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# Dosage Effect of Prenatal Home Visiting on Pregnancy Outcomes in At-Risk, First-Time Mothers

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# Dosage Effect of Prenatal Home Visiting on Pregnancy Outcomes in At-Risk, First-Time Mothers


## abstract

**BACKGROUND AND OBJECTIVE:** Home visiting programs seek to improve care management for women at high risk for preterm birth (<37 weeks). Our objective was to evaluate the effect of home visiting dosage on preterm birth and small for gestational age (SGA) infants.

**METHODS:** Retrospective cohort study of women in southwest Ohio with a singleton pregnancy enrolled in home visiting before 26 weeks' gestation. Vital statistics and hospital discharge data were linked with home visiting data from 2007 to 2010 to ascertain birth outcomes. Eligibility for home visiting required ≥1 of 4 risk factors: unmarried, low income, <18 years of age, or suboptimal prenatal care. Logistic regression tested the association of gestational age at enrollment and number of home visits before 26 weeks with preterm birth. Proportional hazards analysis tested the association of total number of home visits with SGA status.

**RESULTS:** Among 441 participants enrolled by 26 weeks, 10.9% delivered preterm; 17.9% of infants were born SGA. Mean gestational age at enrollment was 18.9 weeks; mean number of prenatal home visits was 8.2. In multivariable regression, ≥8 completed visits by 26 weeks compared with ≤3 visits was associated with an odds ratio 0.38 for preterm birth (95% confidence interval: 0.16–0.87), while having ≥12 total home visits compared with ≤3 visits was significantly associated with a hazards ratio 0.32 for SGA (95% confidence interval: 0.15–0.68).

**CONCLUSIONS:** Among at-risk, first time mothers enrolled prenatally in home visiting, higher dosage of intervention is associated with reduced likelihood of adverse pregnancy outcomes. *Pediatrics* 2013;132:S118–S125



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**KEY WORDS**

home visit, preterm birth, small for gestational age, low birth weight, prenatal care


**ABBREVIATIONS**

aOR—adjusted odds ratio
CI—confidence interval
ECS—Every Child Succeeds
HR—hazard ratio
MIECHV—Maternal, Infant, and Early Childhood Home Visiting
SGA—small for gestational age

Dr Goyal conceptualized and designed the study, performed statistical analysis, and drafted the initial manuscript; Dr Hall coordinated and supervised administrative data collection and data linkages and reviewed and revised the manuscript; Dr Meinzen-Derr assisted with study design, supervised all statistical analysis, and reviewed and revised the manuscript; Dr Kahn assisted with design of the study and interpretation of the data and reviewed and revised the manuscript; Ms Short coordinated data collection for the home visiting program, assisted with interpretation of the data, and critically reviewed the manuscript; Dr Van Ginkel supervised data collection for the home visiting program and critically reviewed the manuscript; Dr Ammerman supervised the conceptualization of the study and designed the study, supervised interpretation of the data, and reviewed and revised the manuscript; and all authors approved the final manuscript as submitted.


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Preterm birth (birth before 37 weeks' gestation) is the single most challenging problem in modern obstetric practice and child health. The last 4 decades have seen a rise in preterm birth rates, with 12% of pregnancies, or 500 000 infants annually, delivering prematurely in the United States.[1] Decades of research demonstrate that this outcome occurs with profound sociodemographic disparities and is mediated by a complex matrix of biological, genetic, social, and environmental factors.[2–5]

Home visiting is 1 strategy to improve maternal-child health outcomes through family education, training, and social support.[6–8] Recently, the Health Services and Resources Administration created the Maternal, Infant, and Early Childhood Home Visiting (MIECHV) program, with 1 aim to improve care management for pregnant women at high risk for preterm birth and low birth weight (<2500 g).[9] However, existing studies of home visiting and pregnancy outcomes have yielded inconsistent results, likely in part due to limitations in approach, lack of a theoretical framework specific to pregnancy outcomes, and variation in content and delivery of the intervention.[10–12]

An important component of home visiting may be "dosage," or duration of enrollment and intensity of participation. Evidence suggests that benefits of home visiting, measured on a range of outcomes, are affected by extent of exposure.[13–15] This may be particularly important for preterm birth, where modifiable risk factors such as nutrition, physical or mental health, and lifestyle behaviors may only be amenable to intervention if exposure begins early and is sustained at a sufficiently high intensity.[11] The goal of our study is to evaluate the effect of dosage of home visiting on pregnancy outcomes by using a regional perinatal data resource containing linked administrative and community-based program data. We hypothesized that, after adjustment for clinical, social, and demographic factors, higher number of prenatal visits in the first and second trimester are associated with a reduced likelihood of adverse pregnancy outcomes.

## METHODS

### Study Design and Population

This was a retrospective, cohort study to examine the dosage effect of prenatal home visiting on singleton pregnancy outcomes in a population of at-risk, first-time mothers enrolled in an established, regional home visiting program, Every Child Succeeds (ECS), in southwest Ohio from 2007 to 2010.

ECS is a large community-based, home visiting program managed by Cincinnati Children's Hospital Medical Center. Eligible mothers must have at least 1 of 4 risk characteristics: unmarried, low income (up to 300% of poverty level, receipt of Medicaid, or reported concerns about finances), <18 years of age, or suboptimal prenatal care. Participants are enrolled during pregnancy or before their child reaches 3 months of age. Home visits are provided by social workers, child development specialists, nurses, or paraprofessionals, starting with weekly or more-frequent visits and tapering to fewer visits as the child ages. ECS agencies in Ohio use the Healthy Families America model of home visiting; program goals are to (1) improve pregnancy outcomes through nutrition education and substance use reduction, (2) support parents in providing children with a safe, nurturing, and stimulating home environment, (3) optimize child health and development, (4) link families to health care and other services, and (5) promote economic self-sufficiency.

Referrals to the program may be self-initiated, or come from clinics, hospitals, and other community sources. To avoid inclusion of women who would not have had time for an intervention to influence their risk of delivering preterm, analyses were restricted to women enrolled before 26 weeks' gestation. Women with multiple gestation pregnancies were also excluded from analysis because of their higher expected incidence of preterm birth.

### Data Sources

ECS data were abstracted from a Web-based data entry system used to collect service provision data and for billing. This system contains detailed information on each participant, including enrollment timing by weeks of gestation, prenatal home visit history, and maternal demographic and psychosocial screening information.[16] Enrolled participants were consented to data being used for the purpose of quality assurance benchmarking and research.

These data were linked to Ohio vital statistics, available from the Ohio Department of Health, and birth-related hospital discharge of both mother and infant, available from the Ohio Hospital Association. Because there is no common unique identifier, record linkage was accomplished by using LINKS (University of Manitoba), an SAS-based probabilistic matching program (SAS Institute, Inc, Cary, NC). Selected variables used for linking included maternal and infant dates of birth, hospital of birth, delivery method, gender, and maternal address. Further details of linkage of data sources is described elsewhere by Hall et al.[17] The resulting data set provides information regarding maternal-child health, including demographics, social factors, pregnancy-related conditions, and infant outcomes. The Ohio Department of Health and Cincinnati Children's Hospital Medical Center Institutional Review Boards approved this study.

## Measures

### Outcomes

Preterm birth was defined as infant birth before 37 weeks' gestation; gestational age measures were obtained from vital statistics and represented the best clinical estimates. Because risk factors attributable to preterm birth may differ based on gestational age grouping (ie, 32–34 weeks' vs 35–36 weeks' gestation), we also repeated analyses with preterm birth specified as gestational age <35 weeks.[18] Our second key outcome was infant birth weight, also obtained from vital statistics, which was categorized as small for gestational age (SGA) versus appropriate or large for gestational age by using validated growth curves.[19]

As a sensitivity analysis, we repeated evaluations by using a combined gestational age estimate from vital statistics rather than the clinical gestational age estimate, since previous studies have demonstrated discordance between these measures and potential unreliability of either one for population-based research.[20] The combined gestational age estimate incorporates the clinical estimate but primarily relies upon a calculated estimate based on maternal report of last menstrual period.

### Predictors

The primary predictor was dosage of prenatal home visiting (ie, the amount of intervention received among enrolled participants). To measure timing of onset, dates of enrollment were extracted from ECS and used to calculate gestational age at enrollment on the basis of the date of birth and gestational age at birth. Intensity of participation was measured as the number of completed prenatal home visits, also extracted from the ECS data system.

Although previous work has demonstrated an association between prenatal home visiting duration and preterm birth,[15] one potential concern may be that duration of prenatal enrollment is tautologically related to length of pregnancy and thus gestational age at delivery. Similarly, total number of completed prenatal home visits may reflect length of pregnancy, thereby limiting the ability to infer causality for preterm birth. To offset this concern, we used number of home visits before 26 weeks' gestation for the preterm birth analysis, whereas for the SGA analysis we used total number of home visits. These variables were categorized into groupings of visit counts on the basis of reasonable cutoffs for ease of interpretation, as well as on the basis of distribution of the data.

### Covariates

As described by Hall et al,[17] data for maternal covariates were obtained through a combination of linked vital statistics, hospital discharge records, and home visiting data. These included race, ethnicity, payer source, maternal age, employment status, marital status, and education level. In addition to maternal BMI, calculated from vital statistics measures, indicator variables for relevant maternal comorbidities and obstetrical risk factors were constructed by using *International Classification of Diseases, Ninth Revision, Clinical Modification* codes and vital statistics data. These included chorioamnionitis, previous poor birth outcome (defined as previous fetal loss, stillbirth, or neonatal death), placental abnormalities, cervical abnormalities, hypertension/preeclampsia, anemia, diabetes, oligohydramnios, and premature rupture of membranes. Measures of tobacco, alcohol, and other substance use, as well as maternal living arrangement and frequency of contact with the infant's father, were also obtained.

In addition to individual-level covariates, we measured the percent of residents living below poverty level by census tract for each participant's geocoded address by using 5-year estimates from the 2010 American Community Survey,[21] as poverty has been demonstrated to be an important area-level measure associated with a range of health outcomes, including preterm birth.[3,22]

## Statistical Analysis

### Preterm Birth

Bivariate analyses by using $\chi^2$ or *t* tests were used to identify covariates associated with preterm birth. Factors deemed to be empirically or statistically important ($P < .25$) were considered and tested in multiple logistic regression analyses by using step-wise multivariable modeling to derive parsimonious models. Models were tested for goodness of fit by using Akaike Information Criterion values and link tests for model specification. Multicollinearity was also assessed, with variance inflation factors for all retained variables < 10.[23]

### SGA Status

The independent association of home visiting exposure with SGA status was assessed by using a Cox proportional hazards survival model because of differences in timing to the outcome (birth) on the basis of gestational age at delivery. As above, bivariate analyses were used to identify covariates associated with the outcome; factors were then considered and tested in multivariable analyses by using step-wise multivariable modeling. Models were tested for goodness of fit and multicollinearity. Testing for violation of proportional hazards assumption was performed by using Schoenfeld residuals, which were not statistically significant.

All statistical tests were 2-sided, and type I error was controlled at 0.05. Final models were adjusted for clustering by home visiting agency by using robust

SEs for cluster-correlated data. Analyses were performed by using Stata 11.0 (Stata Corp, College Station, TX).

## RESULTS

From the data set representing 2330 women with linked home visiting records and Ohio birth certificates for the years 2007–2010, we identified 918 prenatally enrolled first-time mothers with a single gestation pregnancy. Of these, 441 enrolled by 26 weeks' gestation and were included in the final analytic sample. The preterm birth rate among the sample was 10.9%, and 17.9% of infants were born SGA. Sixty-one percent were African American and 32% were white, 98% were unmarried, 53% had not completed high school, mean maternal age was 20 years, and 84% were insured through Medicaid. Mean gestational age at enrollment was 18.9 weeks, and number of total completed prenatal home visits ranged from 1 to 26 visits. As expected, there were fewer visits completed before 26 weeks' gestation, ranging from 1 to 16.

**TABLE 1** Clinical and Demographic Characteristics of Mothers Enrolled in Home Visiting Prenatally With and Without Preterm Birth

| | Birth < 37 wk (*N* = 48) | Birth ≥ 37 wk (*N* = 393) | *P* |
|---|---|---|---|
| Race, % (*n*) | | | .16 |
| White | 27.1 (13) | 32.8 (129) | — |
| African American | 62.5 (30) | 61.1 (240) | — |
| Other | 6.3 (3) | 2.0 (8) | — |
| Multirace | 4.2 (2) | 4.1 (16) | — |
| Hispanic ethnicity, % (*n*) | 4.2 (2) | 3.8 (15) | .91 |
| Unmarried, % (*n*) | 97.9 (47) | 97.7 (384) | .98 |
| No high school degree, % (*n*) | 62.5 (30) | 51.9 (204) | .17 |
| Insurance, % (*n*) | | | .72 |
| Medicaid | 85.4 (41) | 83.2 (327) | — |
| Private | 12.5 (6) | 14.8 (58) | — |
| Self-pay | 2.1 (1) | 0.8 (3) | — |
| Daily contact with infant's father, % (*n*) | 41.7 (20) | 47.1 (185) | .37 |
| Maternal age <18 y, % (*n*) | 31.3 (15) | 20.9 (82) | .10 |
| Lives alone, % (*n*) | 16.7 (8) | 15.9 (62) | .83 |
| Chorioamnionitis, % (*n*) | 8.3 (4) | 4.6 (18) | .26 |
| Disorders of placentation, % (*n*) | 4.2 (2) | 0.5 (2) | .01 |
| Hypertension / preeclampsia, % (*n*) | 27.1 (13) | 12.0 (47) | .004 |
| Cigarette use, % (*n*) | 29.2 (14) | 35.0 (137) | .43 |
| Other drug use, % (*n*) | 8.3 (4) | 12.7 (50) | .38 |
| Previous poor birth outcome, % (*n*) | 25.0 (12) | 10.7 (42) | .004 |
| Percent living below poverty level by census tract, mean | 30.4 | 29.0 | .82 |
| Maternal BMI, mean | 22.6 | 24.4 | .32 |
| Gestational age at enrollment in weeks, mean | 19.1 | 18.8 | .71 |
| Number of prenatal home visits before 26 wk gestation, % (*n*) | | | .56 |
| 1–3 prenatal home visits | 64.6 (31) | 58.0 (228) | — |
| 4–7 prenatal home visits | 31.3 (15) | 34.4 (135) | — |
| ≥8 prenatal home visits | 4.2 (2) | 7.6 (30) | — |

### Bivariate Comparisons

Table 1 depicts comparisons of key predictors and covariates with preterm birth. In bivariate analyses, preterm birth was not significantly associated with gestational age at enrollment or categorized number of home visits before 26 weeks. A higher percentage of women delivering preterm had a history of previous poor pregnancy outcome (25.0% vs 10.7%), hypertension/preeclampsia (27.1% vs 12.0%), and disorders of placentation (4.2% vs 0.5%) compared with women delivering at full term gestations, all $P < .05$.

As shown in Table 2, bivariate comparisons demonstrated that women delivering an SGA infant were not significantly different from women without SGA infants in mean gestational age at enrollment or categorized number of total prenatal home visits. A higher percentage of women delivering an SGA infant had a history of cigarette use (46.8% vs 31.5%) and other drug use (19.0% vs 10.8%) compared with women delivering non-SGA infants, $P < .05$. Mean maternal BMI was significantly higher in the group with SGA infants (25.7 vs 23.9, $P < .01$).

### Multivariable Analyses

#### *Preterm Birth*

As shown in Table 3, timing of enrollment in home visiting was not independently associated with preterm birth. However, number of home visits before 26 weeks was statistically significant; compared with the reference group of ≤3 home visits, completion of 8 or more home visits by 26 weeks was associated with an adjusted odds ratio (aOR) 0.38 for preterm birth (95% confidence interval [CI]: 0.16–0.87). This association was robust to re-specification of the outcome as delivery before 35 weeks' gestation. Several maternal covariates were associated with a significantly increased AOR of preterm birth, including hypertension/preeclampsia (AOR, 2.99 [95% CI: 1.66–5.41]), previous poor pregnancy outcome (2.87 [95% CI: 1.52–5.44]), and placental disorders (6.77 [95% CI: 1.58–29.0]).

Overall models and coefficients for key predictors did not change significantly when combined versus clinical gestational age estimates were used; therefore, these data are not shown.

#### *SGA Status*

Table 4 depicts results of the multivariable proportional hazards analysis for SGA. After adjustment for all

**TABLE 2** Clinical and Demographic Characteristics of Mothers Enrolled in Home Visiting Prenatally With and Without SGA infants

| | SGA ($N = 79$) | Non-SGA ($N = 362$) | $P$ |
|---|---|---|---|
| Race, % (*n*) | | | |
| White | 30.4 (24) | 32.6 (118) | — |
| African American | 64.6 (51) | 60.5 (219) | .57 |
| Other | 3.8 (3) | 2.3 (8) | — |
| Multirace | 1.3 (1) | 4.7 (17) | — |
| Hispanic ethnicity, % (*n*) | 2.5 (2) | 4.1 (15) | .50 |
| Unmarried, % (*n*) | 98.7 (78) | 97.8 (354) | .59 |
| No high school degree, % (*n*) | 51.9 (41) | 53.3 (193) | .82 |
| Insurance, % (*n*) | | | .16 |
| Medicaid | 79.7 (63) | 84.3 (305) | — |
| Private | 15.2 (12) | 14.4 (52) | — |
| Self-pay | 1.3 (1) | 0.8 (3) | — |
| Daily contact with infant's father, % (*n*) | 36.7 (29) | 48.6 (176) | .18 |
| Maternal age <18 y, % (*n*) | 22.8 (18) | 21.8 (79) | .85 |
| Lives alone, % (*n*) | 11.4 (9) | 16.9 (61) | .23 |
| Chorioamnionitis, % (*n*) | 3.8 (3) | 5.2 (19) | .59 |
| Disorders of placentation, % (*n*) | 1.3 (1) | 0.8 (3) | .71 |
| Hypertension / preeclampsia, % (*n*) | 17.7 (14) | 12.7 (46) | .24 |
| Cigarette use, % (*n*) | 46.8 (37) | 31.5 (114) | .009 |
| Other drug use, % (*n*) | 19.0 (15) | 10.8 (39) | .04 |
| Previous poor birth outcome, % (*n*) | 15.2 (12) | 11.6 (42) | .38 |
| Maternal BMI, mean | 25.7 | 23.9 | .004 |
| Percent living below poverty level by census tract, mean | 29.0 | 29.2 | .84 |
| Mean gestational age at enrollment in weeks, mean | 18.7 | 18.9 | .22 |
| Number of total prenatal home visits, % (*n*) | | | .87 |
| 1–3 prenatal home visits | 7.6 (6) | 9.1 (33) | — |
| 4–7 prenatal home visits | 39.2 (31) | 38.7 (140) | — |
| 8–11 prenatal home visits | 38.0 (30) | 34.2 (124) | — |
| ≥12 prenatal home visits | 15.2 (19) | 18.0 (65) | — |

covariates, receipt of ≥12 prenatal home visits compared with the reference group of 1 to 3 prenatal home visits was significantly associated with a 0.32 hazard ratio (HR) of SGA status (95% CI: 0.15–0.68). This association was not detected for categories with fewer numbers of total prenatal home visits (ie, 4–7 visits or 8–11 visits). Maternal age <18 years was significantly associated with SGA status compared with age >18 years (HR: 1.37 [95% CI: 1.06–1.76]), as was maternal race classified as Other compared with white (HR: 3.06 [95% CI: 1.13–8.25]).

## DISCUSSION

Although the effectiveness of home visiting has been demonstrated for many outcomes, including child abuse, infant development, and parenting, the impact of this intervention for pregnancy outcomes is currently not well understood.[6–8,10,11,24] Given the importance of preterm birth to pediatric morbidity and health care spending, as well as the investment of federal funding in home visiting through MIECHV, further conceptualization and measurement of prenatal delivery of home visiting is critical to a comprehensive understanding of the utility and potential cost benefits of this intervention. The current study is a retrospective analysis of dosage of home visiting and singleton pregnancy outcomes in a regional population of at-risk, first time mothers. Results demonstrate that a significant reduction in the likelihood of preterm birth and SGA status is associated with receipt of the highest number of prenatal visits compared with women receiving the lowest number of visits.

This study builds on previous work evaluating the impact of ECS on infant outcomes at a population level, in which program enrollment as a dichotomous predictor was not associated with differences in infant gestational age.[25] Although many previous randomized controlled trials and quasi-experimental studies of community-based programs have revealed promise in improving preterm birth and infant birth weight,[26–31] several reviews of the existing body of literature have demonstrated an overall lack of consistent evidence to support the effectiveness of prenatal home visiting.[10,11,24,32,33] One cause for the overall low percent of positive findings may be lack of attention to dosage of the intervention (ie, the number or duration of home visits per participant).[11,15] Given the complexity of biological, genetic, social, and environmental factors influencing preterm birth, any intervention addressing modifiable risks like nutrition or health behaviors would seem to require adequate intensity and length of exposure to be effective. The importance of home visiting dosage has already been shown for other outcome domains, including child behavioral problems and maternal parenting.[13,14]

Strengths of the current study include minimized selection bias associated with enrollment among an at-risk population by constraining analyses to women enrolled in home visiting prenatally. Furthermore, the sample was restricted to those enrolled before 26 weeks' gestation to maximize the likelihood that participants had time for the intervention to influence their pregnancy. Rather than focus on total number of visits or duration of prenatal participation, which present a problem of tautology with regards to length of pregnancy and thus preterm birth, we measured only visits before 26 weeks for the preterm birth analysis, which is also consistent with our hypothesis that early intervention at a high intensity is required to address modifiable risk factors for preterm birth. An additional strength is our

**TABLE 3** Multivariable Logistic Regression of Predictors With Preterm Birth, AORs

| | Birth < 37 wk, aOR (95% CI)[a] | Birth < 35 wk, aOR (95% CI) |
|---|---|---|
| Race | | |
| White | Reference | Reference |
| African American | 0.94 (0.51–1.73) | 0.87 (0.32–2.37) |
| Other | 3.31 (0.75–14.48) | (Omitted due to collinearity) |
| Multirace | 0.81 (0.21–3.08) | 1.79 (0.67–4.79) |
| Maternal education | | |
| High school degree completed | Reference | Reference |
| No high school degree | 1.49 (0.79–2.82) | 2.34 (0.93–5.89) |
| Maternal age | | |
| ≥18 y | Reference | Reference |
| <18 y | 1.61 (0.75–3.47) | 1.35 (0.49–3.71) |
| Hypertension/preeclampsia | 2.99 (1.66–5.41)[b] | 4.18 (2.04–8.58)[b] |
| Chorioamnionitis | 1.73 (0.80–3.76) | 3.51 (1.55–7.95)[b] |
| Previous poor birth outcome | 2.87 (1.52–5.44)[b] | 6.09 (2.22–16.68)[b] |
| Disorders of placentation | 6.77 (1.58–29.0)[b] | 19.37 (4.97–75.42)[b] |
| Percent below poverty level, by census tract[c] (%) | 1.00 (0.98–1.03) | 0.99 (0.96–1.02) |
| Number of home visits before 26 wk gestation | | |
| 1–3 prenatal home visits | Reference | Reference |
| 4–7 prenatal home visits | 0.67 (0.31–1.45) | 0.60 (0.17–2.12) |
| ≥8 prenatal home visits | 0.38 (0.16–0.87)[b] | 0.31 (0.10–0.89)[b] |
| Gestational age at enrollment, wk | 0.97 (0.91–1.04) | 0.98 (0.86–1.11) |

[a] Final covariates retained in the multivariable analysis of preterm birth were race, maternal education, maternal age <18 y of age, chorioamnionitis, hypertension/preeclampsia, disorders of placentation, previous poor birth outcome, and percent of residents living below poverty by census tract. Model also adjusts for clustering by individual home visiting agency by using robust variance estimators.

[b] Values indicate statistical significance with $P < .05$.

[c] Continuous variable representing percentage of census tract residents with incomes below the federal poverty level based on American Communities Survey data, 5-y combined estimate 2010.

**TABLE 4** Multivariable Cox Proportional Hazards Analysis of Predictors With SGA Status, Adjusted HRs

| | SGA, HR (95% CI)[a] |
|---|---|
| Race | |
| White | Reference |
| African American | 1.28 (0.75–2.17) |
| Other | 3.06 (1.13–8.25)[b] |
| Multirace | 0.31 (0.04–2.34) |
| Maternal education | |
| High school degree completed | Reference |
| No high school degree | 0.71 (0.42–1.19) |
| Daily contact with infant's father | 0.69 (0.45–1.06) |
| Maternal age | |
| ≥18 y | Reference |
| <18 y | 1.37 (1.06–1.76)[b] |
| Maternal BMI | 1.00 (0.99–1.01) |
| Hypertension/preeclampsia | 2.05 (0.96–4.37) |
| Other drug use | 1.34 (0.52–3.47) |
| Percent below poverty level, by census tract[c] (%) | 1.00 (0.99–1.01) |
| Cigarette use | 1.52 (0.87–2.66) |
| Total number of home visits | |
| 1–3 prenatal home visits | Reference |
| 4–7 prenatal home visits | 1.18 (0.62–2.25) |
| 8–11 prenatal home visits | 0.99 (0.44–2.22) |
| ≥12 prenatal home visits | 0.32 (0.15–0.68)[b] |

[a] Final covariates retained in the multivariable analysis of SGA were race, education, frequency of contact with the father, maternal age <18 y of age, maternal BMI, hypertension/preeclampsia, cigarette use, other drug use, and percent of residents living below poverty by census tract. Model also adjusts for clustering by individual home visiting agency by using robust variance estimators.

[b] Values indicate statistical significance with $P < .05$.

[c] Continuous variable representing percentage of census tract residents with incomes below the federal poverty level based on American Communities Survey data, 5-y combined estimate 2010.

application of linked data systems to support policy relevant research in a "real world" setting, which may be particularly important given the requirement for evaluation of home visiting within existing, established programs as services are expanded.

There are several limitations related to use of administrative data in this retrospective analysis. Complications and comorbidities identified by using vital statistics and hospital discharge data may be undercoded or overcoded, resulting in a misclassification bias.[34–36] Another limitation may be generalizability of findings given the sample size and regional population represented. Although we attempted to maintain parsimonious regression models, the number of preterm cases is small relative to the number of retained covariates. Although the ECS prenatal curriculum provides guidance to home visitors for standardized content on the basis of the week of pregnancy, another limitation of this study is potential variation in the content of home visits across participants in this cohort, which is not included in analyses. Lastly, an important limitation of any observational study is the inability to infer causality from observed associations; differences in maternal risk because of nonrandom assignment into groups of higher and lower dosage of home visiting may in part account for the lack of significant association between visit number and outcomes in bivariate analyses. Although we attempted to minimize bias through study design and inclusion of important covariates in multivariate analyses, the extent to which findings were attributable to unmeasured confounding (ie, maternal motivation or self-efficacy) is unclear. This concern may be partially addressed by further omission of subgroups potentially contributing to bias from the analysis; as an example, when alcohol and other substance users ($n = 64$) are

omitted, the aOR of preterm birth associated with highest number of prenatal visits before 26 weeks remains statistically significant (0.35 [95% CI 0.19–0.64]).

## CONCLUSIONS

Given the contribution of birth outcomes to pediatric morbidity and health care spending, as well as the federal investment in home visiting through MIECHV, further conceptualization and measurement of prenatal delivery of home visiting is critical to a comprehensive understanding of the utility and potential cost benefits of this intervention. Current findings support that high dosage of prenatal home visits is associated with reduced odds of preterm birth or SGA status. As programs expand services within at-risk populations, enrollment early in pregnancy and promotion of high levels of engagement in the first and second trimester may be important to achieving measurable benefits of this intervention.


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## REFERENCES


1. Martin JA, Hamilton BE, Ventura SJ, et al. Births: final data for 2009. *Natl Vital Stat Rep*. 2011;60(1):1–70
2. South AP, Jones DE, Hall ES, et al. Spatial analysis of preterm birth demonstrates opportunities for targeted intervention. *Matern Child Health J*. 2012;16(2):470–478
3. DeFranco EA, Lian M, Muglia LA, Schootman M. Area-level poverty and preterm birth risk: a population-based multilevel analysis. *BMC Public Health*. 2008;8:316
4. Institute of Medicine US Committee on Understanding Premature Birth and Assuring Healthy Outcomes. Behrman RE, Butler AS, eds. Preterm birth: causes, consequences, and prevention. Washington, DC: National Academies Press; 2007:5
5. Muglia LJ, Katz M. The enigma of spontaneous preterm birth. *N Engl J Med*. 2010; 362(6):529–535
6. Sweet MA, Appelbaum MI. Is home visiting an effective strategy? A meta-analytic review of home visiting programs for families with young children. *Child Dev*. 2004;75 (5):1435–1456
7. Kitzman H, Olds DL, Henderson CR Jr, et al. Effect of prenatal and infancy home visitation by nurses on pregnancy outcomes, childhood injuries, and repeated childbearing. A randomized controlled trial. *JAMA*. 1997;278(8):644–652
8. American Academy of Pediatrics. Council on Child and Adolescent Health. The role of home-visitation programs in improving health outcomes for children and families. *Pediatrics*. 1998;101(3 pt 1):486–489
9. Maternal I, Early Childhood Home Visiting Program. Health Resources and Services Administration Web site. Available at: http://mchb.hrsa.gov/programs/homevisiting/index.html. Accessed September 7, 2012
10. McNaughton DB. Nurse home visits to maternal-child clients: a review of intervention research. *Public Health Nurs*. 2004;21(3):207–219
11. Issel LM, Forrestal SG, Slaughter J, Wiencrot A, Handler A. A review of prenatal home-visiting effectiveness for improving birth outcomes. *J Obstet Gynecol Neonatal Nurs*. 2011;40(2): 157–165
12. Bull J, McCormick G, Swann C, Mulvihill C. Ante- and post-natal home-visiting programmes: a review of reviews: evidence briefing summary. London: Health Development Agency; 2004. Available at: www.nice.org.uk/nicemedia/documents/home_visiting_summary.pdf. Accessed October 11, 2012
13. Lyons-Ruth K, Melnick S. Dose-response effect of mother-infant clinical home visiting on aggressive behavior problems in kindergarten. *J Am Acad Child Adolesc Psychiatry*. 2004;43(6):699–707
14. Nievar MA, Van Egeren LA, Pollard S. A meta-analysis of home visiting programs: moderators of improvement in maternal behavior. *Infant Ment Health J*. 2010;31(5): 499–520
15. Slaughter JC, Issel LM. Developing a measure of prenatal case management dosage. *Matern Child Health J*. 2012;16(5):1120–1130
16. Ammerman RT, Putnam FW, Kopke JE, et al. Development and implementation of a quality assurance infrastructure in a multisite home visitation program in Ohio and Kentucky. *J Prev Intervent Community*. 2007;34(1–2): 89–107
17. Hall ES, Goyal NK, Ammerman RT, et al Development of a linked perinatal data resource from state administrative and community-based program data [published online ahead of print February 10 2013]. *Matern Child Health J*. 2013.
18. Goldenberg RL, Iams JD, Mercer BM, et al; NICHD MFMU Network. The preterm prediction study: the value of new vs standard risk factors in predicting early and all spontaneous preterm births. *Am J Public Health*. 1998;88(2):233–238
19. Alexander GR, Himes JH, Kaufman RB, Mor J, Kogan M. A United States national reference for fetal growth. *Obstet Gynecol*. 1996;87(2):163–168
20. Wingate MS, Alexander GR, Buekens P, Vahratian A. Comparison of gestational age classifications: date of last menstrual period vs. clinical estimate. *Ann Epidemiol*. 2007;17(6):425–430
21. American Community Survey. US Census Bureau Web site. Available at: www.census.gov/acs/www/. Accessed November 12, 2012
22. Krieger N, Chen JT, Waterman PD, Rehkopf DH, Subramanian SV. Race/ethnicity, gender, and monitoring socioeconomic gradients in health: a comparison of area-based socioeconomic measures—the public health disparities geocoding project. *Am J Public Health*. 2003; 93(10):1655–1671
23. O'brien R. A caution regarding rules of thumb for variance inflation factors. *Qual Quant*. 2007;41:673–690
24. Hollowell J, Oakley L, Kurinczuk JJ, Brocklehurst P, Gray R. The effectiveness of antenatal care programmes to reduce infant mortality and preterm birth in socially disadvantaged and vulnerable women in high-income countries: a systematic review. *BMC Pregnancy Childbirth*. 2011;11(13):13
25. Donovan EF, Ammerman RT, Besl J, et al. Intensive home visiting is associated with decreased risk of infant death. *Pediatrics*. 2007;119(6):1145–1151

26. Carabin H, Cowan LD, Beebe LA, Skaggs VJ, Thompson D, Agbangla C. Does participation in a nurse visitation programme reduce the frequency of adverse perinatal outcomes in first-time mothers? *Paediatr Perinat Epidemiol*. 2005;19(3):194–205
27. Dubois S, Coulombe C, Pencharz P, Pinsonneault O, Duquette MP. Ability of the Higgins Nutrition Intervention Program to improve adolescent pregnancy outcome. *J Am Diet Assoc*. 1997;97(8):871–878
28. Lee E, Mitchell-Herzfeld SD, Lowenfels AA, Greene R, Dorabawila V, DuMont KA. Reducing low birth weight through home visitation: a randomized controlled trial. *Am J Prev Med*. 2009;36(2):154–160
29. Reece EA, Leguizamon G, Silva J, Whiteman V, Smith D. Intensive interventional maternity care reduces infant morbidity and hospital costs. *J Matern Fetal Neonatal Med*. 2002; 11(3):204–210
30. Wells N, Sbrocco T, Hsiao CW, Hill LD, Vaughn NA, Lockley B. The impact of nurse case management home visitation on birth outcomes in African-American women. *J Natl Med Assoc*. 2008;100(5):547–552
31. Olds DL, Henderson CR Jr, Tatelbaum R, Chamberlin R. Improving the delivery of prenatal care and outcomes of pregnancy: a randomized trial of nurse home visitation. *Pediatrics*. 1986;77(1): 16–28
32. Hodnett ED, Fredericks S. Support during pregnancy for women at increased risk of low birthweight babies. *Cochrane Database Syst Rev*. 2003; (3):CD000198
33. Blondel B, Bréart G. Home visits during pregnancy: consequences on pregnancy outcome, use of health services, and women's situations. *Semin Perinatol*. 1995;19(4):263–271
34. Romano PS, Mark DH. Bias in the coding of hospital discharge data and its implications for quality assessment. *Med Care*. 1994;32(1):81–90
35. Iezzoni LI, Foley SM, Daley J, Hughes J, Fisher ES, Heeren T. Comorbidities, complications, and coding bias. Does the number of diagnosis codes matter in predicting in-hospital mortality? *JAMA*. 1992;267(16):2197–2203
36. Hsia DC, Krushat WM, Fagan AB, Tebbutt JA, Kusserow RP. Accuracy of diagnostic coding for Medicare patients under the prospective-payment system. *N Engl J Med*. 1988;318(6): 352–355


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