R., and D. B. Rubin. 1983. "The Central Role of the Propensity Score in Observational Studies for Causal Effects." *Biometrika* 70 (1): 41–55.

Schulman, E. D., D. J. Sheriff, and E. T. Momany. 1997. "Primary Care Case Management and Birth Outcomes in the Iowa Medicaid Program." *American Journal of Public Health* 87 (1): 80–4.

Wells, R., D. Cilenti, and L. M. Issel. 2015. "The Political Economy of a Public Health Case Management Program's Transition into Medical Homes." *Social Science and Medicine* 145: 98–106.

SUPPORTING INFORMATION

Additional supporting information may be found online in the supporting information tab for this article:

Appendix SA1: Author Matrix.