Demographic, Clinical and Occupational Characteristics Associated With Early Onset of Delivery: Findings From the Duke Health and Safety Surveillance System, 2001–2004

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Background *This cross-sectional study explores associations between preterm delivery and demographic, clinical and occupational characteristics of women employed within a university and health system.*
Methods *A comprehensive surveillance system linking individual-level data from Human Resources, medical insurance claims and a job-exposure matrix was used to identify women with a single live birth between 2001 and 2004 and describe maternal characteristics during pregnancy.*
Results *Preterm delivery occurred in 7.1% (n = 74) of the 1,040 women, a lower preterm delivery prevalence than observed in the general U.S. population. Nearly all (>99.5%) women utilized prenatal care services. Prevalence of preterm delivery was highest for inpatient nurses, nurses' aides and office staff. In multivariate analyses, preterm delivery was positively associated with several clinical conditions: placenta previa, diabetes and cardiovascular disorder/disease.*
Conclusions *We observed associations between preterm delivery and several previously indicated clinical conditions. Further study of the effect of job characteristics on preterm delivery is warranted.* Am. J. Ind. Med. 51:911–922, 2008. *© 2008 Wiley-Liss, Inc.*

KEY WORDS: preterm delivery; surveillance system; administrative data; maternal occupation; prevalence ratio

INTRODUCTION

Labor force participation among women in the United States has increased substantially in the past three decades; furthermore, a higher percentage of employed women are working full time or are holding multiple jobs [Bureau of Labor Statistics, 2005]. Women are also working later into pregnancy; the proportion of women who remained in the workforce until less than a month before their first birth has risen from 23% in the early 1960s to 53% in the early 1990s [Smith et al., 2001b]. Given these trends in maternal employment, researchers have begun to examine workforce participation among women during pregnancy to measure how various occupational characteristics may influence pregnancy outcomes.

A recent study [Callaghan et al., 2006] identified preterm birth (before 37 completed weeks of gestation) as the most frequent cause of infant mortality in the United States, accounting for 34% of all infant deaths. Serious morbidity and disability, and their long-term emotional and economic consequences, also result from preterm birth and often require healthcare services, specialized educational services,

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social services and out-of-pocket expenses [Petrou et al., 2001]. An increase in the incidence of preterm birth has been observed over the past few decades. Partly attributed to a rise in the rate of multiple births [Tucker and McGuire, 2004], this increase is seen among singleton births as well. Among singleton pregnancies, the rate of preterm birth rose from 9.7% in 1990 to 10.8% in 2004 [Martin et al., 2006]. Possible explanations for this increase in the incidence of preterm deliveries among singletons include greater use of obstetric intervention and changes in how gestational age is measured clinically [Tucker and McGuire, 2004].

Studies comparing women who are employed with those who are not employed have shown that employment itself is not a risk factor for preterm delivery or other adverse pregnancy outcomes. Some studies show a lower incidence of early gestation among employed women [Marbury et al., 1984; Saurel-Cubizolles and Kaminski, 1986; Stengel et al., 1987; Brett et al., 1997]. Given recent trends in maternal employment and pregnancy outcomes, however, the relationship between various adverse pregnancy events and potentially hazardous, but modifiable, occupational characteristics such as physical exertion, prolonged standing, long working hours, shift work and psychosocial stress have been the focus of a growing body of literature, including several reviews [Stein et al., 1986; Simpson, 1993; Gabbe and Turner, 1997; Mozurkewich et al., 2000; Poissonnet and Veron, 2000; Bonzini et al., 2007]. Occupational exposure to specific chemical or biological agents, noise and extreme temperatures has been studied as well [McDonald et al., 1988; Savitz et al., 1989; Zhang et al., 1992; Luke et al., 1995]. Study findings are discrepant, and differences are often attributed to variations in methodology, differences in definitions of risk factors and outcomes, and a limited capacity to control for certain potential confounding effects. Without a consensus on occupational characteristics that pose a threat to the time of delivery, uncertainty remains regarding what types and amounts of work exposures should be avoided during pregnancy as well as at what point during pregnancy changes in employment should be made.

Many demographic and clinical characteristics and their relationship to preterm labor and delivery have received much attention in the literature as well; however, the underlying mechanisms of their relationship to various clinical presentations leading to preterm birth are not clear. Despite the complex etiology of preterm birth, several risk factors for preterm birth have been indicated: history of preterm or low birth weight (i.e., <2,500 g) delivery, history of second trimester abortion, multiple pregnancy, abnormalities of the placenta (previa, abruption), preeclampsia/eclampsia, cervical or uterine anomality, hemorrhage during pregnancy, infection, smoking, certain chronic diseases (e.g., diabetes, hypertension, kidney disease), maternal age (e.g., <18 or >35 years), poor nutrition, substance abuse, low socioeconomic status, psychosocial stress and strenuous physical workload [Moutquin, 2003; Goffinet, 2005; Reedy, 2007].

The purpose of this study was to investigate associations between preterm birth and demographic, clinical and occupational characteristics of women employed at Duke University and Health System. Data collected through a comprehensive surveillance system were used to capture workers with a single live birth and identify characteristics about each woman during her pregnancy.

MATERIALS AND METHODS

DHSSS

The Duke Health and Safety Surveillance System (DHSSS) was developed by researchers at the Duke University Medical Center (DUMC) as part of an ongoing project funded originally by the National Institute for Occupational Safety and Health [Dement et al., 2004a]. The DHSSS captures information from several integrated data sources, including human resources, health benefits, workers' compensation and a job-exposure matrix (JEM). Each year data are linked across datasets to allow for analyses at the individual level; confidentiality measures have been taken to remove all identifying information. Previous research using data from the DHSSS has focused on risk factors for blood and body fluid exposure [Dement et al., 2004b], obesity and workers' compensation [Østbye et al., 2007] and musculoskeletal injuries and disorders among hospital workers [Pompeii et al., 2008].

The DHSSS includes all employees who are employed at Duke University and Health System. Health insurance coverage is available for employees working at least 20 hr per week and for faculty working at least 1,000 hr per year. About 90% of the employees who are eligible for insurance choose to participate in one of the plans. The current analyses include only women who are enrolled in one of Duke's health insurance plans. The Duke University Medical Center Institutional Review Board approved all study procedures.

Study Population

Restricted to include the years 2001–2004, medical health care claims were searched to identify women with an outcome of delivery of "single liveborn" (ICD-9-CM V27.0). To define many of the pregnancy-related variables, all additional medical and mental health care claims these women accrued during the 280 days (40 weeks) prior to delivery were considered. A claim history of 294 days (42 weeks) was established for women who experienced a prolonged pregnancy (ICD-9-CM 645). In addition, claims occurring within 1 week post-delivery were included in the pregnancy history in order to capture all discharge claims. Pregnancy histories for six women with conflicting claim information, such as codes for a single live birth (ICD-9-CM V27.0) and twin live births (ICD-9-CM V27.2) on the same day, were excluded. Pregnancy histories were also excluded for women not insured through a Duke health insurance plan during their whole pregnancy. For women with more than one pregnancy captured in the health care claims that resulted in a single live birth, the first of these births with a comprehensive pregnancy history was chosen.

Variables

For this study, many variables of interest were defined solely through diagnosis and procedure codes listed in the DHSSS insurance medical and mental health care claims databases. The outcome of interest was preterm birth, defined as ''spontaneous onset of delivery or premature labor with onset of delivery prior to 37 completed weeks of gestation'' [PMIC, 1999] (ICD-9-CM 644.2). Additional variables were included given literature-based evidence of association with preterm delivery, inclusion in the ICD-9-CM Tabular List of ''Complications mainly related to pregnancy (640–648),'' [PMIC, 1999] and ability to define properly using the DHSSS. Both International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) [PMIC, 1999] and Current Procedural Terminology (CPT) [American Medical Association, 1999] codes were employed. Up to five diagnosis codes and seven procedure codes were allowed per claim line. All possible codes were searched when defining a variable of interest; if a woman is treated or monitored for more than one pregnancy complication, the American Health Information Management Association allows the corresponding codes to be entered in any sequence [AHIMA, 2001]. Claims-defined outcome and independent study variables are described in Table I.

Demographic and occupational characteristics and exposures were defined using several data sources. Information on age, race, date of hire/termination, insurance coverage start/end dates, job title, occupational group and job location were all available through the surveillance system. Though not part of the DHSSS, Human Resources also provided information on salary range by job title as early as 2002; the mid-range salary value was used for these analyses. An average annual rate of growth (calculated using salary information from 2002 and 2004) was used to estimate salaries for 2001. Women were assigned to a salary category (<$30K, $30K to $60K, >$60K) based on their mid-range salary in the year in which they delivered. Salaries were not listed for several of the executive and academic positions; these individuals were placed in salary categories based on Department of Labor and American Association of University Professors statistics, respectively [AAUP, 2004; Bureau of Labor Statistics, 2006].

The DHSSS places employees into 1 of 50 occupational groups. For purposes of measuring variation in preterm delivery prevalence by occupational group more robustly, occupational groups as defined through DHSSS were collapsed into broader categories (hereby referred to as ''occupational group$_{NEW}$''). For example, the newly created occupational group$_{NEW}$ ''Office support'' was made up of workers from the DHSSS occupational groups ''Office support-General,'' ''Office support-Medical'' and ''Office support-Secretarial.''

Data from a JEM [Dement et al., 2004a] were used to characterize each woman as having potential occupational exposure to the following: animals, blood borne pathogens, chemicals, infectious agents, radiation and laboratory work.

All preterm births were grouped for analyses in this study; however, to better understand a woman's delivery history and identify clinical subgroups of delivery, a variable was constructed to define whether a woman labored. Based on an algorithm previously validated with medical charts [Henry et al., 1995], women with a vaginal delivery (CPT 59400, 59409, or 59410) or medical claim codes for labor abnormalities (ICD-9-CM 653, 659.0, 659.1, 660, 661, or 662), fetal distress (ICD-9-CM 656.3), cord prolapse (ICD-9-CM 663.0) or breech converted to cephalic presentation (ICD-9-CM 652.1) were defined as having labored.

Delivery was characterized as induced if a claim was made for one of the following: induction of labor by artificial rupture of membranes (ICD-9-CM 73.01), other surgical induction of labor (ICD-9-CM 73.1) or medical induction of labor (ICD-9-CM 73.4). Cesarean deliveries were characterized by one or more of the following: classical cesarean section (ICD-9-CM 74.0), low cervical cesarean section (ICD-9-CM 74.1), extraperitoneal cesarean section (ICD-9-CM 74.2), or cesarean delivery, without mention of indication (ICD-9-CM 669.7). In the absence of labor (previously defined), these deliveries were classified as elective; moreover, cesarean deliveries were classified as emergent if the woman labored. For these analyses women with an iatrogenic birth (medically induced or elective cesarean section) or a birth following premature rupture of membranes (ICD-9-CM 658.1) were retained and grouped with women whose deliveries were spontaneous.

ANALYSES

The study population was described in terms of its demographic and maternal characteristics. Categorizations of maternal age (quartiles) and salary (tertiles) followed the variables' distributions among women without a preterm delivery. Maternal race was categorized as ''white'' or ''non-white,'' with the latter category including ''black,'' ''Asian/Pacific Islander,'' ''Hispanic,'' and ''American Indian/Alaskan native.'' All clinical variables were dichotomized (yes or no).

Bivariate and multivariate logistic regression techniques were used to calculate prevalence odds ratios (POR) and 95% confidence intervals (CI) to describe associations between

TABLE I. Variables of Interest and Associated ICD-9-CM Diagnosis or Procedure Codes*

Variable	ICD-9-CM code(s)
Outcome variables	
Single live birth	V27.0
Preterm delivery	644.2
Characteristics of labor/delivery	
Cesarean delivery	74.0, 74.1, 74.2, 669.7
Induced	73.01, 73.1, 73.4
Labored	Detailed in paper[c]
Premature rupture of membranes	658.1
Spontaneous preterm labor	644.0 or (644.2 and "Labored")
Threatened labor without delivery	644.0, 644.1
Clinical variables	
Anemia	648.2, 280–285
Antepartum hemorrhage[a]	641.2, 641.3, 641.8, 641.9
Cardiovascular disorders/diseases	648.5, 745–747, 648.6, 390–398, 410–429
Diabetes	648.0, 250, 648.8, 790.2
Drug abuse/dependence	648.3, 304, 305 (excluding 305.0, 305.1)
Edema/Excessive weight gain	646.1
Excessive vomiting	643
Genitourinary tract infection	646.6, 590, 595, 597, 599.0, 614–616
Habitual aborter	646.3
Hemorrhage in early pregnancy	640.0, 640.8, 640.9
Hypertension	642.0–642.3, 642.9, 401–405
Mental disorders	648.4, 290–303, 305–319
Other infections[b]	647, 042, 050–079, 084, 090–099, 010–018
Placenta previa	641.0, 641.1
Preeclampsia/eclampsia	642.4–642.7
Prenatal supervisory care	V22.0, V22.1, V23
Tobacco dependence	305.1
Thyroid dysfunction	648.1, 240–246
Unspecified renal disease	646.2

*Where applicable, predictor variables were defined by any relevant ICD-9-CM codes. For example, diabetes is defined by 648.0 or 648.8, as well as 250 or 790.2.
[a]Without placenta previa.
[b]Includes: syphilis, gonorrhea, other venereal diseases, tuberculosis, malaria, rubella, other viral diseases, other specified/unspecified diseases.
[c]Based on algorithm by Henry et al. [1995].

exposures and preterm birth. With respect to the prevalence of preterm delivery found in this cross-sectional study, the POR provides a reasonable approximation of the more easily interpreted prevalence ratio (PR) [Zocchetti et al., 1997]; results will therefore be presented in terms of the latter measure.

Demographic, clinical and occupational characteristics with a crude prevalence ratio (cPR) $\geq$1.5 (or $\leq$0.67) or a Wald Chi-square test statistic P-value $\leq$0.1 in at least one stratum in bivariate analyses were considered for inclusion in an initial multivariate logistic regression model. Correlations among independent variables were assessed using Spearman correlation coefficients. To identify possible effect modification, two-way interaction terms of predictor variables included in the initial multivariate model were tested individually for significance, and those terms with a P-value $\leq$0.1 were considered for inclusion as well.

A more parsimonious intermediate multivariate model was obtained using a stepwise selection strategy to systematically remove least significant variables from the model one at a time, given their Wald Type III P-value was >0.1, their removal did not change the association of the remaining variables with preterm delivery more than 20% and (depending on the inclusion of interaction terms) hierarchical soundness was maintained. All analyses were performed using SAS 8.2 [SAS Institute Incorporated, 1999–2001].

RESULTS

A total of 1,040 women with a single live birth and pregnancy history between 2001 and 2004 were included in the analyses. The mean age was 31.8 (standard deviation (SD), 4.7; range, 20–45) years. A majority of the women were white (71.1%) followed by black (18.1%), Asian/Pacific Islander (8.0%), Hispanic (2.6%) and American Indian/Alaskan native (<1%). The predominant occupational group was clinical/technical (16.9%), followed by office support (16.5%), faculty/research (15.7%), inpatient nursing (14.8%) and administrative/managerial (11.5%). Many of the women worked in jobs with potential exposure to blood borne pathogens (46.7%), infectious agents (46.9%), and/or chemicals (51.9%).

Nearly all women (>99.5%) received prenatal care. Drug or tobacco dependence was diagnosed in less than 2% of the study sample. Genitourinary tract infection was the most prevalent clinical condition during pregnancy, occurring in 28% of the women. Early or antepartum hemorrhage (20.2%), hypertension (11.0%) and diabetes (9.3%) were also prevalent among these workers.

Preterm delivery occurred in 74 (7.1%) of the women. Most of these deliveries were spontaneous (68%). Premature rupture of membranes (PROM) and medically indicated deliveries (in absence of PROM or spontaneous preterm labor) accounted for the remaining 23% and 9% of the preterm births, respectively.

Although none of the potential occupational exposures captured through the JEM were significantly related to preterm delivery, several other job-based characteristics met requirements for inclusion in the initial multivariate model (Table II). Preterm delivery was associated with lower salary (trend P-value = 0.07). Compared to women working in the large tertiary care medical center, prevalence of preterm delivery was higher for women employed in Duke Home Health Services [cPR 1.5, 95% CI (0.9–2.5)] and in the two community hospitals [cPR_{DRH} 1.4, 95% CI (0.5–3.8); cPR_{RCH} 2.3, 95% CI (0.8–7.0)], although none of these differences reached statistical significance.

TABLE II. Occupational Characteristics Associated With Preterm Delivery Among Women Employed at and Insured Through Duke University and Health System 2001–2004 (N = 1040), With Crude (cPR) and Adjusted (aPR) Prevalence Ratios and 95% Confidence Intervals (CI)

	Preterm delivery[a]							
	Yes		No					
Characteristic	N (74)	% (7.1)	N (966)	% (92.9)	cPR	95% CI	aPR[b]	95% CI
Employer unit								
Durham Regional Hospital	5	6.8	57	5.9	1.4	0.5–3.8		
Duke Home Health Services	32	43.2	343	35.5	1.5	0.9–2.5		
Raleigh Community Hospital	4	5.4	28	2.9	2.3	0.8–7.0		
Duke University Medical Center	33	44.6	538	55.7	1.0			
Salary								
Less than $30K	16	21.6	173	17.9	1.9	0.9–4.1		
$30K—less than $60K	45	60.8	520	53.8	1.8	1.0–3.4		
$60K or more	13	17.6	273	28.3	1.0			
Occupational group$_{NEW}$[c]								
Administrative/Managerial	8	6.7	112	93.3	1.0	0.5–2.0	1.1	0.5–2.2
Clinical/Technical	10	5.7	166	94.3	0.8	0.4–1.6	0.7	0.4–1.4
Inpatient nursing	17	11.0	137	89.0	1.7	0.9–2.9	1.5	0.8–2.7
IT, Scientific/Electronics technology	6	5.8	97	94.2	0.8	0.4–1.8	0.8	0.4–1.8
Nursing aides	3	20.0	12	80.0	3.3	1.0–10.8	2.9	0.9–9.9
Office support	16	9.3	156	90.7	1.4	0.8–2.4	1.2	0.7–2.2
Other nursing (non-inpatient)	1	2.2	44	97.8	0.3	0.1–1.8	0.3	0.0–1.8
Physician/Phys. Assoc./House staff	4	6.5	58	93.5	0.9	0.4–2.4	1.0	0.4–2.8
Services/Skilled craft	3	10.0	27	90.0	1.5	0.5–4.5	1.6	0.5–4.9
Faculty/Research Associate	6	3.7	157	96.3	0.5	0.2–1.1	0.6	0.3–1.5

[a]Early onset of delivery before 37 completed weeks of gestation (ICD-9-CM code 644.2).
[b]Adjusted for age, cardiovascular disorder/disease, diabetes and placenta previa.
[c]Prevalence ratios are measuring the effect of each occupational group level compared to the average effect over all levels.

The prevalence of preterm delivery among these working women also varied by occupational group$_{\mathrm{NEW}}$. Compared to the average effect over all levels of occupational group $_{\mathrm{NEW}}$, the crude prevalence of preterm delivery was higher for inpatient nurses [cPR 1.7, 95% CI (0.9–2.9)] and nurses' aides [cPR 3.3, 95% CI (1.0–10.8)] and lower for faculty/ researchers [cPR 0.5, 95% CI (0.2–1.1)]. Only the crude prevalence ratio of preterm delivery for nurses' aides compared to all other groups was statistically significant.

Several demographic and clinical characteristics were also significantly related to preterm birth in the initial bivariate logistic regression analyses (Table III). The strongest positive associations were observed for placenta previa [cPR 2.7, 95% CI (1.2–5.9)], diabetes [cPR 2.2, 95%

TABLE III. Demographic and Clinical Characteristics Associated With Preterm Delivery Among Women Employed at and Insured Through Duke University and Health System 2001–2004 (N = 1040), With Crude (cPR) and Adjusted (aPR) Prevalence Ratios and 95% Confidence Intervals (CI)

	Preterm delivery[a]							
	Yes		No					
Characteristic	N (74)	% (7.1)	N (966)	% (92.9)	cPR	95% CI	aPR[b]	95% CI
Age in years								
≥35	15	20.3	267	27.6	0.5	0.2–0.9	0.5	0.2–0.9
32–34	11	14.9	235	24.3	0.4	0.2–0.8	0.3	0.2–0.7
29–31	21	28.4	239	24.7	0.7	0.4–1.3	0.7	0.4–1.3
<29	27	36.5	225	23.3	1.0		1.0	
Race								
Non-white	23	7.6	278	92.4	1.1	0.7–1.9		
White	51	6.9	688	93.1	1.0			
Antepartum hemorrhage[c]								
Yes	7	9.5	48	5.0	2.0	0.9–4.6		
No	67	90.5	918	95.0	1.0			
Cardiovascular disorder/disease								
Yes	6	8.1	39	4.0	2.1	0.9–5.1	2.4	1.0–6.1
No	68	91.9	927	96.0	1.0		1.0	
Diabetes								
Yes	13	17.6	84	8.7	2.2	1.2–4.2	2.6	1.3–4.9
No	61	82.4	882	91.3	1.0		1.0	
Excessive weight gain								
Yes	3	4.1	24	2.5	1.7	0.5–5.6		
No	71	96.0	942	97.5	1.0			
Hemorrhage in early pregnancy								
Yes	17	23.0	139	14.4	1.8	1.0–3.1		
No	57	77.0	827	85.6	1.0			
Placenta previa (with or without hemorrhage)								
Yes	8	10.8	42	4.4	2.7	1.2–5.9	2.9	1.3–6.6
No	66	89.2	924	95.7	1.0		1.0	
Preeclampsia/eclampsia								
Yes	7	9.5	50	5.2	1.9	0.8–4.4		
No	67	90.5	916	94.8	1.0			
Unspecified renal disease								
Yes	1	1.4	7	0.7	1.9	0.2–15.5		
No	73	98.7	959	99.3	1.0			

[a]Early onset of delivery before 37 completed weeks of gestation (ICD-9-CM code 644.2).
[b]Adjusted model contains age, cardiovascular disorder/disease, diabetes and placenta previa.
[c]Without placenta previa.

CI (1.2–4.2)] and hemorrhage in early pregnancy [cPR 1.8, 95% CI (1.0–3.1)]. Older age was negatively associated with prevalence of preterm delivery (trend *P*-value <0.01); moreover, compared to women <29 years old, the prevalence of preterm delivery was significantly lower for older women [$cPR_{32-34\ years}$ 0.4, 95% CI (0.2–0.8); $cPR_{\geq 35\ years}$ 0.5, 95% CI (0.2–0.9)]. Other variables included in the multivariate model were antepartum hemorrhage (without placenta previa), preeclampsia/eclampsia, excessive weight gain, cardiovascular disorder/disease and renal disease.

One interaction term, diabetes × age ($P = 0.06$), met the requirements for inclusion in the initial multivariate model; however, among women who were diabetic and delivered preterm, all of the age categories contained small numbers of women (range 1–7). Because estimates rendered through this interaction term would be imprecise and dependent on cautious interpretation, diabetes × age was not included in the initial multivariate model.

Maternal race was not associated with preterm delivery in the initial bivariate logistic regression analyses [$cPR_{non\text{-}white}$ 1.1, 95% CI (0.7–1.9)]; however, non-white race is a well-documented risk factor for preterm delivery. Among our study sample, non-white race was associated with several independent variables, including cardiovascular disorder/disease, diabetes and lower salary (data not shown). Race was viewed as a potential confounder in these analyses and thus included in the initial multivariate model as well.

Adjusting for occupational variables and occupational $group_{NEW}$ in one model could constitute overcontrolling, perhaps limiting our ability to observe a significant independent effect of these variables with preterm delivery in a multivariate model; therefore, our initial multivariate model contained demographic, clinical, and occupational variables that met requirements for inclusion, with the exception of occupational $group_{NEW}$. Following the aforementioned selection strategy, the occupational variables dropped out of the model; age, placenta previa, cardiovascular disorder/disease and diabetes were retained. Results from this model are presented in Table III.

Although other occupational variables of interest were not retained in the reduced multivariate model, we decided to look at the association of categories of occupational group $_{NEW}$ with preterm delivery, controlling for those variables which were retained in this model. Results of this model are presented in Table II. When controlling for age, placenta previa, cardiovascular disorder/disease and diabetes, a moderately increased prevalence of preterm delivery, though imprecise and not statistically significant, was still observed for nurses' aides [aPR 2.9, 95% CI (0.9–9.9)] and inpatient nurses [aPR 1.5, 95% CI (0.8–2.7)].

DISCUSSION

In this study sample of working women with a single live birth, the prevalence of preterm delivery was lower than that in the general U.S. population [Martin et al., 2006]. This difference may be attributed, in part, to a more favorable general health profile of women in the workforce compared to the general population of working and non-working women [Stengel et al., 1987; Savitz et al., 1990]; furthermore, women who are employed during pregnancy often have more favorable behavioral and socio-demographic profiles (e.g., lower parity, more likely to be married, higher educational level, higher income, medical insurance, employment benefits, earlier prenatal care, less likely to smoke) that are associated with non-adverse pregnancy outcomes compared to non-employed pregnant women [Moss and Carver, 1993; Gabbe and Turner, 1997].

Use of prenatal care services, a function in part of health insurance, was documented for nearly all of the women in our study sample. Provision of educational information (e.g., symptom recognition, diet/exercise, bed rest) and timely intervention in the case of pregnancy complications may have had a positive effect on pregnancy outcome. While prenatal care has been associated with lower preterm birth rates in the U.S., even among women with complications during pregnancy [Vintzileos et al., 2002], discrepancies surround the effectiveness of prenatal care on reducing adverse pregnancy outcomes, such as preterm delivery [Fiscella, 1995].

We did not observe a statistically significant difference in prevalence of preterm delivery by race. Past studies of the U.S. population have highlighted large and persistent racial disparities for the outcome of preterm delivery. Recent data showed that the risk of preterm birth in the U.S. among non-Hispanic black newborns was 50% higher than the risk of preterm birth among non-Hispanic white newborns [Martin et al., 2006]. Though studies have looked at biological and genetic facets of gestation time by race, such as fetal maturation and maternal pelvic size [Papiernik et al., 1990; Patel et al., 2004], health disparity measures often correlated with race (e.g., attitude toward seeking pregnancy-related healthcare, poor access to healthcare facilities or neonatal intensive care, lack of insurance) also perpetuate the race discrepancy in the preterm birth rate in the U.S. [Demissie et al., 2001; Anachebe and Sutton, 2003]. It is likely that many of these often-documented health disparities did not play a major role among our study group; all of the women in our study were insured, most all received prenatal care, and all worked within or close to a reputable health care system [US News and World Report, 2006].

The proportion of preterm births within clinical subgroups among our study sample fell within ranges reported previously [Moutquin, 2003]. Because our study population included only working women with employer-based medical insurance, we were not surprised that the percentage of preterm deliveries resulting from premature rupture of the amniotic membranes (PROM), a clinical indication observed more often within disadvantaged populations [Moutquin, 2003], was toward the lower end of the reported range. Furthermore, infection has been cited as a cause of PROM [Moutquin, 2003; Reedy, 2007]; of our study women who delivered following preterm PROM, 23.5% were classified as having a genitourinary tract infection. This percentage was not statistically different from the percentage of infection seen among women with spontaneous ($P = 0.72$) or iatrogenic ($P = 0.34$) preterm delivery.

Among our study population, the percentage of preterm births following maternal or fetal medical indication was also on the lower end of the range. It is possible that this finding is partly attributed to our group of working women having fewer illnesses or chronic conditions (i.e., healthy worker effect [Stengel et al., 1987]) that could necessitate an iatrogenic preterm delivery.

Genitourinary tract infection was the most prevalent clinical complication among the study sample, affecting about 28% of the women; however, it was not significantly associated with preterm delivery. In contrast, a significant positive association was observed between genitourinary tract infection and threatened labor without delivery (ICD-9-CM 644.0, 644.1) [cPR 2.0, 95% CI (1.5–2.7)]. With nearly all women receiving prenatal care, treatment of early signs of upper and lower genitourinary tract infection may have prevented progression of infection and preterm delivery in some of the women, although previous study findings on antibiotic efficacy in low-risk groups are inconsistent [Leitich et al., 2003; Reedy, 2007].

In multivariate analyses, placenta previa, diabetes and cardiovascular disorder/disease were associated with an increased prevalence of preterm delivery. Placenta previa, a cause of bleeding in the second and third trimesters of pregnancy, has been described previously as being associated with an increase in the risk of preterm birth [Crane et al., 1999; Ananth et al., 2003]. The prevalence of placenta previa observed in this study (4.8%) is similar to past studies that considered placenta previa during the course of pregnancy [Oyelese and Smulian, 2006]. Because placenta previa may self-correct during pregnancy, this condition is seen with much lower frequency at birth, occurring in less than 1% of all pregnancies at delivery [Ananth et al., 2003; Crane et al., 1999].

Cardiovascular disorders and diseases, including anomalities of the heart or circulatory system, ischemic heart disease, acute or chronic rheumatic heart disease and pulmonary circulatory disease, were also associated in multivariate analyses with increased prevalence of preterm delivery in our study. Previous research supports this finding [Hameed et al., 2001; Siu et al., 2001; Khairy et al., 2006]. Pregnancy places a burden on the maternal cardiovascular system; the capability of the maternal heart to adapt to the needs of a growing fetus through various stages of pregnancy is important [Hunter and Robson, 1992; Davekot and Peeters, 1994], especially for women who enter pregnancy with an adverse heart condition or develop one through the course of pregnancy. Additionally, complicated pregnancies and adverse pregnancy outcomes may lead to subsequent development of cardiovascular complications [Jonsdottir et al., 1995; Smith et al., 2001a], affecting management and outcomes of future pregnancies.

Because both preexisting and gestational diabetes are characterized by similar etiological factors and attributes (e.g., insulin resistance and impaired insulin secretion) [Virjee et al., 2001; Ben-Haroush et al., 2003], claims for these conditions were grouped together for analyses. Past studies have shown that maternal glucose intolerance is associated with pregnancy complications and adverse outcomes, including preterm delivery [Yang et al., 2002; Hedderson et al., 2003]; however, across-study comparisons are difficult due to variations in screening, diagnostic, and inclusion criteria. We observed an association of diabetes with preterm delivery among this group of working women. A limitation to this study is that we were unable to control for maternal body mass index (BMI), a factor which has been indicated to confound the relationship between diabetes and early gestation [Ray et al., 2001].

Compared to women less than 29 years old, older women had a lower prevalence of preterm delivery in this study. While this finding is in contrast to studies showing an increased risk of preterm delivery and other adverse pregnancy outcomes among women of extreme ages (e.g., <18 or >35 years) [Ancel et al., 1999; Moutquin, 2003], studies of working women have shown similar trends to those seen in the current study. For example, Brett et al. [1997] found a decreased risk of preterm delivery with increasing age among white working women, and Luke et al. [1995] measured a higher (though insignificant) risk for women ≤ 24 years old compared to those >24 years old. Mean birth weight has been shown to increase with increasing maternal age among working women as well [Wergeland et al., 1998]. Of other studies of working women measuring the association of occupational factors with preterm birth adjusted for maternal age, results may show no strong association of typical high-risk categories of maternal age with preterm delivery [Pompeii et al., 2005; Croteau et al., 2007], or the magnitude of the effect of maternal age on preterm delivery may go unaddressed [Homer et al., 1990; Launer et al., 1990; Fortier et al., 1995; Escriba-Aguir et al., 2001]. Of importance in the current study is the age range and accessibility to medical care; women are all at least 20 years of age, and older women who may have been at higher risk for complications all had access to medical care to treat pregnancy-related complications that could have made them more prone to an early delivery (either spontaneously or medically indicated). Furthermore, the healthy worker effect could also contribute to the observed results, as women of older age who are in the workforce during pregnancy are less likely to be affected by serious age-related complications that would keep others from working. Also, among this group of workers, women of older age were more likely to have a higher salary (P-value <0.0001) and may have been more likely to take time off to manage complications related to pregnancy.

Although our occupational variables of interest were not retained in the multivariate model and results indicated no statistically significant effect of occupational group$_{NEW}$ on preterm delivery (Type III P-value $= 0.1576$), these results should not be interpreted as having measured no effect of work on preterm delivery among these workers. Without the ability to identify an appropriate occupational group to serve as a referent category, we measured the effect of each group relative to the average effect of all occupational groups. A lack of statistical power limited our ability to assess relative differences in prevalence of preterm delivery across multiple occupational groups. Furthermore, the surveillance system lacked information on more detailed measures of work, such as physical demands and work organization within occupational groups. Given the nature of jobs within a health-care setting, many female workers are in work positions that are physically demanding and require shift work, such as inpatient nursing and nursing care assistance. Some positions, such as nursing care assistance and secretarial work, may be characterized by low job control, high psychological work demands, or both. The relationship between preterm delivery and occupational psychosocial stress has been measured previously [Mamelle et al., 1984; Homer et al., 1990; Henricksen et al., 1994; Luke et al., 1995; Brett et al., 1997; Escriba-Aguir et al., 2001; Saurel-Cubizolles et al., 2004; Croteau et al., 2007], with variable conclusions.

All cases of preterm delivery, regardless of their clinical presentation, were aggregated for these analyses; the study sample size was insufficient to distinguish adequately associations by delivery indication. Previous studies vary in approaches to the study of subsets of preterm labor, and discussions of the implications of aggregating preterm births of heterogeneous clinical indications offer support for both approaches [Moutquin, 2003; Savitz et al., 2005]. Over the past several decades, the rise in the preterm birth rate was seen among both medically indicated and spontaneous deliveries [Martin et al., 2006]. In addition, the use of ICD-9-CM code 644.2 to define preterm delivery precluded us from addressing the issue of possible heterogeneity in risk factors by preterm gestational age among the preterm births in our study sample. Cutpoints used to divide preterm births into gestational age groups vary across studies, as do results of the strength of association and significance of various maternal factors on these subgroups of preterm delivery [Ancel et al., 1999; Moutquin, 2003; Morken et al., 2005; Reedy, 2007].

Inherent in the use of ICD-9-CM codes is possible misclassification bias. These codes follow a numerical coding scheme, with a three-, four-, or five-digit code representing a diagnosis of interest. Guidelines prepared by the Health Care Financing Administration (HCFA) for use of these codes on medical claims forms call for codes to be used at their highest level of specificity [PMIC, 1999]. For example, the claim code assigned to a woman presenting with anemia during pregnancy is ICD-9-CM 648.2; ICD-9-CM 648 would not be sufficient in defining this condition. In the current study, if a woman with anemia was assigned only codes of ICD-9-CM 648 for her condition, those particular claims would not result in a classification of anemia, resulting in a false negative classification for analyses. Among the study group, a search was conducted to identify sources of misclassification bias among all three-digit claim codes which required a fourth digit to define the variable of interest. Three instances of the use of a non-specific code were found; however, a more specific version of the code was listed in a timely manner, allowing the variable of interest to be defined. For example, one study individual was assigned the code ICD-9-CM 644, with no modifier. ICD-9-CM 644.03 was listed as a separate diagnosis code in the same visit, so the woman was defined as having "threatened premature labor."

The association of several variables with preterm birth was not addressed in these analyses due to small numbers of women with both the exposure and the outcome of interest as well as limitations inherent in the DHSSS. Many of these absent variables, such as BMI or smoking, have been shown to be important predictors of preterm labor and delivery. Also, because DHSSS data for this study were limited by the time a person was employed at and insured through the university or its health system, the study was unable to fully account for a woman's general and pregnancy-related medical history prior to the start of her employment and insurance enrollment in the system.

Analyses using health care data should be interpreted with caution in epidemiological research. Limitations inherent in the use of health care administrative data and medical claims codes for research purposes, including pregnancy-related events and outcomes, have been documented [Henry et al., 1995; Black and Roos, 1998; Virnig and McBean, 2001; Gregory et al., 2002; Alexander et al., 2003; Lorence and Ibrahim, 2003; Geller et al., 2004; Korst et al., 2004; Quan et al., 2004; DeCoster et al., 2006; Yasmeen et al., 2006]; these data are complex, may have irregular coding schemes, are susceptible to validity variability (not addressed in this study) and may lack clarity. Furthermore, entry error (as seen in the initial stages of this analysis by the presence of conflicting claims) and variation in data collection and quality control by department contribute to disparities in data quality. Random misclassification resulting from these limitations would likely bias our results toward the null. Given the nature of how claims data are coded, it is possible that at the time of billing, high-risk events that happened during pregnancy but long before the birth may be included in the group of claim codes listed at or after the birth for insurance purposes. Differential misclassification bias may occur if these high-risk events were coded more often for pregnancies resulting in a preterm delivery than for pregnancies resulting in a term delivery.

While this study is not impervious to these and other limitations, it capitalizes on the unique system already in place to capture data from a broad array of sources linked at the individual level, and it provides a foundation from which to observe changes in the prevalence of preterm delivery and associated risk factors among this population of working women. Future initiatives at the administrative level are a means to identify areas of improvement, including reducing claim discrepancies; assessing the validity of administrative, diagnosis, and procedure codes; and improving consistency of coding schemes.

CONCLUSION

In this study of working women, a lower prevalence of preterm delivery compared to the general U.S. population is likely attributed, in part, to more favorable health and socio-demographic profiles of working women compared to their non-working counterparts. The high use of prenatal care services among this group of working women seems to indicate that women with medical insurance and access to medical care, regardless of race or socio-economic status, consistently use medical services for prenatal care; disparities in health care utilization by race and income among workers with medical insurance and access to care have been documented for other services [Richman, 2007].

Although occupational factors were not included in our final multivariate model, bivariate results indicate significant differences in the prevalence of preterm delivery by occupational group and work-related characteristics. Further study into the nature of specific jobs within occupational groups is warranted. Preterm delivery was higher among women who experienced placenta previa, diabetes or cardiovascular disorder/disease; prior studies have documented statistical associations between these clinical conditions and preterm delivery.

The use of a surveillance system to provide comprehensive and linked data on demographic, clinical and occupational characteristics is a cost-effective way to approach this outcome of suspected multi-factorial origin and provide foundational directives for future studies and research priorities. Continuous efforts should be made to ensure consistency, accuracy, and reliability of health care claims data for their use in epidemiological research studies.

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