Infant Prematurity in Snohomish County, 1990 - 1999

Report

SNOHOMISH HEALTH DISTRICT

Health Statistics & Assessment
3020 Rucker Avenue, Suite 102
Everett, WA 98201
425.339.5290
www.snohd.org/hlthstats

Infant Prematurity in Snohomish County, 1990 - 1999

Report

SNOHOMISH HEALTH DISTRICT

Health Statistics & Assessment
3020 Rucker Avenue, Suite 102
Everett, WA 98201-3900
425.339.5290
www.snohd.org/hlthstats

Contacts & Acknowledgements

Snohomish Health District
Health Statistics and Assessment
Manager: Jane Ballard, PhD, MS
Analysis: Mark Serafin, MA, MS
Graphic Design: Tina Outzen and Wendy Blaisdell

Health Statistics and Assessment acknowledges;
M. Ward Hinds, MD, MPH, Health Officer, Snohomish Health District
Anne Mitchell, RN, MC, MN, Snohomish Health District
Gail Wellenstein, MD, MPH
Charles Blackledge, MPH
for their assistance in this project.

For more information on this report, or to request additional copies, please contact:
Snohomish Health District,
Health Statistics and Assessment
3020 Rucker Avenue, Suite 102
Everett, WA, 98201
425.339.8618

or e-mail wblaisdell@shd.snohomish.wa.gov. This report is also available on-line at: www.snohd.org/hlthstats

Mission Statement:

To improve the health of individuals, families, and communities through disease prevention, health promotion, and protection from environmental threats.

Contents

List of Tables

Page

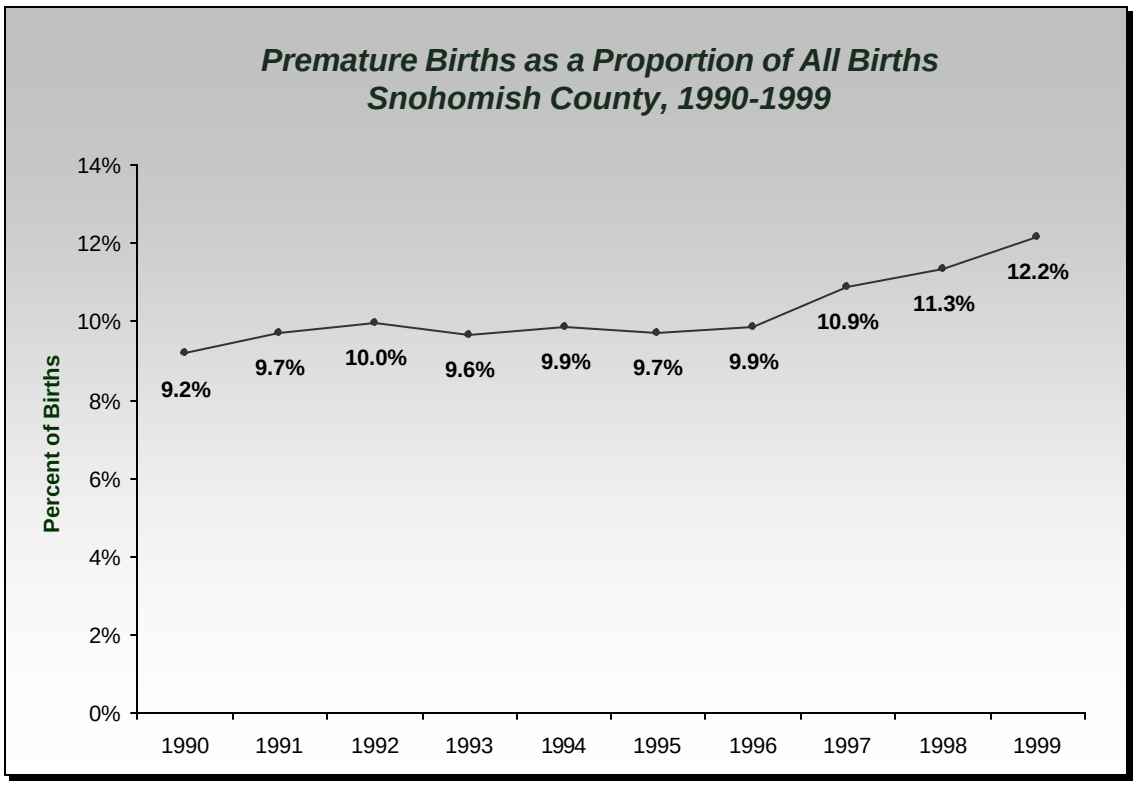
List of Figures

Page

Executive Summary

Prematurity in Snohomish County, 1990-1999

Premature birth (i.e., occurring before the 37th week of gestation) is associated with many health risks to the newborn infant. It is the leading cause of perinatal death in the United States and the primary determinant of low birth weight. Snohomish County experienced an increase in the proportion of infants who were born prematurely between 1990 and 1999. Increasing trends were also observed at the state and national levels, and internationally.



Objective and Methodology

To determine the reasons for the increase in prematurity, birth certificate data for Snohomish County from 1990 to 1999 were examined. After a review of the literature and consultation with a pediatrician, measures of potential risk factors for prematurity were identified in the birth certificate data. The prevalence of those risk factors significantly associated with preterm birth were examined for the ten-year period. Those that also increased during that time were probable contributors to the increase in premature births.

Findings

- Most of the increase in premature births in Snohomish County occurred after 1996.
- Multiple gestation births were 13.5 times more likely than singletons to be born prematurely. An increase in the proportion of births from multiple gestations (from 9.2% of births in 1990 to 12.2% in 1999) contributed to the overall increase in prematurity.
- There was an increase in the proportion of mothers at increased risk for premature delivery due to their age. The proportion of births to mothers younger than 20 years old increased from 7.9% in 1990 to 8.7% in 1999. Births to mothers 35 and older increased from 9.5% to 14.1%.
- When multiple births and births to very young and older mothers were removed from the analysis, there was still a significant increase in premature births between 1990 and 1999.
    - Significantly increasing risk factors among singleton births to mothers between the ages of 20 and 34 years included not being married (from 15.6% in 1990 to 19.1% in 1999) and mothers who were Black or Native American (from 2.2% of all births in 1990 to 3.7% in 1999).
    - Increases also occurred in the proportion of mothers who had chronic or gestational hypertension and chronic diabetes. These conditions are related to obesity, for which there was no direct measure in the data. This suggests that the increase in obesity noted in the general population over the prior decade may have contributed to the increase in prematurity.
- Delivery method (natural vs. medical intervention) did not seem to be a related to the increase in premature births. When caesarean section births were removed from the analysis, the increase in premature births remained.
- Although factors contributing to the increase in premature births were identified, most of the increase cannot be explained by the data at hand.
- It is advised that physicians and health providers educate women who are pregnant or planning a pregnancy about the potential risks of premature delivery.

Introduction

A birth is considered premature (or preterm) if it occurs before the 37th week of gestation. Prematurity is associated with many health risks to the newborn. Preterm infants are at increased risk for developmental delays, severe respiratory distress syndrome, chronic respiratory problems, neurological impairments, necrotizing enterocolitis, intraventricular hemorrhage, and death[1, 2, 3, 4]. Preterm birth is the leading cause of perinatal death in the United States[5]. It is estimated that between 75% and 90% of neonatal deaths occur among infants who are born prematurely[1,2]. Preterm delivery is the primary determinant of low birth weight, which has been associated with numerous complications, including an increased risk of death in the first year of life[5].

Preterm infants incur greater delivery and health-related costs than full-term babies[6]. Such babies are more likely to be delivered by caesarean section. Costs associated with caesarean delivery averaged 50% more than those for a vaginal delivery[7]. Preterm infants often spend significant amounts of time in neo-natal intensive care units, which further increases costs associated with the birth[8]. Because of long-term health problems associated with prematurity, the estimated lifetime medical costs of caring for a preterm child were estimated to be at least $500,000 in 1991[9]. Total annual costs associated with preterm births are estimated to exceed $4 billion in the United States[10]. These costs are borne largely by public sources of funding [6].

Although research and prevention efforts regarding preterm births have increased during the past decade, the preterm birth rate has remained unchanged worldwide. In fact, the rate has increased in many industrialized countries[5, 7]. During the 1990's the United States experienced an 11% increase in preterm births, from 10.6% of births in 1990 to 11.8% in 1999 [1]. This increase occurred mostly among infants who were born mildly or moderately preterm (i.e., born between the 33rd and 36th week of pregnancy). The proportion of very preterm infants (i.e., born prior to the 33rd week of gestation) remained approximately 2%[1].

Most of the increase in premature birth rates at the national level occurred among non-Hispanic Whites. Preterm births in this group increased by 24%, from 8.5% in 1991 to 10.5% in 1999. At the same time preterm births among non-Hispanic Black infants decreased from 19.0% in 1991 to 17.6% in 1999. The rates of preterm births among Hispanics, Native Americans, and Asian/Pacific Islanders also increased during the 1990's, but to lesser degrees than among non-Hispanic Whites[1]. The increasing trend among Whites is highly relevant to the present analysis because the majority of Snohomish County's population is non-Hispanic White (83.4%)[11].

Preterm birth is the leading cause of perinatal death in the United States.

Introduction

Table 1 shows the prevalence of birth complications at birth among premature and full-term infants previously born to Snohomish County women between 1990 and 1999. Premature infants were significantly more likely to suffer from low birth weight, congenital anomalies, and abnormal conditions at birth than full-term infants.

They also had significantly lower APGAR scores (an assessment of the infant's general condition) at both one minute and five minutes after birth and were more likely to have been delivered through a caesarean section. These findings are consistent with those found in the literature.

Table 1

Birth Complications among Preterm and Full-Term Infants
Snohomish County, 1990-1999

	Preterm			Full-term			Significance
	Cases	Percent*	Mean	Cases	Percent*	Mean	(p-value)
Total Births	8,284			72,639			
Birth Weight							
Normal Birth Weight	5,397	65.3		71,370	98.3		0.0001
Moderately Low Birth Weight †	2,868	27.6		1,223	1.6		0.0000
Very Low Birth Weight‡	588	7.1		43	1		0.0000
Mean Birth Weight			2657.3			3541.4	
(Missing Cases)	(19)			(46)			
Abnormal Condition §	1,953	23.7		6,643	9.1		0.0000
No Abnormal Condition	6,298	76.3		65,979	90.9		
(Missing Cases)	(33)			(17)			
Congenital Malformation	257	3.1		1,767	2.4		0.0002
No Congenital Malf.	7,994	96.9		70,848	97.6		
(Missing Cases)	(33)			(24)			
Caesarean Section	2,230	27.2		12,601	17.5		0.0000
No C Section	5,962	72.8		59,492	82.5		
(Missing Cases)	(92)			(600)			
Mean APGAR Scores							
One Minute			7.2			7.8	0.0000
Five Minutes			8.5			8.9	0.0000
(Missing Cases)	(52)			(253)			

** Missing cases not included in calculation of risk factor prevalence.*
†Moderately Low Birth Weight is defined as between 1500 and 2499 grams.
‡Very Low Birth Weight is defined as less than 1500 grams at birth.
§Abnormal Conditions include anemia, birth injuries, fetal alcohol syndrome, seizures, etc.

Introduction

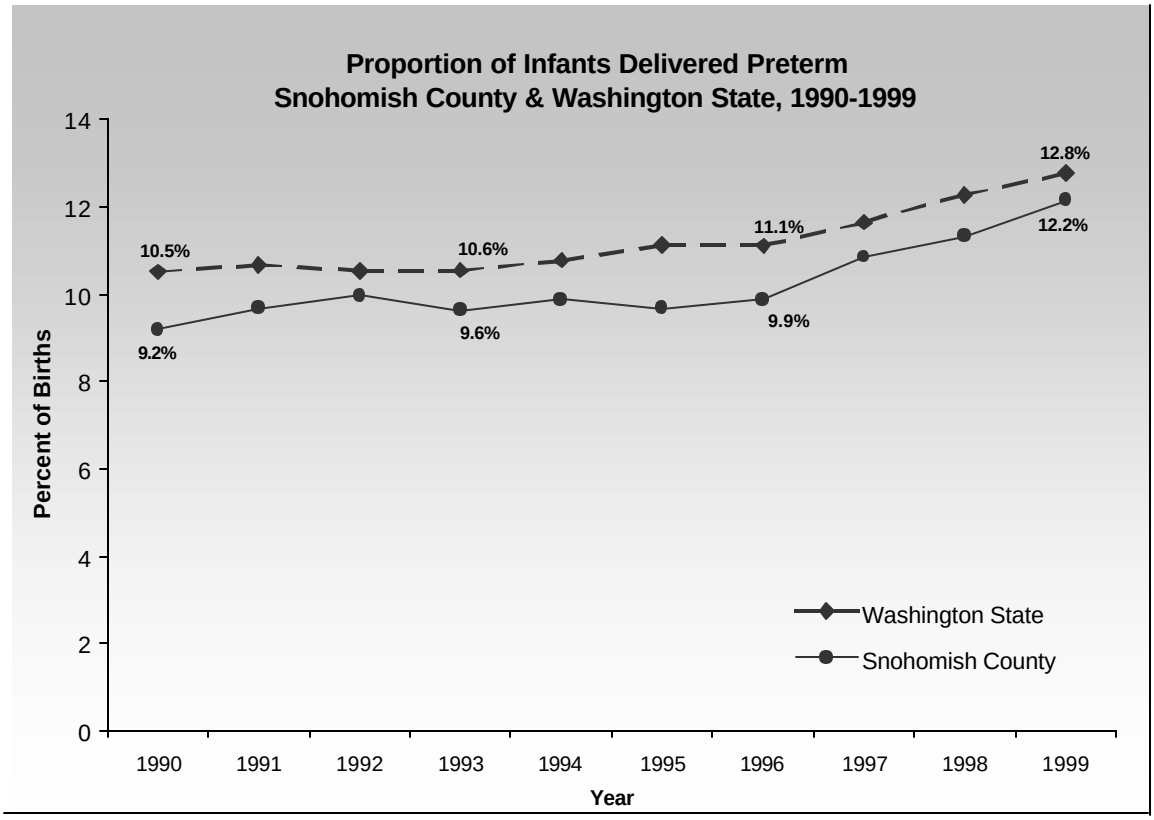
Premature births to Snohomish County women increased from 9.2% of all births in 1990 to 12.2% in 1999 (Figure 1). This trend was statistically significant ($p < 0.0001$). The proportion of births that were premature increased from 9.2% of births in 1990 to 10.0% 1992. Between 1992 and 1996 the prevalence remained fairly constant (e.g., no significant trend was found). After 1996 there was a large increase in premature births, from 9.9% of births in 1996 to 12.2% in 1999 ($p < 0.001$).

A similar increase was seen in Washington State from 10.5% in 1990 to 12.8% in 1999 ($p < 0.0001$). However, at the statewide level the increase began after 1994. Although the rate of premature births was significantly lower in Snohomish County than the state for this 10-year period ($p < 0.05$), this difference had disappeared by 1999.

As was the case nationally, the increase in Snohomish County preterm infants was comprised of infants who were born either mildly or moderately preterm. There was no significant change in the proportion of infants who were born very preterm (less than 33 weeks gestation) between 1990 and 1999 (approximately 1.0%).

Premature births to Snohomish County women increased from 9.2% of births in 1990 to 12.2% in 1999.

Figure 1



Risk Factors for Prematurity

Despite the tremendous amount of research to determine the causes of prematurity, it is estimated that only 25% to 40% of preterm births occur to women with an identifiable risk factor.

A variety of risk factors have been found to be associated with preterm births. They generally fall into one of three categories:

- ***Demographic characteristics of the mother:*** these include age, with mothers younger than the age of 20 and those age 35 and older being at greater risk of giving birth prematurely[4]. Prematurity has also been associated with various indicators of maternal stress, including being unmarried and/or of lower socio-economic status[12,13]. The literature also shows a relationship between prematurity and the race of the mother. Mothers who are Black or Native Americans are more likely than other races to give birth prematurely[5]. For this analysis, mothers of these races were combined to form a single race variable (i.e., mothers who were Black or Native American compared to those who were White, Asian or some other race).

.

- ***Physical characteristics associated with the mother and the pregnancy:*** risk factors in this category include multiple gestation[7], no prior pregnancies, a previous preterm birth or prenatal loss, diabetes, hypertension, anemia, heart disease, lack of adequate prenatal care, inadequate weight gain during pregnancy [14], inadequate spacing between pregnancies[15], and tobacco and/or alcohol use during pregnancy[12].

- ***Specific medical problems associated with the pregnancy:*** medical problems include premature rupture of membranes, uterine bleeding, eclampsia, cord prolapse, polyhydramniosis, and olygohydramniosis. Recent research has also discovered that many women giving birth prematurely have genito-urinary infections that may be a risk factor[16].

In recent years epidemiological research has concentrated on specific physiological characteristics of the mother. These are proximate risk factors for giving birth prematurely, in particular, the presence of genito-urinary infections. Other recent efforts have attempted to determine the etiology of prematurity by using the risk factors mentioned above to develop a model of how the mother's demographic characteristics lead to the development of more immediate causes, such as higher rates of genito-urinary infection[17]. Despite the tremendous amount of research to determine the causes of prematurity, it is estimated that only 25% to 40% of preterm births occur to women with an identifiable risk factor[14].

Methodology

Birth certificate data from the years 1990 through 1999 were analyzed to determine possible causes for the increasing rate of premature births in Snohomish County. The 'calculated' gestational age of the child (the time between the birth and the mother's last menses) was used to determine prematurity because it is considered to be more reliable than the "estimated" gestational age (a clinical judgement made by the attending physician). However, regardless of how gestational age was determined, the same pattern of increase in premature births was observed.

The data set included records on 81,041 births, of which 8,242 (10.2%) were determined to be premature. Risk factors identified in the literature (see page 4) were matched to variables collected on the birth certificates. Data for some risk factors were not available in the birth certificate data (e.g., presence of genito-urinary infection) while others were not considered reliable enough for analysis (e.g., maternal alcohol consumption). For some risk factors data were not available for the full period of this study. This was the case for indicators of socio-economic status (e.g. participation in the WIC program or Medicaid use), which were only collected after 1991. Unreliable variables and those collected during only part of the study period were not included in the analysis to avoid biasing the results.

Consultation with medical professionals suggested that the hospital at which the birth occurred and delivery by a midwife were potential risk factors. Analysis by facility was not possible, because during the period under study only one facility had an Neonatal Intensive Care Unit (University of Washington Medical Center). Practically all premature births to Snohomish County women occurred at this facility. Delivery by midwife was not found to be a risk factor, as only 5.6% of babies delivered by midwives were premature, compared to the overall average of 10.2%.

Data on some risk factors were available in the birth certificate data, but affected only a very few cases. Various placental and uterine complications were found to be significant risk factors for prematurity, but most affected less than 1% of women. Because these conditions were so rare, they were combined into a single variable that denoted the presence of one or more of these conditions. A list of risk factors available for analysis is provided in Table 2.

Methodology

Odds ratios (OR) were calculated for each of the risk factors. An *odds ratio* is an estimate of the increase in the risk of having a premature birth associated with each risk factor. The probability of having a premature birth among those with the risk factor is compared to those without the risk factor (the referent group). An odds ratio of 1.0 implies that the event is equally likely in the two groups being compared. If the odds ratio is greater than 1.0, then the event is more likely in the group with the risk factor than in the referent group. When the odds ratio is less than 1.0, the event is less likely in the group with the risk factor.

For example, if a given risk factor had an odds ratio of 2, women with that risk factor were twice as likely to experience a premature birth as those without the risk factor. Those variables that were found to have statistically significant odds ratios were used to construct a multivariate logistic regression model. Such modeling allows for the calculation of odds ratios while controlling for the effects of all other risk factors included in the model. That is, modeling controls for multiple risk factors and inter-relationships between the risk factors to identify those with the strongest associations to prematurity. Such odds ratios are called *adjusted* odds ratios. *Unadjusted* odds ratios are those calculated without taking the other risk factors into consideration (such as those shown in Table 3).

Because the purpose of this study was to explain the increase in premature births over time, the next step was to determine if those risk factors found to be most strongly associated with prematurity also increased in prevalence during the period in question. For example, since race was found to have a strong association with prematurity, the data from 1990 through 1999 were examined to determine if there was an increase in the proportion of births that occurred to mothers of races known to be at increased risk for premature birth. Risk factors that increased in prevalence during the ten-year period were likely to have contributed to the overall increase in preterm infants.

Results

Descriptive Statistics

The distribution of potential risk factors in Snohomish County between 1990 and 1999 are shown in Table 2 below. The table includes the number of births with a given risk factor for all births, preterm, and full-term infants.

Also included is the significance level of a chi-square test comparing the proportions of preterm and full-term births for each risk factor. These proportions exclude cases with missing data. The percent of cases for which data were missing is also presented for each factor.

Table 2

Comparison of Risk Factor Prevalence among Preterm and Full-Term Births Snohomish County, 1990-1999

	Overall			Preterm		Full-Term		
	Cases	Percent*	Percent of Missing Data †	Cases	Percent*	Cases	Percent*	Significance
Total Births	81,041	100	0.1	8,284	10.2	72,639	89.6	N/A
Demographic Characteristics								
Mother's Age (in years)								<0.0001
Less than 20	6,797	8.4	0.0	838	10.1	5,949	8.2	
20 to 34	63,949	79.0		6,224	75.2	57,641	79.4	
35 or Older	10,257	12.7		1,219	14.7	9,014	12.4	
Black/Native American	2,454	3.2	4.0	365	4.7	2,083	3.0	<0.0001
Unmarried	17,594	21.7	0.1	2,167	26.2	15,395	21.2	<0.0001
Maternal History								
Prior preterm delivery	751	1.0	2.4	195	2.4	556	0.8	<0.0001
Prior induced termination of pregnancy	14,106	17.4	0.0	1,499	18.1	12,601	17.4	0.0892
Prior fetal death/spontaneous termination	18,621	23.5	2.1	2,045	25.7	16,565	23.2	<0.0001
First Child	23,483	29.5	1.9	2,520	31.2	20,963	29.3	0.0006
Maternal Health & Lifestyle Issues								
Smoking during pregnancy	13,994	18.0	4.3	1,678	22.3	12,307	17.6	<0.0001
Prenatal care	9,884	12.9	5.4	1,198	16.7	8,674	12.5	<0.0001
Multiple gestation (current pregancy)	1,955	2.4	0.0	1,109	13.4	839	1.2	<0.0001
Anemia	1,977	2.5	2.4	254	3.2	1,723	2.4	0.0001
Chronic Diabetes	2,546	3.1	0.0	437	5.3	2,108	2.9	<0.0001
Gestational Diabetes	2,282	2.8	0.0	352	4.3	1,929	2.7	<0.0001
Chronic Hypertension	837	1.1	2.4	202	2.5	633	0.9	<0.0001
Gestational Hypertension	5,205	6.6	2.4	876	10.9	4,322	6.1	<0.0001
Cardiac Disease	163	0.2	2.4	29	0.4	134	0.2	0.0013
Placental/Uterine Complications								
Premature rupture of membranes	2,293	2.9	2.8	747	9.4	1,537	2.2	<0.0001
Abruptio placentae	499	0.6	2.8	207	2.6	289	0.4	<0.0001
Placenta previa	238	0.3	2.8	101	1.3	137	0.2	<0.0001
Uterine Bleeding	636	0.8	2.4	128	1.6	508	0.7	<0.0001
Eclampsia	117	0.2	2.4	32	0.4	85	0.1	<0.0001
Incompetent Cervix	110	0.1	2.4	49	0.6	59	0.1	<0.0001
Cord Prolapse	93	0.1	2.8	16	0.2	77	0.1	0.0242
Polyhydramnios	435	0.6	2.4	81	1.0	354	0.5	<0.0001
Oligohydramnios	1,555	2.0	2.4	406	5.1	1,145	1.6	<0.0001
Any of the Above	3,538	4.5	3.4	1,134	14.3	2,404	3.4	<0.0001

** Percents may not sum up to 100 due to rounding.*

† Not included in calculation of risk factor prevalence.

Results

Descriptive Statistics

The data show that approximately one in ten Snohomish County infants (10.2%) were born prematurely between 1990 and 1999.

After excluding 118 cases for which no gestational age was calculated, 80,923 births remained for analysis. The data show that approximately one in ten Snohomish County infants (10.2%) were born prematurely between 1990 and 1999. Preterm births were significantly more likely than full-term infants to have been exposed to each of the risk factors identified in the birth certificate data, except for the risk factor 'mother having had a previous induced termination of pregnancy' ($p < 0.089$). This risk factor was dropped from further analyses.

As an example of what Table 2 contains, let us examine the risk factor 'race.' According to the literature, Black and Native American mothers are at increased risk for premature birth[1, 4, 5]. Only 3.2% of births in Snohomish County between 1990 and 1999 were to mothers of these races. However, a higher proportion of the preterm births were to mothers in these racial groups than among full-term births (4.7% vs. 3.0%), reflecting the findings of the literature. The significance level of a chi-square test comparing these proportions was less than 0.0001.

Note that 4.0% of the cases had no recorded data on the mother's race. These mothers experienced even more preterm births than Black or Native American mothers. It is impossible to determine if or how these missing data bias the results. However, one way to measure the extent of any bias is to assume that all the missing cases were either Black or Native American, or that none of them were. In the first case (assuming all the missing cases were in the high-risk category) the resulting odds ratio would be 1.69, while in the second (assuming none were Black or Native American) the odds ratio would be 1.56. Both of these values fall within the 95% confidence interval (CI) of the odds ratio calculated without the missing cases (OR = 1.61, 95% CI = 1.43, 1.80). Hence, the missing data probably did not greatly effect the final conclusions about the effect of race on prematurity.

Main Effects

Analysis by Individual Risk Factor

Table 3 presents the number and percentage of births (either preterm or full-term) where each risk factor was present. Also included is the unadjusted odds ratio for the risk factor compared to those births where the risk factor was not present. For example, there were 838 premature births to women younger than 20, representing 10.1% of all premature births. The prevalence of premature births to women in this age range was compared to that of women between the age of 20 and 34 to compute the odds ratio.

In this case the odds ratio was 1.30. The column labeled "95% CI" represents the 95% confidence interval for the odds ratio. If this interval does not include the value of 1.0, then the odds ratio is considered statistically significant. This means that there is less than a 5% chance that the observed odds ratio occurred randomly and does not represent a real difference between those with the risk factor and those without.

Table 3

Mothers' Risk Factors for Preterm and Full-Term Births, Unadjusted Odds Ratios
Snohomish County, 1990-1999

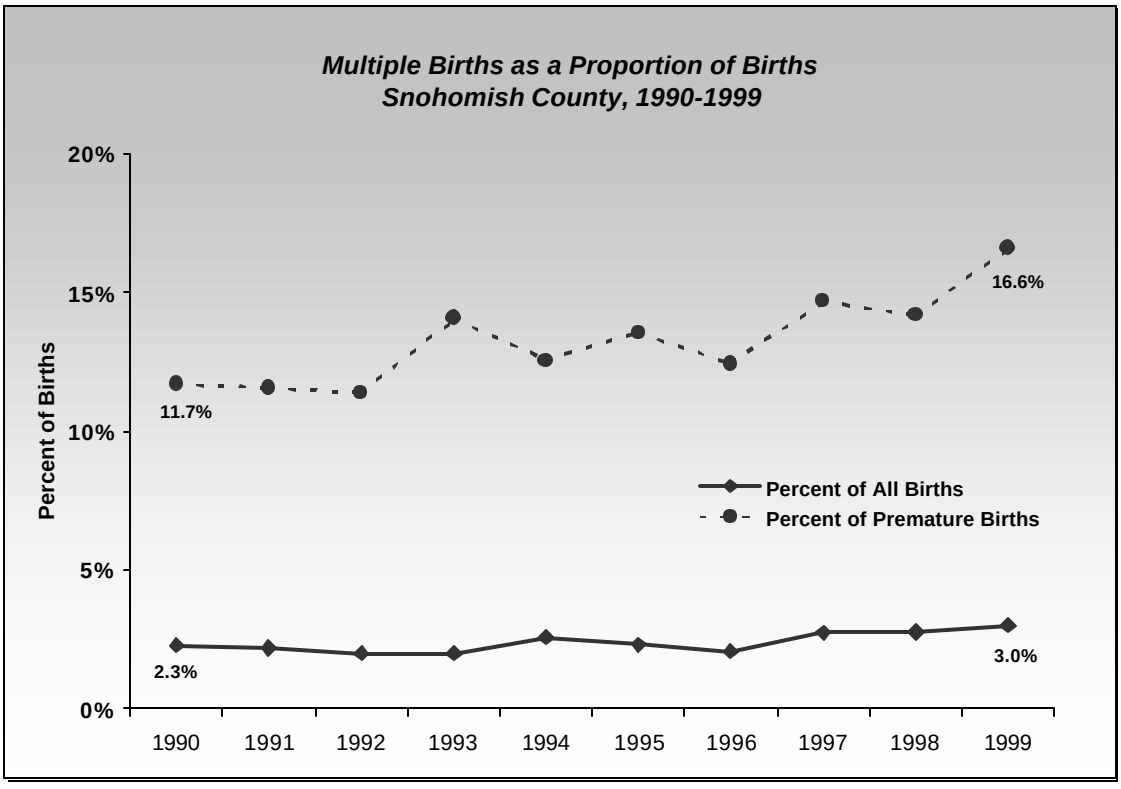
	Preterm		Full-Term			
	Cases	Percent	Cases	Percent	OR *	95% CI†
Maternal Socio-Demographic Features						
Maternal age						
<20 Years	838	10.1	5,949	8.2	1.30	(1.21, 1.41)
>= 35 Years	1,219	14.7	9,014	12.4	1.25	(1.17, 1.34)
20 - 34 Years	6,224	75.1	57,641	79.4	1.00	N/A
Black or Native American	365	4.7	2,083	3.0	1.61	(1.43, 1.8)
Marital status (Unmarried)	2,167	26.2	15,395	21.2	1.32	(1.25, 1.39)
Maternal History						
Previous pre-term delivery	195	2.4	556	0.8	3.15	(2.67, 3.71)
Prior Fetal death/Spontaneous outcome	2,045	25.6	16,565	23.2	1.14	(1.08, 1.2)
First Child	2,520	31.2	20,963	29.3	1.09	(1.04, 1.15)
Maternal Health & Lifestyle Issues						
Smoking during pregnancy	1,678	22.3	12,307	17.6	1.34	(1.27, 1.42)
Late or no prenatal care‡	1,198	16.7	8,674	12.5	1.41	(1.32, 1.5)
Multiple gestation	1,109	13.4	839	1.1	13.23	(12.05, 14.52)
Anemia	254	3.2	1,723	2.4	1.31	(1.15, 1.5)
Diabetes				0.0		
Chronic	437	5.3	2,108	2.9	1.86	(1.68, 2.07)
Gestational	352	4.2	1,929	2.7	1.63	(1.45, 1.83)
Hypertension				0.0		
Chronic	202	2.5	633	0.9	2.86	(2.44, 3.36)
Gestational	876	10.9	4,322	6.1	1.89	(1.75, 2.04)
Cardiac Disease	29	0.4	134	0.2	1.91	(1.28, 2.86)
Placental/Uterine Complications	1,144	13.8	2,420	3.3	4.65	(4.32, 5.01)

* Unadjusted = Odds Ratio (OR) calculated for risk factor separately
† CI = confidence interval
‡Late prenatal care is defined as beginning in the 2nd or 3rd trimester

The strongest risk factor for premature birth was multiple gestation (OR = 13.2). There was a significant increase in the proportion of births resulting from multiple gestation, from 2.3% of all births in 1990 to 3.0% in 1999 ($p < 0.001$). In addition, the proportion of multiple births that were premature increased over the decade under study. Between 1990 and 1995, 53.7% of multiple gestation babies were born prematurely, but this increased to 61.0% in the period from 1996 to 1999 ($p < 0.001$). Together, these two trends caused the proportion of premature births resulting from multiple gestations to grow from 11.7% in 1990 to 16.6% in 1999 (Figure 2). These findings reflect trends found in both North America and Europe[5].

Another risk factor found to be associated with prematurity was the presence of placental or uterine complications (OR = 4.65). These complications affected only 4.5% of mothers. Having delivered a previous infant prematurely was also a strong risk factor (OR = 3.15), suggesting that some women may be predisposed to deliver prematurely for as-yet unknown reasons. However, only 1% of mothers fit in this category. These risk factors illustrate a consistent pattern among the findings: those risk factors most strongly associated with prematurity (i.e., those with the largest odds ratios) tended to affect only a small percentage of women. While these risk factors were obviously important in understanding prematurity, they were not likely to be the major causes for the increasing trend in premature births in the county.

Figure 2



Maternal Age

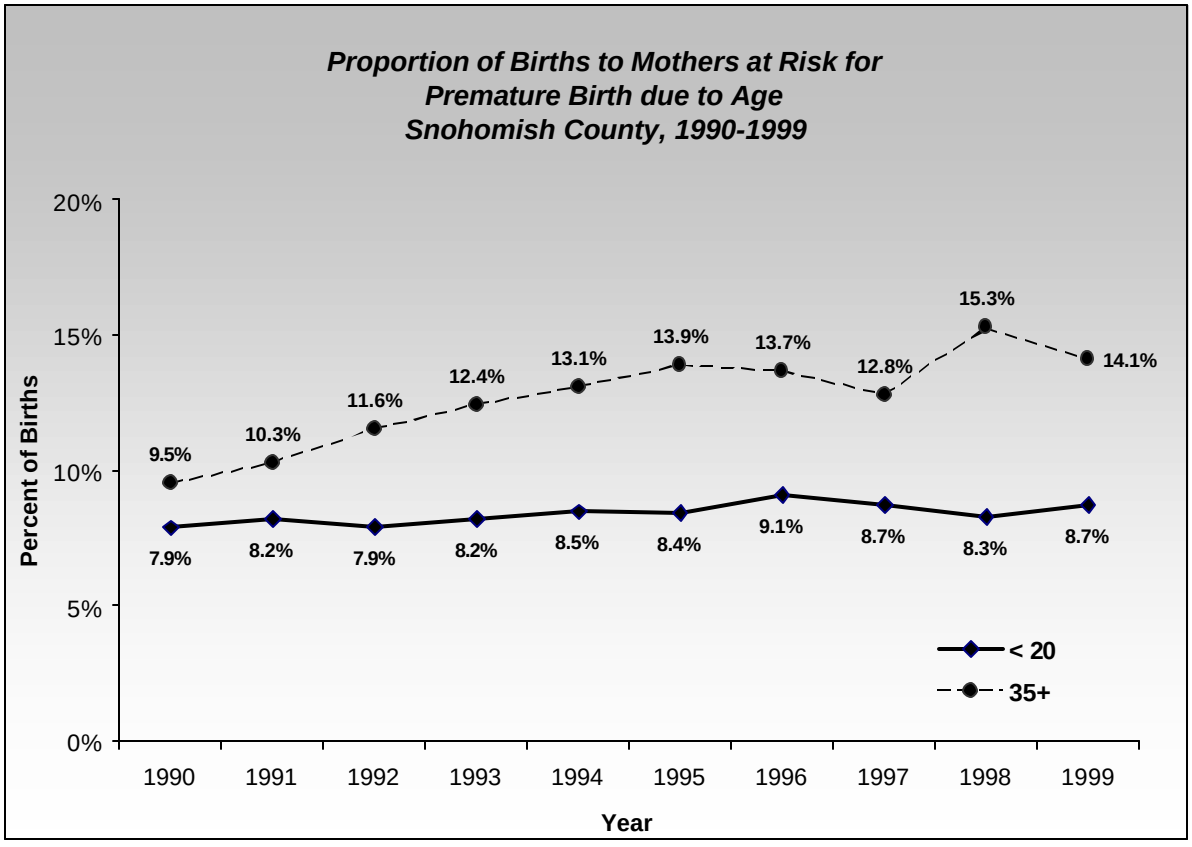
Maternal age is a well-known risk factor for prematurity[4]. In the Snohomish County data, mothers younger than 20 and older than 34 years were found to be somewhat more likely to give birth prematurely than women between the ages of 20 and 34 (Table 3, adjusted odds ratios of 1.30 and 1.25, respectively).

Between 1990 and 1999, mothers in these age groups also gave birth to increasing proportions of Snohomish County infants (Figure 3). The proportion of births occurring to women less than 20 years of age increased from 7.9% in 1990 to 8.7% in 1999 ($p < 0.008$). The proportion of mothers who were 35 and older increased from 9.5% in 1990 to 14.1% in 1999 ($p < 0.0001$).

The increase in mothers at risk for preterm birth due to age contributed to the increase in premature births. In addition to the increase in mothers 35 and older, there was also a significant increase in the proportion of premature births to these women, from 12.4% of their births in 1990 to 14.5% in 1999 ($p < 0.003$). In effect, being 35 and older became more of a risk factor for prematurity during this period. The combination of these two trends led to an increase in the proportion of premature births that occurred to women 35 and older, from 12.9% of all premature births in 1990 to 16.8% in 1999 ($p = 0.004$).

Women 35 and older gave birth to an increasing proportion of the premature infants in the county, from 12.9% of all premature births in 1990 to 16.8% in 1999.

Figure 3



Multiple Gestation by Age Group

The effect of multiple gestation on the trend of premature births differed by age group.

The effect of multiple gestation on the trend in premature births differed by age group. Among women less than 20 years of age, there was no increase in the proportion of premature births[A] (Table 4). There was an increase in the proportion of premature births resulting from multiple gestation[C], but there was no corresponding increase among singleton births[B]. Since there was no overall increase in prematurity in this age group, the increase among multiple gestation births is of interest only because it reflects trends found among other age groups (see below).

Among women 35 years and older, two different trends relating to multiple gestation explained the increase in premature births. First, the proportion of all births resulting from multiple gestations increased from 1.8% of births in this age group in 1990 to 3.9% in 1999.

Second, the proportion of multiple gestation infants who were born prematurely to mothers in this age group increased significantly over time from 42.9% in 1990 to 71.7% in 1999 ($p<0.005$). No significant increase in the proportion of premature infants was observed among singleton births to older mothers[H] ($p<0.092$). Hence, the increase in premature births to women more than 35 years of age was caused by both the increase in multiple births and the growing tendency for multiparous infants to be born prematurely.

Table 4

Trends in Premature Births by Parity and Age of Mother
Snohomish County, 1990-1999

Age Group of Mother	Preterm as Proportion of All Births *p-value*	Preterm as Proportion of Singleton Births *p-value*	Preterm as Proportion of Multiple Births *p-value*
All Women	↑ *p = 0.0001*	↑ *p = 0.0001*	↑ *p = 0.0001*
Less Than 20	**O** p = 0.533[A]	**O** p = 0.747[B]	↑ *p = 0.013[C]*
20 to 34	↑ *p = 0.0001[D]*	↑ *p = 0.0001[E]*	↑ *p = 0.009[F]*
35 and older	↑ *p = 0.0006[G]*	**O** p = 0.092[H]	↑ *p = 0.005[I]*

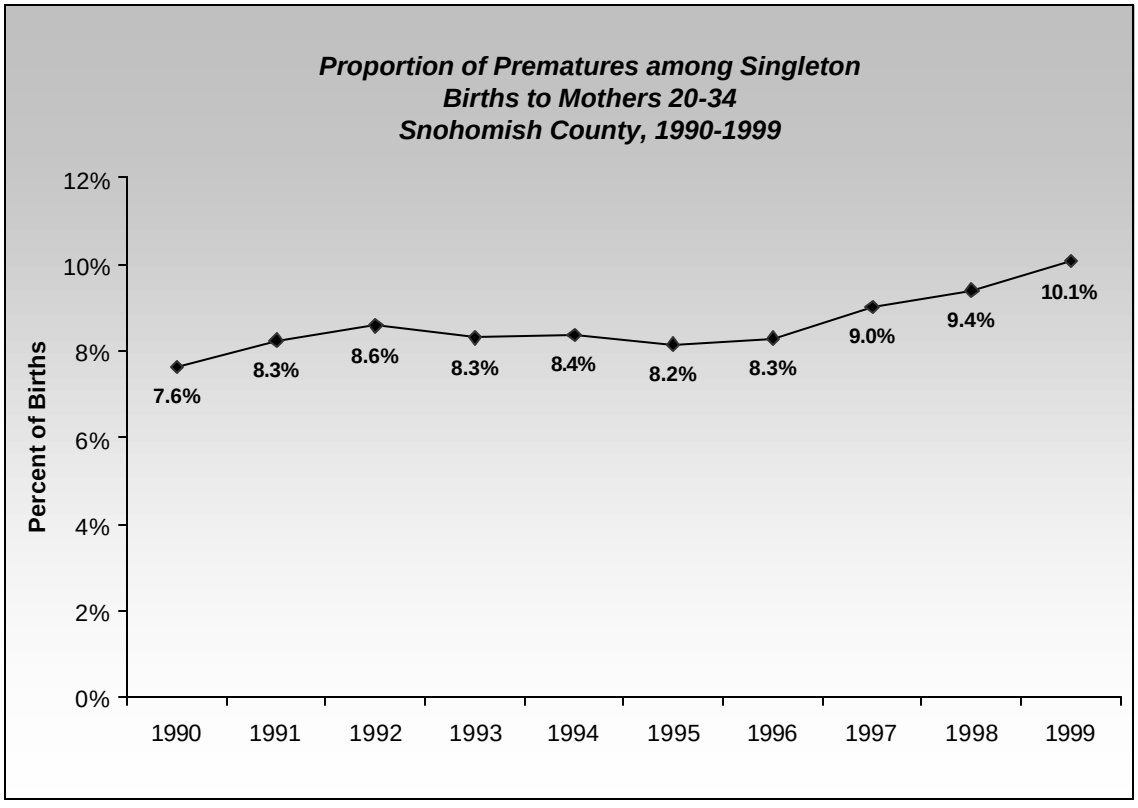
↑ = *Significant increasing trend*
O = *No change over time*
p = *significance level of trend over time.*

Multiple Gestation by Age Group

Among women between the ages of 20 and 34, **premature births increased among both multiple** and single births [E]. The increase in prematurity among singleton births to women in this age group, from 7.6% in 1990 to 10.1% in 1999 (Figure 4), remained unexplained [D]. Since such births comprised the majority of all births in Snohomish County (79%) , the remaining analyses focused just on them. Multivariate logistic regression was used to determine which risk factors were most strongly associated with premature birth.

There was a significant increase in prematurity among singleton births to women betweem the age of 20-34, which constituted the largest proportion (79%) of all births.

Figure 4



Combined Effects

Singleton Births to Mothers 20-34 Years Old

Table 5 presents the risk factor data for singleton births to mothers between the age of 20 and 34. It includes both the univariate (unadjusted) and multivariate (adjusted) odds ratios for each risk factor. The unadjusted odds ratios represent the increase in the probability of a premature birth for each factor taken individually.

The adjusted odds ratios represent the increase in the probability for premature birth associated with each risk factor after adjusting for each of the others. Risk factors that were not statistically significant in the univariate analysis were not included in the multivariate analysis. Adjusted odds ratios were not presented for these risk factors.

Table 5

Mothers' Risk Factors for Preterm and Full-Term Births
Odds Ratios for Singleton Births to Mothers 20-34 Years Old
Snohomish County, 1990-1999

	Preterm		Full-Term		Unadjusted*		Adjusted†	
	Cases	Percent	Cases	Percent	OR	95% CI§	OR	95% CI§
Total Births	56,954	91.4	5,363	8.6		N/A		N/A
Maternal Socio-Demographic Features								
Black or Native American	212	4.2	1,467	2.7	1.60	(1.38, 1.85)	1.36	(1.16, 1.61)
Unmarried	1,172	21.9	9,957	17.5	1.32	(1.24, 1.42)	1.11	(1.02, 1.20)
Maternal History								
Previous pre-term delivery	144	2.8	447	0.8	3.52	(2.91, 4.25)	3.48	(2.80, 4.33)
Prior Fetal death/Spontaneous outcome	1,283	24.9	12,623	22.6	1.14	(1.07, 1.22)	1.08	(1.00, 1.16)
First Child	1565	29.2	16040	28.2	1.05	(0.99, 1.12)	Not Included	
Maternal Health & Lifestyle Issues								
Smoking during pregnancy	1,096	22.5	9,236	16.8	1.43	(1.33, 1.54)	1.33	(1.22, 1.44)
Late or no prenatal care ‡	711	15.4	6,121	11.2	1.43	(1.32, 1.56)	1.38	(1.26, 1.51)
Anemia	131	2.5	1,278	2.3	1.10	(0.92, 1.32)	Not Included	
Diabetes								
Chronic	250	4.7	1,576	2.8	1.72	(1.50, 1.97)	3.51	(2.41, 5.11)
Gestational	194	3.6	1,436	2.5	1.45	(1.25, 1.69)	0.42	(0.28, 0.63)
Hypertension								
Chronic	116	2.2	468	0.8	2.69	(2.19, 3.30)	2.77	(2.19, 3.50)
Gestational	526	10.1	3,254	5.8	1.81	(1.64, 2.00)	2.04	(1.84, 2.27)
Cardiac Disease	15	0.3	96	0.2	1.67	(0.97, 2.89)	Not Included	
Placental/Uterine Complications	753	14.0	1,865	3.3	4.82	(4.41, 5.28)	4.82	(4.35, 5.33)

** Unadjusted = Odds Ratio calculated for risk factor separately*
†Adjusted = Odds Ratio calculated in combination with other risk factors (logistic regression modelling)
‡Late prenatal care is defined as beginning in the 2nd or 3rd trimester
§ CI = confidence interval

Singleton Births to Mothers 20-34 Years Old

After births to the youngest and oldest mothers and multiparous births were removed from the analysis, several risk factors were no longer significantly associated with prematurity. These included having no previous children, anemia, and cardiac disease. Having had no previous children and anemia were strongly associated with the youngest age group. Cardiac disease was most prevalent in the oldest age group. It is therefore not surprising that these variables were no longer significant when those age groups were removed from the analysis.

The multivariate modelling showed that women with a history of a prior preterm birth were 3.5 times more likely to deliver prematurely (95% CI = 2.8, 4.3) than those without such a history. Medical factors associated with an increased risk of having a preterm birth included chronic diabetes (OR = 3.8), chronic hypertension (OR = 2.8), and gestational hypertension (OR = 2.0). The presence of at least one placental/uterine complications (as defined in Table 2) also significantly increased the probability of having a premature infant (OR = 4.8, 95% CI = 4.4, 5.3).

Other factors were associated with smaller*, but still significant, increases in the chance of having a premature infant. These included inadequate prenatal care, maternal smoking, Black or Native American race, and marital status. Having experienced a prior fetal death was not a significant risk factor after taking the other risk factors into consideration. Curiously, gestational diabetes went from being a risk factor when taken by itself (unadjusted OR = 1.45) to a protective factor when analyzed in combination with the others (adjusted OR = 0.42), suggesting interaction with one or more of the other risk factors.

Women with a history of a prior preterm birth were 3.5 times more likely to have delivered prematurely than women without such a history.

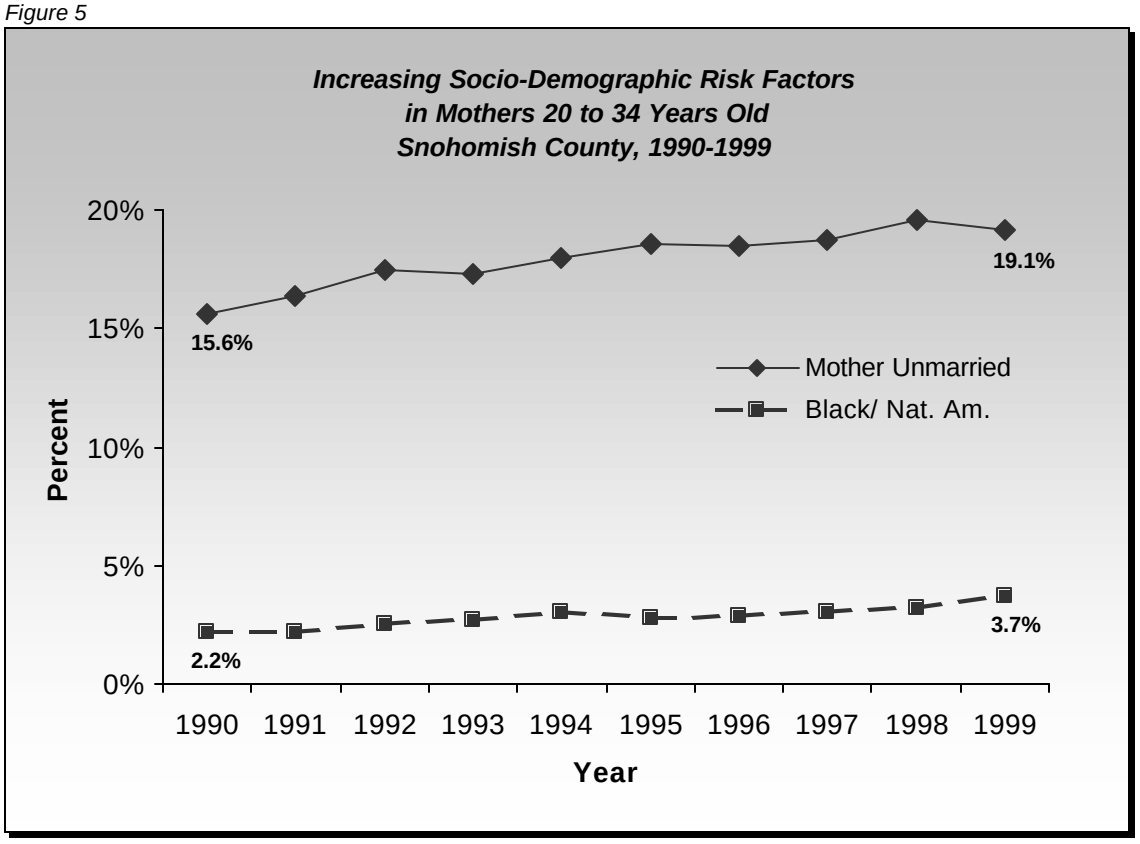
*odds ratio less than 2.0

Trend Effects

Singleton Births to Mothers 20-34 Years Old

Trend analyses for the period from 1990 to 1999 were conducted for those risk factors that were found to have a significant adjusted odds ratio among singleton births to mothers between the ages of 20 to 34 years old. The proportion of births occurring to mothers in high-risk racial groups (Blacks and Native Americans) increased from 2.2% of births in 1990 to 3.7% in 1999 ($p < 0.001$, Figure 5). The prevalence of unmarried mother increased from 15.6% in 1990 to 19.1% in 1999 ($p < 0.001$). Both of these factors probably contributed to the increase in prematurity.

. Figure 5



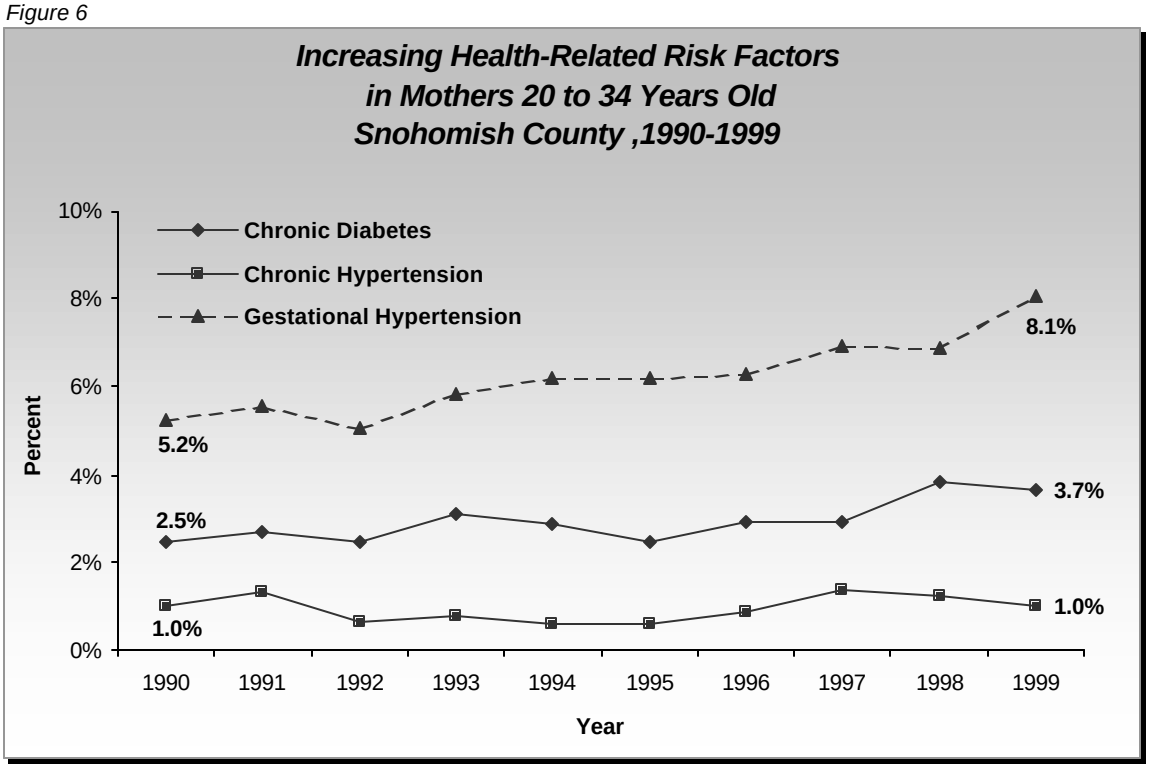
Singleton Births to Mothers 20-34 Years Old

Medical risk factors that increased over time (Figure 6) included the proportion of mothers with chronic diabetes (from 2.5% to 3.7%, $p < 0.001$) and gestational hypertension (from 5.2% to 8.1%, $p < 0.001$).

Not all the risk factors found to be significant in the multivariate analysis increased in prevalence during this period. The proportion of mothers who had experienced a previous preterm birth fell from 1.3% in 1990 to 0.4% in 1999, while those with a placental or uterine complication decreased from 5.4% to 3.3% ($p < 0.0001$). The proportion of women who had late or inadequate prenatal care declined from14.6% to 9.5% ($p < 0.001$).

There was also a decrease in reported maternal smoking, from 12.5% to 7.1% ($p < 0.001$). There was no change in the proportion of women who had lost a previous infant. Since the prevalence of these risk factors declined or remained constant during the period in which the rate of preterm births increased, they could not have caused the increase.

Figure 6



Discussion

Three inter-related factors were associated with the increase in prematurity.

Three inter-related factors were associated with the increase in prematurity: an increase in multiple gestations, increasing proportions of mothers younger than 20 or older than the age of 34, and an increase in pregnancies among women at risk for complications due to demographic and medical factors. The increasing prevalence of multiple births explained the increases in premature births to women less than 20 and older than 34, but was only one of several important risk factors for women between 20 and 34 years old. The birth certificate data did not include any data to explain why there was an increase in multiple births, but anecdotal evidence points to increasing use of fertility treatments as a possible cause, particularly by older women. Such treatments have been found to be associated with greater risks of multiple gestation and prematurity[18,19].

Other significant risk factors for prematurity that increased during this period included the proportions of mothers who were unmarried, Black or Native American, or who had chronic diabetes, chronic hypertension, or gestational hypertension.

Evidence of a possible causal relationship between these risk factors and the increase in prematurity is supported by the findings of a trend analysis on premature births to women who had none of these risk factors. When all the women with one or more of these risk factors were excluded from the analysis, the trend in preterm births was no longer statistically significant ($p < 0.112$).

The prevalence of several important risk factors (e.g., having had a previous preterm birth, late prenatal care, smoking) declined during the period in question, and thus, could not have contributed to the increase in prematurity. This also suggests that the cumulative increase in some risk factors must have been greater than the cumulative decrease in others. However, because there are other known risk factors that were not available for analysis (e.g., use of fertility treatments), such a theory cannot be verified.

Study Limitations

Despite providing some indications as to why there has been an increase in premature births in the county, this analysis is not conclusive. First, the amount of variation explained by logistic regression was small (approximately 10%). Since even the best research studies can identify risk factors in only 25-40% of mothers giving birth prematurely, this result was not unexpected. Secondly, there are other known risk factors that could not be included in the analysis (e.g., inadequate maternal weight gain, use of fertility treatments) because they were not available in the birth certificate data. Data on other known risk factors (e.g., socio-economic status) were available for only part of the period under consideration. Data on risk factors like maternal alcohol consumption were not considered reliable enough for use in this study (page 5, Methodology section).

Another factor that could not be examined using the birth certificate data was maternal weight. Unfortunately, while the birth certificate data include the mother's weight, it does not include information on her height, which is necessary for calculating Body Mass Index (BMI). The BMI is a standard measure to determine whether someone is overweight. Data from the Snohomish County Behavioral Risk Factor Survey indicate that there has been an increase in the proportion of women of child-bearing age (18 to 45 years) who are considered overweight (Body Mass Index $\geq$ 25), from 39.6% in 1993 to 43.0% in 1999 ($p < 0.0018$). The proportion of women considered obese (BMI $\geq$ 30) increased from 11.3% to 18.9% during the same period ($p < 0.0045$).

Similar increases have occurred at the state level and national levels. While being overweight has not been identified as a risk factor for prematurity, conditions associated with being overweight (such as chronic diabetes and hypertension) have been identified as risk factors. The increases observed in the number of mothers with chronic hypertension and diabetes (see page 15) support this theory. The inability to calculate BMI also made it impossible to determine if mothers gained sufficient weight during pregnancy, since such guidelines are based on the mother's pre-pregnancy BMI.

One of the more puzzling aspects of the increase in premature births in Snohomish County is the sudden increase between 1996 and 1997. This may be simply a statistical anomaly, since the increases at the state and national levels occurred more consistently over the period in question. It is also possible that new medical technologies became available in the county at that time. Such technologies would include fertility treatments and better medical support for high-risk pregnancies. Technologies of the latter type would facilitate child-bearing by women who would have been previously advised not to get pregnant due to the possibility of complications. The increases in the proportion of women with chronic conditions like diabetes and hypertension and the growing proportion of mothers more than 35 years old suggest that such technology might play a part.

Data from the Snohomish County Behavioral Risk Factor Survey indicate that there has been an increase in the proportion of women of child-bearing age (18 to 45 years) who are considered overweight or obese.

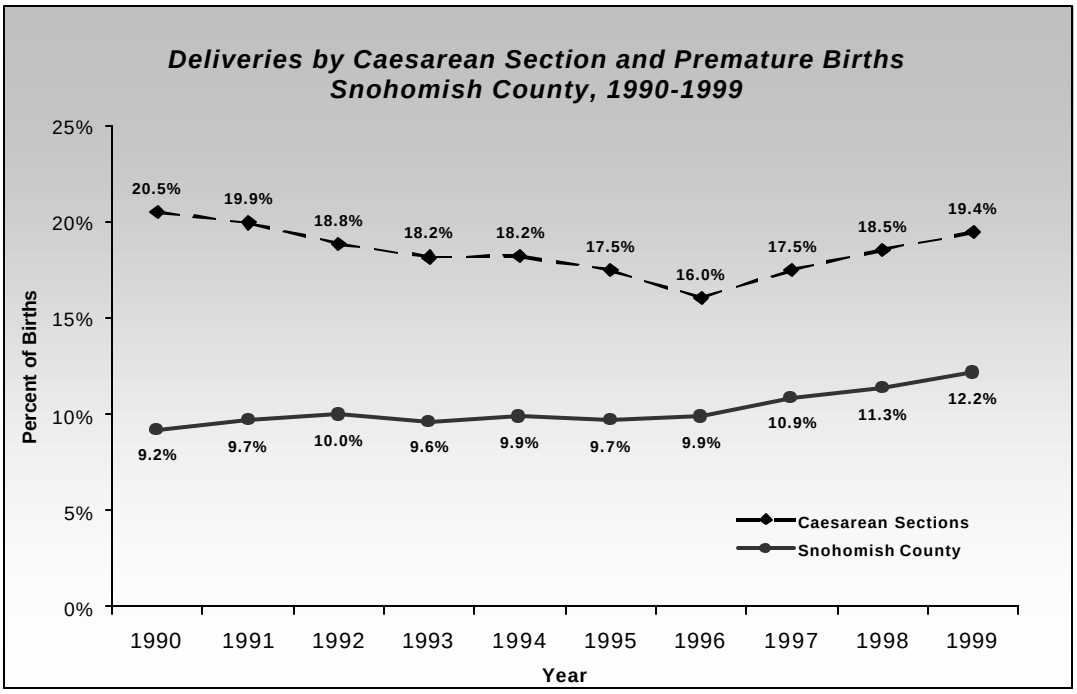
Study Limitations

However, the proximity of Snohomish County to the city of Seattle (King County) argues against this explanation. Such facilities would probably exist in Seattle before Snohomish County, and county residents are close enough to avail themselves of such services with relative ease. The lack of a corresponding sharp increase in the proportion of King County births that were premature between 1996 and 1997 suggests that there was no sudden change in the availability of new medical services.

Delivery method has been described in the literature as a possible confounding factor when examining premature birth, and it has been suggested that when studying the causes of preterm births, cases of medical intervention (caesarean sections, induced labor, etc.) should be analyzed separately[17]. Medical interventions in Snohomish County births (mostly caesarean sections) decreased from 28.3% of cases in 1990 to 21.1% in 1999 (Figure 7).

Closer examination of this period reveals that while medical interventions declined between 1990 and 1996, they began to increase after 1996. This reflects an increase in the prevalence of caesarean sections nationwide between 1996 and 2000[1]. This was the same period during which the increase in premature births began (Figure 5). This temporal correlation makes it tempting to conclude that the increase in medical interventions was associated with the increase in premature births, but this was not the case. In this study, controlling for delivery method did not significantly change the results. Neither the pattern of increase in premature births nor the risk factors significantly associated with it changed if cases of medical intervention were removed from the analysis. It is more likely that the increase in medical intervention is a reflection of the increase in premature births, or that the increases in the both were associated with some underlying factor.

Figure 7



Conclusions

The largest part of the increase in premature births cannot be explained by the data at hand. Increases in a number of factors (multiple births, mothers at risk due to age and demographic characteristics, and some medical risk factors) seem to have contributed, but fail to explain most of the increase. Increases in prematurity among singleton births to mothers in the optimal child-bearing ages (20 to 34 years of age) seem to be due in part to an increasing prevalence of health problems among these mothers (chronic diabetes, etc.). Further investigation into obstetric practices during the period of this study is a logical next step toward understanding the increase in premature births.

In the meantime, physicians and health providers should educate women who are planning a pregnancy, or who are pregnant, about the potential risk of premature birth. This is especially important if these women are in a high-risk group, e.g., are younger than 20, or older than 34, unmarried, Black or Native American, have been diagnosed with chronic diabetes or hypertension, etc. A survey commissioned by the March of Dimes[20] found that "less than half [of women] know prematurity is an issue." Until there is a more complete understanding of the causes of prematurity, the best options available for prevention of premature births will continue to be awareness on the part of medical staff of known risk factors and education of expectant women about risk factors for premature birth and the negative consequences associated with it.

It is advised that physicians and health providers educate women who are planning a pregnancy, or who are pregnant, about the potential risk of premature birth.

References

1. Division of Vital Statistics. National Vital Statistics Reports, Births: Final Data for 1999. April 17, 2001; Vol 49 (1) .
2. Alexander GR. ***Preterm birth: Etiology, Mechanisms and Prevention.*** Prenatal and Neonatal Medicine , 1998; Vol 3, pp 3-9.
3. Hediger, ML, Overpeck MD, Ruan WJ, Troendle JF. ***Birthweight and Gestational Age Effects on Motor and Social Development.*** Paediatric and Perinatal Epidemiology, Jan 2002; Vol 16(1), p 33.
4. Blackmore CA, Rowley DL, Kiely JL. ***Preterm birth,*** Chapter in From Data to Action, Centers for Disease Control and Prevention, 1994.
5. Demissie K, Rhoads GG, Ananth CV, Alexander GR, Kramer MS, Kogan MD, Joseph KS. ***Trends in Preterm Birth and Neonatal Mortality Among Blacks and Whites in the United States from 1989 to 1997.*** American Journal of Epidemiology, 2001; Vol 154 (4) pp 307-315.
6. Rogowski JA. ***The Economics of Preterm Delivery.*** Prenatal and Neonatal Medicine, 1998; Vol 3 pp 16-19.
7. Blondel B, Kogan MD, Alexander GR, Dattani N, Kramer MS, Macfarlane A, Wen SW. ***The Impact of the Increasing Number of Multiple Births on the Rates of Preterm Birth and Low Birthweight: An International Study,*** American Journal of Public Health, 2002; Vol 92 (8), pp 1323-1329.
8. Mushinski M. ***Average Charges for Uncomplicated Cesarean and Vaginal Deliveries,*** Statistical Bulletin, Oct.-Dec. 1994 MetLife.
9. Walker CK. ***Healthy Babies for Healthy Companies,*** Healthy Business, 1993.
10. National Institute of Health, News Release, Jan 23 2002.
11. Census 2000, US Census Bureau.
12. Kogan MD, Alexander GR. ***Social and Behavioral Factors in Preterm Birth,*** Prenatal and Neonatal Medicine, 1998; Vol 3, pp 29-31.
13. Dole N, Savitz DA, Hertz-Picciotto I, Siega-Riz AM, McMahon MJ, Buekens P. ***Maternal Stress and Preterm Birth,*** American Journal of Epidemiology, 2003; Vol 157(1), pp 14-24.
14. Berkowitz GS, Blackmore-Prince C, Lapinski RH, Savitz DA. ***Risk Factors for Preterm Birth Subtypes,*** Epidemiology , May 1998; Vol 9(3), pp 279-285.
15. Fuentes-Afflick E, Hessol NA. ***Interpregnancy Interval and the Risk of Premature Infants*****,** Obstetrics and Gynecology, March 2000; Vol 95 (3), pp 383-390.
16. Lockwood CJ. ***Predicting Premature Delivery – No Easy Task,*** New England Journal of Medicine , Jan. 24, 2002; Vol 346 (4), pp 282-284.
17. Holzman C, Paneth N, Fisher R. ***Rethinking the Concept of Risk Factors for Preterm Delivery: Antecedents, Markers and Mediators,*** Prenatal and Neonatal Medicine ,1998; Vol 3, pp 47-52.
18. Tan SL, Doyle P, Campbell S, Beral V, Rizk B, Brindsen P, Mason B, Edwards RG. ***Obstetric Outcome of In Vitro Fertilization Pregnancies Compared with Normally Conceived Pregnancies,*** American Journal of Obstetrics and Gynecology ,Sep 1992; Vol 167 (3), pp 778-784.
19. Mitchell AA . ***Infertility Treatment – More Risks and Challenges,*** New England Journal of Medicine , March 7, 2002; Vol 346 (10), pp 769-770.
20. Pellet J. ***Why do Some Babies Come Early?*** , Special Advertising Section Sponsored by the March of Dimes in Working Mother, April 2003.