Influence of the Adequacy of the Prenatal Care Utilization Index on Small-For-Gestational-Age Infants and Preterm Births in the United States

Dayeon Shin and Won O. Song

1 Department of Food and Nutrition, Inha University, Incheon 22212, Korea; dyshin@inha.ac.kr
2 Department of Food Science and Human Nutrition, Michigan State University, East Lansing, MI 48824, USA
* Correspondence: song@msu.edu; Tel.: +1-517-353-3332

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Abstract: Little is known about the associations of Adequacy of Prenatal Care Utilization (APNCU) index with small-for-gestational-age (SGA) infants and preterm births. This study investigated the association between the Adequacy of Prenatal Care Utilization (APNCU) index in relation to small-for-gestational-age (SGA) infants and preterm births. We used data from 212,050 pregnant women from the Pregnancy Risk Assessment Monitoring System (PRAMS) between 2004 and 2011. Multivariable logistic regression analyses were performed to examine the effect of the APNCU index on SGA infants and preterm births after controlling for maternal sociodemographic factors. Women who received adequate-plus prenatal care in reference to adequate prenatal care had increased odds for delivering SGA infants (adjusted odds ratio (AOR) = 1.08, 95% confidence interval (CI) = 1.03–1.15). Women with 9–11 prenatal care visits had increased odds of delivering SGA infants (AOR = 1.07, 95% CI = 1.02–1.14) compared to those with more than 12 visits. Among the four APNCU index categories, the highest rate of preterm births was observed in the adequate-plus group. Compared to those with adequate prenatal care, women who received adequate-plus prenatal care had increased odds of preterm birth (AOR = 1.69, 95% CI = 1.55–1.84). Compared to those with more than 12 visits, women with fewer than eight prenatal care visits had increased odds of preterm birth (AOR = 1.29, 95% CI = 1.13–1.48). In conclusion, women in the adequate-plus APNCU index category were more likely to deliver SGA infants and to have preterm births compared to those in the adequate APNCU index category. Women in the U.S. with high-risk pregnancies were prone to receiving adequate-plus prenatal care. Future prospective studies are warranted to investigate the influence of APNCU index in relation to pregnancy and birth outcomes.

Keywords: Pregnancy Risk Assessment Monitoring System (PRAMS); Adequacy of Prenatal Care Utilization (APNCU) index; small-for-gestational-age (SGA); preterm birth

1. Introduction

Preterm birth is the most frequent cause of infant and neonatal death in the U.S. [1] and is also the most important factor influencing an infant’s subsequent health and survival [2]. Compared to full-term infants (37–41 weeks of gestation), preterm infants (<37 weeks of gestation) have a wide variety of health and developmental problems, including long-term cognitive, behavioral, social, emotional, and neurodevelopmental difficulties [3]. Low birth weight and small-for-gestational-age (SGA) infants are the next most common causes of infant death [1]. Also, low birth weight and SGA are associated with poor neurocognitive development among infants [4]. For these reason, Healthy People 2020, the health objectives for the nation, includes the goal of a reduction of low birth weight rate from a baseline of 8.2% to 7.8% of live births by 2020 [5].
An important approach to reducing the risk of preterm birth and SGA infants is adequate prenatal care [6,7]. Prenatal care is a frequently used health service that may reduce the incidence of perinatal morbidity and mortality by treating medical conditions, identifying and reducing potential risks, and helping women to address behavioral factors that contribute to poor outcomes [8]. Studies analyzing trends in prenatal care and birth outcomes have used a number of methods to assess the adequacy of prenatal care [9]. One of the more recently developed methods, the Adequacy of Prenatal Care Utilization (APNCU) index, is an improvement on the Kessner Index from the Institute of Medicine, which considers only the trimester of initiation of prenatal care and the number of prenatal visits [10]. The APNCU index is used for precise and comprehensive measurement of prenatal care [11].

The beneficial effect of prenatal care utilization indicated by the APNCU index was a reduced risk of preterm birth or SGA [6,12–15], whereas no beneficial effects of prenatal care were shown in the prevention of adverse birth outcomes [16–19]. There is still significant debate in the U.S. regarding the effectiveness of prenatal care in reducing SGA and preterm-birth pregnant women. The objectives of this study were to determine the rate of prenatal care utilization among pregnant women in the U.S. and to determine the association of the adequacy of prenatal care utilization with SGA and preterm birth. We hypothesized that the adequacy of prenatal care utilization is associated with the risk of SGA and preterm birth in U.S. pregnant women.

2. Materials and Methods

2.1. Study Populations

The present study used data from the Pregnancy Risk Assessment Monitoring System (PRAMS). The PRAMS is an ongoing surveillance project from the Centers for Disease Control and Prevention (CDC) and state health departments of 40 U.S. states and New York City. The most recent dataset that was attainable at the beginning of this project was from 2004 to 2011, including phases 5 (2004–2008) and 6 (2009–2011). The PRAMS sample is chosen from among all women with recent live births; therefore, findings can be applied to the participating state’s entire population of women who have recently delivered live-born infants. The PRAMS provides state-specific data, and also allows for comparisons among participating states because the same data collection methods are used in all states. The PRAMS, which collects data from the state birth certificate files, is a stratified systematic sample of 100–300 new mothers who have delivered live-born infants in the preceding 2–4 months. A self-administered questionnaire is mailed to each mother. If the mother fails to respond a second, and usually a third, questionnaire is mailed to each mother. If the mother does not respond to the mailings, telephone interviews are used for follow-up. Each completed questionnaire is then linked to information from the state’s birth certificate file. The birth certificate files include information on total gestational weight gain and SGA infants. A self-administered questionnaire was mailed to each mother to obtain information on preterm birth. As the survey is conducted several months after delivery, recall bias is possible regarding the mothers’ observations or experiences [20]. However, recall bias is of minimal concern for risk factors related to maternal or neonatal morbidity [21].

The initial PRAMS 2004–2011 cohort included 313,735 women from Michigan. After excluding women with missing data on APNCU (N = 11,445), the number of prenatal care visits (N = 1366), time of the first prenatal care initiation (N = 6565), starting prenatal care in the first trimester (N = 7), previous history of preterm birth (N = 4785), SGA infants (N = 22,336), pre-pregnancy body mass index (BMI) (N = 14,181), gestational weight gain (N = 17,460), and maternal sociodemographic characteristic variables (N = 23,540), the final analytic sample size for the present study was 212,050 women.

2.2. Exposure Variables

The APNCU index developed by Kotelchuck determines the adequacy of prenatal care utilization based on two parts: the month in which prenatal care is initiated and the number of visits from initiation of care until delivery and then categorized into four: “Inadequate” care is defined as either
starting prenatal care after the 4th month of pregnancy or receiving less than 50% of expected visits based on the schedule of prenatal care visits recommended by American College of Obstetricians and Gynecologists (ACOG). “Intermediate” care is care begun by month 4 and with 50–79% of expected visits received; “adequate” care is that begun by month 4 and with 80–109% of expected visits received; “adequate plus” care is begun by month 4 and with 110% or more of expected visits received [10]. The expected number of prenatal visits was calculated from the month of initiation of prenatal care and gestational age at birth, based on the schedule of prenatal care visits recommended by the American College of Obstetrics and Gynecology (ACOG). The ACOG recommends one visit every four weeks for the first 28 weeks, five times for 32 weeks, six times for 36 weeks, and 7–11 times for 37–41 weeks of pregnancy [22]. Consequently, the ratio of observed number to expected number of visits was calculated and used in categorizing women into four different groups: inadequate, intermediate, adequate, and adequate-plus utilization of prenatal care services. Inadequate utilization is defined as either starting prenatal care after the 4th month of pregnancy or receiving fewer than 50% of the expected visits based on the schedule of prenatal care visits recommended by the ACOG. Intermediate care is care begun by month 4 and with between 50% and 79% of the expected visits received; adequate care is that begun by month 4 and with 80–109% of the expected visits received; adequate-plus care is begun by month 4 and with 110% or more of the expected visits received.

The initiation of prenatal care in the first trimester was categorized as yes, no, or no prenatal care. The number of prenatal care visits was categorized into less than eight visits, 9–11 visits, or more than 12 visits.

2.3. Outcome Variables

If the birth certificate indicated that the infant’s birth weight was below the 10th percentile for the gestational age, the mother was determined to have experienced the outcome of SGA. From the PRAMS questionnaire, if the infant was born at <37 completed weeks of gestation, the mother was considered to have had a preterm birth.

2.4. Covariates

Covariates in the study were maternal age in three groups (≤24, 25–34, or ≥35 years). race/ethnicity consisted of non-Hispanic white, non-Hispanic black, Hispanic, and other non-Hispanic race/ethnicities, maternal education clustered (<high school, high school diploma, or more than high school), annual household income classified into five categories (<$15,000, $15,000–35,000, $35,000–50,000, or ≥$50,000). Marital status was divided into two groups (married or other). Gestational age at birth was categorized into five groups (≤27, 28–33, 34–36, 37–42, or ≥43 weeks). Women, infants, and children (WIC) status during pregnancy was divided into two groups (yes or no). Smoking status was divided into two groups (yes or no). Previous preterm birth was categorized into two groups (yes or no). Parity number was categorized into five groups (0, 1, 2, 3–5, or ≥6).

2.5. Statistical Analyses

The participants’ characteristics were described using weighted frequency distributions and adjusted for survey sampling. Tests of associations between the APNCU index and maternal characteristics were performed using chi-squared statistics. Multivariable logistic regression was used to examine the relationship between the adequacy of prenatal care and SGA infants or preterm births as an outcome after controlling for pre-pregnancy BMI, gestational weight gain, maternal age, race, education level, income level, marital status, gestational weeks, WIC participation during pregnancy, smoking status during pregnancy, and previous history of preterm birth. The independent variables of interest were the APNCU index (adequate-plus, adequate, intermediate, and inadequate utilization of prenatal care), timing of the initiation of prenatal care (start prenatal care in the first trimester, start prenatal care in the second or third trimester, or none) and the number of prenatal care visits (≥12, 9–11, or ≤8).
3. Results

Table 1 presents the distributions of maternal characteristics by SGA and preterm births. Pre-pregnancy BMI, the adequacy of gestational weight gain, maternal age, education, annual household income, marital status, gestational age at birth, WIC participation during pregnancy, smoking status, previous live birth number, timing of initiation of prenatal care, and number of prenatal care visit all significantly differed by the status of SGA and preterm birth, respectively (all $p < 0.05$). Maternal race only differed by the status of preterm birth.

Table 1. Maternal sociodemographic characteristics by small-for-gestational-age (SGA) and preterm births.

|                          | SGA ($n = 35,137$) | Non SGA ($n = 176,913$) | Preterm Birth ($n = 52,602$) | Non Preterm Birth ($n = 159,448$) | $p$ Value $^*$ | $p$ Value $^{**}$ |
|--------------------------|--------------------|--------------------------|-------------------------------|---------------------------------|----------------|------------------|
| Pre-pregnancy BMI $^1$   |                    |                          |                               |                                 |                |                  |
| Underweight              | 3091               | 8.1                      | 8310                          | 4.3                             | <0.0001        | <0.0001          |
| Normal                   | 18,981             | 56.5                     | 90,417                        | 52.0                            | 26,570         | 50.2             |
| Overweight               | 7107               | 19.9                     | 42,622                        | 24.1                            | 11,846         | 23.3             |
| Obese                    | 5958               | 15.4                     | 35,564                        | 19.6                            | 10,413         | 20.4             |
| Gestational weight gain $^2$ |                  |                          |                               |                                 |                |                  |
| Inadequate               | 11,139             | 28.7                     | 36,438                        | 17.4                            | <0.0001        | 15,599           |
| Adequate                 | 11,027             | 32.1                     | 50,988                        | 28.6                            | 15,259         | 28.6             |
| Excessive                | 12,971             | 39.2                     | 89,487                        | 54.0                            | 21,744         | 49.1             |
| Maternal age (y)         |                    |                          |                               |                                 |                |                  |
| ≤24                      | 13,698             | 38.7                     | 56,851                        | 30.3                            | <0.0001        | 21,556           |
| 25–34                    | 16,375             | 48.1                     | 92,552                        | 54.9                            | 24,750         | 50.4             |
| ≥35                      | 5064               | 13.2                     | 27,510                        | 14.8                            | 6296           | 11.2             |
| Maternal race            |                    |                          |                               |                                 |                |                  |
| Non-Hispanic White       | 22,025             | 65.7                     | 101,487                       | 65.4                            | 0.1082         | <0.0001          |
| Non-Hispanic Black       | 5362               | 12.8                     | 26,490                        | 13.3                            | 9766           | 16.3             |
| Hispanic                 | 4051               | 14.0                     | 22,660                        | 14.3                            | 6284           | 13.9             |
| Other non-Hispanic       | 3699               | 7.6                      | 26,276                        | 7.0                             | 5195           | 5.1              |
| Maternal education       |                    |                          |                               |                                 |                |                  |
| <High school             | 6029               | 17.5                     | 24,170                        | 13.6                            | <0.0001        | 9760             |
| High school diploma      | 11,314             | 31.0                     | 49,444                        | 26.8                            | 17,370         | 32.0             |
| Some college             | 8830               | 24.5                     | 46,779                        | 26.0                            | 14,417         | 27.8             |
| ≥College                 | 8964               | 27.0                     | 56,320                        | 33.6                            | 11,055         | 22.2             |
| Annual household income  |                    |                          |                               |                                 |                |                  |
| Less than $15,000        | 12,978             | 35.7                     | 50,734                        | 26.4                            | <0.0001        | 20,011           |
| $15,000–$34,999          | 8737               | 24.4                     | 42,795                        | 23.5                            | 13,754         | 26.2             |
| $35,000–$50,000          | 3591               | 9.9                      | 19,815                        | 10.9                            | 5441           | 10.8             |
| ≥$50,000                 | 9831               | 30.0                     | 63,569                        | 39.2                            | 13,396         | 28.0             |
| Marital status           |                    |                          |                               |                                 |                |                  |
| Married                  | 20,130             | 56.2                     | 114,569                       | 65.8                            | <0.0001        | 29,606           |
| Other                    | 15,007             | 43.8                     | 62,344                        | 34.2                            | 22,996         | 42.5             |
| Gestational age at birth (weeks) |            |                          |                               |                                 |                |                  |
| ≤27                      | 473                | 0.5                      | 4152                          | 0.4                             | 0.023          | 2749             |
| 28–33                    | 1694               | 4.1                      | 11,167                        | 1.4                             | 6920           | 4.1              |
| 34–36                    | 5003               | 6.3                      | 18,628                        | 5.6                             | 13,025         | 6.4              |
| 37–42                    | 27,727             | 91.5                     | 142,815                       | 92.5                            | 29,875         | 78.1             |
| ≥43                      | 30                 | 0.1                      | 151                           | 0.1                             | 33             | 0.1              |
| WIC during pregnancy     |                    |                          |                               |                                 |                |                  |
| Yes                      | 17,271             | 51.3                     | 99,930                        | 59.0                            | <0.0001        | 24,340           |
| No                       | 17,766             | 48.7                     | 76,983                        | 41.0                            | 28,262         | 51.1             |
| Smoking status           |                    |                          |                               |                                 |                |                  |
| Yes                      | 7793               | 19.8                     | 20,047                        | 9.7                             | <0.0001        | 10,025           |
| No                       | 27,344             | 80.2                     | 156,866                       | 90.3                            | 42,577         | 83.7             |
| Previous live birth number |                |                          |                               |                                 |                |                  |
| 0                        | 18,668             | 53.2                     | 73,933                        | 40.8                            | <0.0001        | 19,945           |
| 1                        | 9,050              | 26.5                     | 56,336                        | 33.2                            | 16,335         | 34.6             |
| 2                        | 4,575              | 12.8                     | 28,380                        | 16.0                            | 9,570          | 18.6             |
| 3–5                      | 2637               | 6.9                      | 17,194                        | 9.2                             | 6472           | 12.6             |
| 6+                       | 207                | 0.5                      | 1270                          | 0.7                             | 480            | 0.8              |

$^1$ Number of cases and percentages rounded to nearest whole number. $^2$ Number of cases and percentages rounded to nearest whole number.
Table 1. Cont.

| Timing of initiation of prenatal care | SGA (n = 35,137) | Non SGA (n = 176,913) | Preterm Birth (n = 52,602) | Non Preterm Birth (n = 159,448) |
|--------------------------------------|------------------|-----------------------|-----------------------------|-------------------------------|
| n Wt'd %                             | n Wt'd %         | p Value               | n Wt'd %                    | p Value                       |
| 1st trimester                        | 27,971           | 79.1                  | 144,823                     | 82.4                          |
| 2nd or 3rd trimester                 | 6881             | 19.9                  | 30,713                      | 17.0                          |
| None                                 | 285              | 1.0                   | 1377                        | 0.6                           |
| Number of prenatal care visits       |                  |                       |                             |                               |
| ≤5 times                             | 8256             | 20.3                  | 38,701                      | 17.4                          |
| 9-11 times                           | 11,524           | 32.6                  | 56,201                      | 32.1                          |
| ≥12 times                            | 15,357           | 47.1                  | 82,011                      | 50.5                          |
| Pre-pregnancy BMI                    |                  |                       |                             |                               |
| Underweight                          | 1588             | 13.8                  | 1388                        | 13                            |
| Normal                               | 11,416           | 10.2                  | 14,649                      | 14.2                          |
| Overweight                           | 5185             | 10.4                  | 6464                        | 14                            |
| Obese                                | 4298             | 10.7                  | 4664                        | 11.8                          |
| Gestational weight gain              |                  |                       |                             |                               |
| Inadequate                           | 6884             | 15.1                  | 6093                        | 14.1                          |
| Adequate                             | 6033             | 9.9                   | 8125                        | 14                            |
| Excessive                            | 9570             | 9.3                   | 12,929                      | 13.3                          |
| Maternal age (y)                     |                  |                       |                             |                               |
| ≤24                                  | 10,968           | 16.2                  | 9119                        | 14                            |
| 25–34                                | 9026             | 8.2                   | 13,871                      | 13.4                          |
| ≥35                                  | 2493             | 7.3                   | 4157                        | 13.8                          |
| Maternal race                        |                  |                       |                             |                               |
| Non-Hispanic White                   | 9556             | 7.9                   | 14,320                      | 13                            |
| Non-Hispanic Black                   | 5098             | 17.4                  | 3988                        | 14.5                          |
| Hispanic                             | 3994             | 15.8                  | 4013                        | 15.5                          |
| Other non-Hispanic                   | 3839             | 12                    | 4826                        | 15                            |
| Maternal education                   |                  |                       |                             |                               |
| <High school                         | 6197             | 21.5                  | 4208                        | 15.2                          |
| High school diploma                  | 7989             | 13.2                  | 7691                        | 13.5                          |
| Some college                         | 5172             | 9.2                   | 7043                        | 13.3                          |
| ≥College                             | 3129             | 4.7                   | 8205                        | 13.5                          |

++ p value: Chi-squared tests for differences in SGA and preterm births by each sociodemographic variable. Weighted (%d) % accounted for the survey sampling design and coverage. The weighted percentages may not sum to 100 due to rounding. 1 Pre-pregnancy body mass index (BMI) (kg/m²) categories according to the World Health Organization: underweight (<18.5), normal weight (18.5–24.9), overweight (25–29.9), and obese (≥30) groups. 2 Gestational weight gain was divided into inadequate, adequate, and excessive groups according to Institute of Medicine’s 2009 guidelines. WIC: Women, infants and children.

Table 2 shows the characteristics of our study population by APNCU index category (inadequate, intermediate, adequate, or adequate-plus). Overall, 10.5% of women received inadequate prenatal care, 13.7% received intermediate prenatal care, 46.9% received adequate prenatal care, and 28.9% received adequate-plus prenatal care according to the APNCU index. Differences in pre-pregnancy BMI, gestational weight gain, maternal age, race, education, annual income, marital status, gestational weeks, WIC participation during pregnancy, smoking status during pregnancy, and parity across APNCU index categories were all significant (p < 0.0001).

Table 2. Maternal sociodemographic characteristics across Adequacy of Prenatal Care Utilization (APNCU) index categories.

| APNCU Index Category 1 | Inadequate (N = 22,487; 10.5%) | Intermediate (N = 27,147; 13.7%) | Adequate (N = 89,804; 46.9%) | Adequate Plus (N = 72,612; 28.9%) |
|------------------------|---------------------------------|----------------------------------|-----------------------------|-----------------------------------|
| n Wt'd %               | n Wt'd %                        | n Wt'd %                         | n Wt'd %                    | p Value                           |
| Pre-pregnancy BMI 2    |                                 |                                  |                             |                                   |
| Underweight            | 1588                            | 13.8                             | 1388                        | 13                                |
| Normal                 | 11,416                          | 10.2                             | 14,649                      | 14.2                              |
| Overweight             | 5185                            | 10.4                             | 6464                        | 14                                |
| Obese                  | 4298                            | 10.7                             | 4664                        | 11.8                              |
| Gestational weight gain |                                 |                                  |                             |                                   |
| Inadequate             | 6884                            | 15.1                             | 6093                        | 14.1                              |
| Adequate               | 6033                            | 9.9                              | 8125                        | 14                                |
| Excessive              | 9570                            | 9.3                              | 12,929                      | 13.3                              |
| Maternal age (y)       |                                 |                                  |                             |                                   |
| ≤24                    | 10,968                          | 16.2                             | 9119                        | 14                                |
| 25–34                  | 9026                            | 8.2                              | 13,871                      | 13.4                              |
| ≥35                    | 2493                            | 7.3                              | 4157                        | 13.8                              |
| Maternal race          |                                 |                                  |                             |                                   |
| Non-Hispanic White     | 9556                            | 7.9                              | 14,320                      | 13                                |
| Non-Hispanic Black     | 5098                            | 17.4                             | 3988                        | 14.5                              |
| Hispanic               | 3994                            | 15.8                             | 4013                        | 15.5                              |
| Other non-Hispanic     | 3839                            | 12                               | 4826                        | 15                                |
| Maternal education     |                                 |                                  |                             |                                   |
| <High school           | 6197                            | 21.5                             | 4208                        | 15.2                              |
| High school diploma    | 7989                            | 13.2                             | 7691                        | 13.5                              |
| Some college           | 5172                            | 9.2                              | 7043                        | 13.3                              |
| ≥College               | 3129                            | 4.7                              | 8205                        | 13.5                              |
Table 2. Cont.

| APNCU Index Category | Inadequate | Intermediate | Adequate | Adequate Plus | p Value |
|----------------------|------------|--------------|----------|---------------|---------|
|                      | (N = 22,487; 10.5%) | (N = 27,147; 13.7%) | (N = 89,804; 46.9%) | (N = 72,612; 28.9%) |
| n Wt’d % | n Wt’d % | n Wt’d % | n Wt’d % | 

Annual household income

| Less than $15,000 | 11,654 | 19.1 | 8410 | 14.2 | 22,819 | 39.8 | 20,829 | 26.8 | <0.0001 |
| $15,000–$34,999 | 5954 | 12.2 | 6592 | 13.7 | 21,273 | 45.2 | 17,713 | 28.9 |  |
| $35,000–$50,000 | 1687 | 7.3 | 2929 | 13 | 10,618 | 49.5 | 8172 | 30.2 |  |
| $50,000 or more | 3192 | 4.3 | 9216 | 13.4 | 35,094 | 52.2 | 25,898 | 30 |  |

Marital status

| Married | 9505 | 6.9 | 17,205 | 13.6 | 61,061 | 49.8 | 46,928 | 29.7 | <0.0001 |
| Other | 12,982 | 17.2 | 9942 | 13.9 | 28,743 | 41.4 | 25,684 | 27.4 |  |

Gestational age at birth (weeks)

| ≤27 | 471 | 10.2 | 272 | 6.5 | 844 | 18.5 | 3038 | 64.9 | <0.0001 |
| 28–33 | 1392 | 12.5 | 531 | 4.3 | 2141 | 15.4 | 8797 | 67.9 |  |
| 34–36 | 2653 | 10.4 | 1657 | 7 | 4207 | 17.8 | 15,314 | 64.7 |  |
| 37–42 | 17,934 | 10.4 | 24,610 | 14.2 | 82,559 | 49.3 | 45,449 | 25.9 |  |
| ≥43 | 37 | 25.3 | 77 | 31.9 | 53 | 35.2 | 14 | 7.7 |  |

WIC during pregnancy

| Yes | 13,601 | 15.2 | 12,348 | 13.9 | 36,243 | 42.4 | 32,557 | 28.6 | <0.0001 |
| No | 8886 | 7.2 | 14,799 | 13.5 | 53,561 | 50.1 | 40,055 | 29.1 |  |

Smoking status

| Yes | 4839 | 16.2 | 3509 | 12.9 | 9765 | 40.7 | 9727 | 30.1 | <0.0001 |
| No | 17,648 | 9.9 | 23,638 | 13.8 | 80,039 | 47.6 | 62,885 | 28.7 |  |

Previous live birth number

| 0 | 8890 | 9.7 | 11,251 | 13.4 | 39,078 | 47.2 | 33,382 | 29.7 | <0.0001 |
| 1 | 6208 | 9.3 | 8509 | 13.6 | 28,921 | 48.4 | 21,748 | 28.7 |  |
| 2 | 3698 | 11.1 | 4393 | 13.9 | 13,792 | 46.5 | 10,872 | 28.5 |  |
| 3-5 | 3298 | 16.8 | 2734 | 14.3 | 7573 | 41.9 | 6226 | 27.1 |  |
| 6+ | 393 | 27 | 260 | 21.2 | 440 | 32.5 | 384 | 19.2 |  |

Timing of initiation of prenatal care

| 1st trimester | 10,735 | 6.2 | 21,882 | 13.6 | 77,174 | 49.4 | 63,003 | 30.8 | <0.0001 |
| 2nd or 3rd trimester | 10,978 | 29.8 | 5089 | 14.1 | 12,226 | 35.6 | 9301 | 20.5 |  |
| None | 774 | 48.4 | 176 | 9 | 404 | 27 | 308 | 15.6 |  |

Number of prenatal care visits

| ≤8 times | 16,654 | 42.4 | 15,638 | 41.5 | 8764 | 12.4 | 5901 | 3.7 | <0.0001 |
| 9–11 times | 3985 | 6.5 | 11,460 | 19.7 | 36,469 | 60 | 15,811 | 13.8 |  |
| ≥12 times | 1848 | 1.9 | 49 | 0 | 44,571 | 50.6 | 50,900 | 47.4 |  |

p value: Chi-squared tests for differences in APNCU by each sociodemographic variable. Weighted (Wt’d) % accounted for the survey sampling design and coverage. The weighted percentages may not sum to 100 due to rounding. 1 The APNCU index comprises two parts: the month in which prenatal care is initiated and the number of visits from the initiation of care until delivery. Inadequate utilization is defined as either starting prenatal care after the 4th month of pregnancy or receiving fewer than 50% of the expected visits based on the schedule for prenatal care visits recommended by the American College of Obstetricians and Gynecologists (ACOG). Intermediate care is care begun by month 4 and with 50–79% of the expected visits received; adequate care is begun by month 4 and with 80–109% of the expected visits received; adequate-plus care is begun by month 4 and with 110% or more of the expected visits received. 2 Pre-pregnancy body mass index (BMI) (kg/m²) categories according to the World Health Organization: underweight (<18.5), normal weight (18.5–24.9), overweight (25–29.9), and obese (≥30) groups. 3 Gestational weight gain was divided into inadequate, adequate, and excessive groups according to Institute of Medicine’s 2009 guidelines. WIC: Women, infants and children.

Table 3 shows the distributions of women with SGA infants and preterm births by APNCU index categories. The distributions of SGA infants and preterm births differed significantly by each APNCU category, respectively (p < 0.0001). Among the four APNCU categories, the highest rate of SGA infant was observed in the adequate group (43.7%), whereas the highest rate of preterm birth was observed in the adequate-plus group (41.0%).
Table 3. Distributions of small-for-gestational-age (SGA) and preterm births by Adequate Prenatal Care Utilization (APNCU) index categories.

| APNCU Index Category | SGA | Preterm Birth |
|----------------------|-----|---------------|
|                      |     |               |
| Inadequate           | Yes | Yes           |
|                      | No  | No            |
| Intermediate         |     |               |
| Adequate             |     |               |
| Adequate Plus        |     |               |

| p Value | n | Wt’d % | n | Wt’d % | n | Wt’d % | n | Wt’d % |
|---------|----|--------|----|--------|----|--------|----|--------|
| <0.0001 | 4111 | 12.2 | 4194 | 14.9 | 13,000 | 43.7 | 13,832 | 29.2 |
|         | 18,376 | 10.4 | 22,953 | 13.5 | 76,804 | 47.2 | 58,780 | 28.9 |

p value: Chi-squared tests for differences in APNCU by SGA and preterm birth. Weighted (Wt’d) % accounted for the survey sampling design and coverage. The weighted percentages may not sum to 100 due to rounding. 1 The APNCU index comprises two parts: the month in which prenatal care is initiated and the number of visits from the initiation of care until delivery. Inadequate utilization is defined as either starting prenatal care after the 4th month of pregnancy or receiving fewer than 50% of the expected visits based on the schedule for prenatal care visits recommended by the American College of Obstetricians and Gynecologists (ACOG). Intermediate care is care begun by month 4 and with 50–79% of expected visits received; adequate care is that begun by month 4 and with 80–109% of the expected visits received; adequate-plus care is begun by month 4 and with 110% or more of the expected visits received.

Compared to those who had received adequate prenatal care, women who received adequate-plus prenatal care had higher odds of delivering SGA infants (adjusted odds ratio (AOR) = 1.08; 95% CI = 1.03–1.15). Compared to those who had received adequate prenatal care, women who received adequate-plus prenatal care had higher odds for preterm birth (AOR = 1.69; 95% CI = 1.55–1.84) (Table 4).

Table 4. Associations of Adequacy of Prenatal Care Utilization (APNCU) index categories with small-for-gestational-age (SGA) infants and preterm births.

| APNCU Index Category | SGA 1 | Preterm Birth 2 |
|----------------------|-------|-----------------|
|                      | OR    | AOR 95% CI | p Value | OR | AOR 95% CI | p Value | OR | AOR 95% CI | p Value |
| Adequate             | 1.00 (Ref.) | 1.00 | 0.91 | 1.09 | 0.94 | 1.10 | 1.01 | 1.20 | 0.03 | 1.08 | 1.03 | 1.15 | 0.005 |
| Inadequate           | 1.00 (Ref.) | 1.00 | 0.88 | 1.16 | 0.90 | 0.89 | 0.78 | 1.00 | 0.06 | 1.69 | 1.55 | 1.84 | <0.0001 |

AOR: Adjusted odds ratio. Ref.: Reference. 1 Adjusted for pre-pregnancy BMI, gestational weight gain, maternal age, race/ethnicity, marital status, education level, income level, gestational weeks, smoking status, WIC (women, infants, and children) participation during pregnancy, parity, timing of initiation of prenatal care, and number of prenatal care visits. 2 Adjusted for previous history of preterm birth, pre-pregnancy BMI, gestational weight gain, maternal age, race/ethnicity, marital status, education level, income level, gestational weeks, smoking status, WIC (women, infants, and children) participation during pregnancy, parity, timing of initiation of prenatal care, and number of prenatal care visits. 1 The APNCU index comprises two parts: the month in which prenatal care is initiated and the number of visits from the initiation of care until delivery. Inadequate utilization is defined as either starting prenatal care after the 4th month of pregnancy or receiving fewer than 50% of the expected visits based on the schedule for prenatal care visits recommended by the American College of Obstetricians and Gynecologists (ACOG). Intermediate care is care begun by month 4 and with 50–79% of expected visits received; adequate care is that begun by month 4 and with 80–109% of the expected visits received; adequate-plus care is begun by month 4 and with 110% or more of the expected visits received.

Women who did not receive any prenatal care during pregnancy had increased odds of delivering SGA infants compared to those in women who started in the first trimester (AOR = 1.37, 95% CI = 1.03–1.84). Women who started prenatal care in the second or third trimester had lower odds of preterm births than that in women who started prenatal care in the first trimester (AOR = 0.89, 95% CI = 0.81–0.99) (Table 5).
Table 5. Associations of the timing of the initiation of prenatal care with small-for-gestational-age (SGA) infants and preterm birth.

| The Timing of the Initiation of Prenatal Care | Start Prenatal Care in the 1st Trimester | Start Prenatal Care in the 2nd or 3rd Trimester | No Prenatal Care |
|----------------------------------------------|-----------------------------------------|-----------------------------------------------|-----------------|
|                                              | OR                                      | AOR                                          | 95% CI          | \( p \) Value | AOR                                          | 95% CI          | \( p \) Value |
| SGA†                                         | 1.00 (Ref.)                             | 1.03                                          | 0.97            | 1.10         | 0.35                                         | 1.03            | 1.84         | 0.03 |
| Preterm Birth‡                               | 1.00 (Ref.)                             | 0.89                                          | 0.81            | 0.99         | 0.02                                         | 0.61            | 1.04         | 0.07 |

AOR: Adjusted odds ratio. Ref.: Reference. † Adjusted for pre-pregnancy BMI, gestational weight gain, maternal age, race/ethnicity, marital status, education level, income level, gestational weeks, smoking status, WIC (women, infants, and children) participation during pregnancy, parity, number of prenatal care visits, and Adequacy of Prenatal Care Utilization (APNCU) index. ‡ Adjusted for previous history of preterm birth, pre-pregnancy BMI, gestational weight gain, maternal age, race/ethnicity, marital status, education level, income level, gestational weeks, smoking status, WIC (women, infants, and children) participation during pregnancy, parity, number of prenatal care visits, and APNCU index.

Women who received 9–11 prenatal care visits had increased odds of delivering SGA infants compared to those in women who had more than 12 prenatal care visits (AOR = 1.07, 95% CI = 1.02–1.14). Women who received fewer than eight prenatal care visits had increased odds for preterm birth compared to those in women with more than 12 prenatal care visits (AOR = 1.29, 95% CI = 1.13–1.48) (Table 6).

Table 6. Associations of the number of prenatal care visits with small-for-gestational-age (SGA) infants and preterm birth.

| The Number of Prenatal Care Visits | \( \geq 12 \) Times | 9–11 Times | \( \leq 8 \) Times |
|-----------------------------------|---------------------|------------|-------------------|
|                                   | OR                  | AOR        | 95% CI            | \( p \) Value | OR                  | 95% CI        | \( p \) Value |
| SGA†                             | 1.00 (Ref.)         | 1.07       | 1.14              | 0.01         | 1.08                | 0.99          | 1.19         | 0.08 |
| Preterm Birth‡                   | 1.00 (Ref.)         | 1.06       | 1.16              | 0.17         | 1.29                | 1.13          | 1.48         | 0.0002 |

AOR: Adjusted odds ratio. Ref.: Reference. † Adjusted for pre-pregnancy BMI, gestational weight gain, maternal age, race/ethnicity, marital status, education level, income level, gestational weeks, smoking status, WIC (Women, Infants, and Children) participation during pregnancy, parity, timing of initiation of prenatal care visits, and Adequacy of Prenatal Care Utilization (APNCU) index. ‡ Adjusted for previous history of preterm birth, pre-pregnancy BMI, gestational weight gain, maternal age, race/ethnicity, marital status, education level, income level, gestational weeks, smoking status, WIC (Women, Infants, and Children) participation during pregnancy, parity, timing of initiation of prenatal care visits, and APNCU index.

4. Discussion

Our study findings indicated that the effect of inadequate utilization of prenatal care on the risk of SGA birth was not statistically significant, which is in agreement with previous findings [23]. However, inadequate utilization of prenatal care indicated by the APNCU index was reportedly associated with an increased risk for SGA infants in a representative U.S. population [13,24]. This may be due to the fact that those with inadequate utilization of prenatal care were disproportionately mothers under 15 years of age and multiparous women. However, the demographics of pre-pregnancy BMI, maternal age, race, education, and income across the categories of APNCU index categories, as shown in Table 1, showed even distributions.

The results of the present study showed that women who did not receive any prenatal care compared to those women who started prenatal care in the first trimester of pregnancy had increased risks of delivering SGA infants. In addition, women who had 9–11 prenatal care visits, had increased risks for delivering SGA infants compared to those in women with more than 12 prenatal care visits. These results parallel previous findings that the rates of SGA declined with increasing numbers of prenatal care visits [9]. According to previous studies, prenatal care is also beneficial for pregnant
women for the diagnosis and treatment of maternal genital tract [25], and HIV infections [26] or for the imitation of exclusive breastfeeding [27].

In the present study, women in the adequate-plus utilization of prenatal care category were at an increased risk for preterm births compared to those in the adequate utilization of prenatal care category. This may be due to the fact that a shorter gestational age implies a lower number of expected visits, which yields a small denominator in the observed/expected ratio of prenatal care visits [9]. As a result, the observed/expected ratios may exceed 100% and may cause misleading results indicating that women grouped in the adequate-plus category are most likely to have a preterm birth. Thus, the APNCU index yielded results indicating that those women categorized in the highest resource utilization category were most likely to experience preterm births, as confirmed in previous findings [9,24]. Our results also indicated that women in the adequate-plus category had the highest number of gestational-age births (at least 37 weeks) (41.0%) compared to that in women in the inadequate (11.7%), intermediate (10.7%), and adequate (36.7%) APNCU groups. It has been previously suggested that the adequate-plus group includes disproportionately more identified high-risk pregnancies that required more prenatal visits and subsequent interventions [7,10]. Contrary to our findings, among U.S. [6] and Canadian pregnant women [8], the preterm birth rate was significantly higher in the “presence of prenatal care” group compared to that in the “absence of prenatal care” group. However, in that study, prenatal care was considered to be present if there was at least one prenatal visit during the course of pregnancy [6]. The contradictory findings may be due to the definition of the presence of prenatal care, which is different from that in the APNCU index, which considers the month of initiation of prenatal care as well as the total number of prenatal visits.

This study has several limitations. A limitation of the APNCU index is the gestational age bias [9,24]. Gestational age affects categorization within the APNCU index and could have a greater impact on preterm births. Short gestation may result in delivery before the opportunity to initiate care or misclassification into the adequate-plus category, as fewer visits are recommended in early pregnancy and 110% utilization could be met with only one extra visit [24]. Our finding of a 1.69-fold increase in the number of preterm births in the adequate-plus group compared to that in the adequate group may reflect this bias; thus, caution is necessary for the interpretation of the APNCU index in relation to preterm births. Additionally, health insurance information was not considered in assessing the relationship between prenatal care and birth outcomes, although a lack of health insurance is an important risk factor for inadequate prenatal care [28].

Although the APNCU index is a widely considered standard for estimating the adequacy of prenatal care utilization, some researchers [9] reported shortcomings of the index such as a young gestational age implies fewer number of expected visits and, thus, results in the observed/expected ratios often exceeding 100%. Consequently, the authors concluded that the APNCU index yields misleading results indicating that women group in the adequate plus category are most likely to deliver low birth weight infants. Limitations in the definitions and measurement of prenatal care may generate these results, which can also be applied in our study.

Strengths of this study are that PRAMS is a population-based study with the overall response rate of over 70%. The extensive information on maternal sociodemographic and lifestyle factors could be matched with state birth records and, thus, a number of important confounders could be controlled in the present study. However, this study may have several limitations. Due to the retrospective cross-sectional study design, a cause-effect relationship cannot be established. Mothers who were surveyed 2–4 months postpartum could have had some recall bias with memory lapse. Additionally, medically-induced preterm births could not be distinguished from spontaneous preterm births in our study.

5. Conclusions

In conclusion, women in the adequate plus APNCU index category are most likely to deliver SGA infants and preterm birth. Fewer numbers of prenatal visits are associated with higher rates of SGA
infants and preterm birth. We conclude that women with high-risk pregnancy are prone to receive adequate plus prenatal care in the U.S.

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