

## Review

# The epidemiology of smoking during pregnancy: Smoking prevalence, maternal characteristics, and pregnancy outcomes

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The prevalence of smoking during pregnancy varies markedly across countries. In many industrialized countries, prevalence rates appear to have peaked and begun to decline, whereas in other countries smoking is becoming increasingly common among young women. Randomized controlled trials have shown that smoking interventions during pregnancy have had limited success. Smoking during pregnancy is in many countries recognized as the most important preventable risk factor for an unsuccessful pregnancy outcome. Smoking is causally associated with fetal growth restriction, and increasing evidence also suggests that smoking may cause stillbirth, preterm birth, placental abruption, and possibly also sudden infant death syndrome. Smoking during pregnancy also is generally associated with increased risks of spontaneous abortions, ectopic pregnancies, and placenta previa and may increase risks of behavioral disorders in childhood. Smoking during pregnancy will continue to be an important risk factor for maternal and fetal outcomes during pregnancy.

**Introduction**

Cigarette smoking is the leading preventable cause of death in many countries. Lung cancer is today a more common cause of death among U.S. women than is breast cancer (U.S. Department of Health and Human Services [USDHHS], 2001b). The high prevalence of smoking among young women highlights not only smoking-related risks of adverse pregnancy outcomes, such as spontaneous abortions, stillbirth, preterm birth, and fetal growth restriction (USDHHS, 2001b), but also possible smoking-related long-term effects on infants, including neurodevelopmental disorders (Fergusson, Woodward, & Horwood, 1998) and cancers (Schwartzbaum, George, Pratt, & Davis, 1991). Given that pregnant women usually are concerned about fetal well-being, young adulthood and pregnancy may

be an ideal time to quit smoking. Moreover, smoking cessation should reduce mothers' pregnancy risks (i.e., infertility, spontaneous abortion, ectopic pregnancy, and placental disorders) and long-term risks of developing life-threatening diseases such as smoking-related cancers and cardiovascular diseases. This article reviews time trends and maternal characteristics associated with smoking during pregnancy as well as maternal, fetal, and infant outcomes associated with smoking during pregnancy.

**Smoking prevalence**

Smoking prevalence is commonly defined as the percentage of daily smokers in a population. This section gives an overview of changes in smoking prevalence among women in general, young women, and pregnant women. Also illuminated are differences in smoking prevalence among nations, ethnic groups within the United States, and socioeconomic or educational groups. Finally, smoking cessation rates and efforts to improve smoking cessation among young and pregnant women are discussed.

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*Time trends in smoking rates among women*

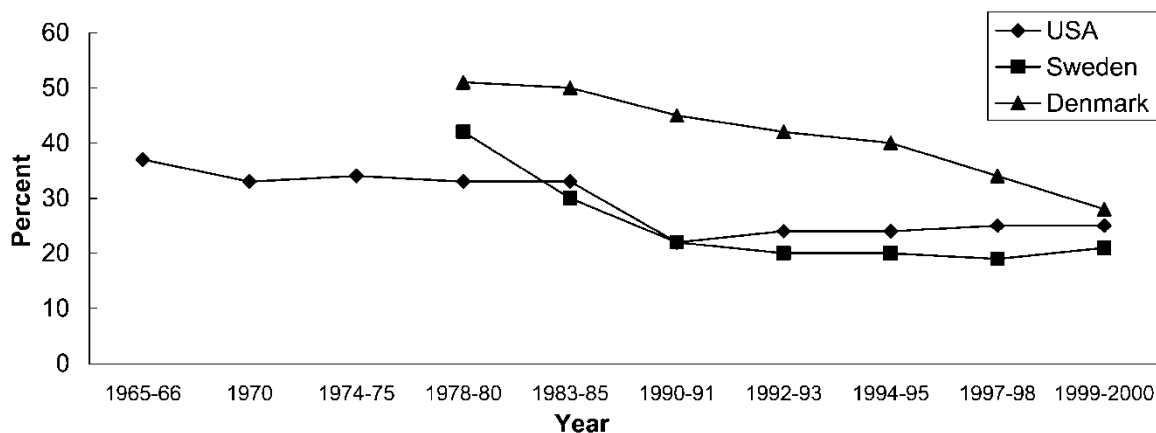
Beginning in 1935, yearly estimates of smoking prevalence from the greater Milwaukee area in the United States were made for commercial purposes. Compared with the U.S. population in general, people included in the Milwaukee surveys more often came from urban areas and also were probably younger. At that time, smoking was more common within urban areas and among young people; therefore, the smoking prevalence figures from the Milwaukee surveys are probably higher than the mean U.S. smoking prevalence figures. From 1935 through 1965, around 60% of males were smokers in the greater Milwaukee area. Among females, daily smoking increased steadily, from 20% in 1935 to around 50% in 1965 (USDHHS, 2001b); the increase was especially pronounced during and after World War II. The increase in smoking prevalence among women is probably due to two reasons. First, smoking prevalence among women increased dramatically in the younger birth cohorts. For example, in the birth cohort of White women born in 1900–1904, around 10% smoked at age 25 years, whereas among women born in 1920–1924, 40% smoked at age 25 years (USDHHS, 2001b). Second, it appears that the tobacco industry's successful promotion, during and after World War II, of smoking as a fashionable thing to do influenced all age groups (Brandt, 1996; Ernster, 1985). Thus, in the 1900–1904 birth cohort, the prevalence of smoking continued to increase until age 50 years, when more than 20% of White women smoked, whereas in the 1920–1924 birth cohort, smoking prevalence peaked at around age 35 years, when close to 50% of all White women smoked (USDHHS, 2001b). A similar but less pronounced pattern of smoking prevalence was observed among Black women. In contrast, among Hispanic women, smoking prevalence rates were generally lower and did not substantially differ between birth cohorts (USDHHS, 2001b).

Since 1965, the National Health Interview Survey has provided yearly estimates of smoking prevalence in the United States among Whites and Blacks, and since 1979, smoking prevalence rates have been available for Hispanics, Asians or Pacific Islanders, Native Americans, and Alaskan natives. During the past four decades, the prevalence of ever smokers among women aged 18 years or older has been fairly stable at around 40% (USDHHS, 2001b).

However, the prevalence of current smoking has dropped from 34% in 1965 (USDHHS, 2001b) to 21% in 2000 (Trosclair, Husten, Pedersen, & Dhillon, 2002). This decline is observed in most ethnic groups, including non-Hispanic Whites, Hispanics, non-Hispanic Blacks, and Asians or Pacific Islanders. In contrast, smoking prevalence has not decreased among Native Americans and Alaskan natives.

The reduction in smoking prevalence during recent decades is especially prominent among women in their reproductive years. In 1965, 38% of women aged 18–24 years smoked, as did 44% of women aged 25–44 years. In 2000, corresponding figures were 25% and 23%, respectively (USDHHS, 2002). However, during the past decade, the reduction in smoking prevalence among young women in the United States appears to have leveled off (Figure 1).

Since the mid-1960s, smoking prevalence has decreased in the United States in virtually all educational groups. The decline has been most pronounced among highly educated women: among those with a bachelor's degree or higher, 26% smoked in 1974, compared with the 10% who smoked in 2000 (USDHHS, 2002). The smallest decline in smoking prevalence occurred among women with only a high school education: 32% smoked in 1974 and 27% smoked in 2000. Smoking prevalence also is higher among women below the poverty level, compared with those at or above it (USDHHS, 2002).



**Figure 1.** Prevalence of daily smoking among young women (United States, 18–24 years; Sweden, 16–24 years; Denmark, 20–29 years). U.S. data from USDHHS (2002), Swedish data from “Swedish Survey of Living Conditions” (2002), and Danish data from National Board of Health Denmark (2002).

Large variations exist in smoking patterns in Europe. In northwestern Europe, smoking prevalence among young women has been reduced during recent decades. For example, in Sweden, around 40% of women aged 16–24 years smoked in 1980, compared with 21% in 2000 (Swedish Survey of Living Conditions, 2002) (see Figure 1). Although the prevalence of smoking among young Danish women is higher, Denmark is experiencing a rapid decline in smoking prevalence. Around 1980, 50% of Danish women aged 20–29 years were daily smokers, whereas the corresponding figure in 2000 was 28% (National Board of Health Denmark, 2002).

In Catalonia, Spain, smoking was rare among females until the late 1960s and was then more common among women with high compared with low education. This social gradient changed in the late 1980s, and smoking is now more common among women with low education compared with those with high education (Borras, Fernandez, Schiaffino, Borrell, & La Vecchia, 2000). In Portugal, the prevalence of daily smoking among women aged 15–24 years increased from 17% in 1984 to 31% in 1988 (European Network for Smoking Prevention, 1999). In former Communist countries in Eastern Europe, several signs indicate a rapid increase in smoking prevalence among young women. In the former East Germany, the smoking prevalence among young women increased from 27% in 1993 to 47% in 1997, whereas similar figures for former West Germany were 36% and 38%, respectively (European Network for Smoking Prevention, 1999). The prevalence of smoking among women is probably increasing in many Latin American countries, whereas smoking in developing countries remains relatively rare (Mackay, 1996).

It has become increasingly common for smokers to quit smoking. In the United States, the percentage of ex-smokers among adult females (18 years or older) doubled from 20% in 1965 to 40% in 1998 (USDHHS, 2001b). The reasons for the increased smoking cessation rates are probably multifactorial. During recent decades, society has become more aware of health concerns associated with tobacco. Many active preventive measures aimed at reducing smoking prevalence have been evaluated as successful. Such activities include prohibiting indoor tobacco use at work or in restaurants, advertisements, age limits for buying cigarettes, and higher tobacco taxes (Task Force on Community Preventive Services, 2001; Wakefield & Chaloupka, 2000).

More than 80% of current smokers started smoking before age 18 years (USDHHS, 2001b). Moreover, smokers who start to smoke early are less likely to later quit. In the United States, current smoking among high school seniors decreased from 39% in 1976 to around 33% in 1998 (USDHHS, 2001b). In Sweden, smoking prevalence has declined little among girls: 18% of 15- to 16-year-old girls smoked in 1983,

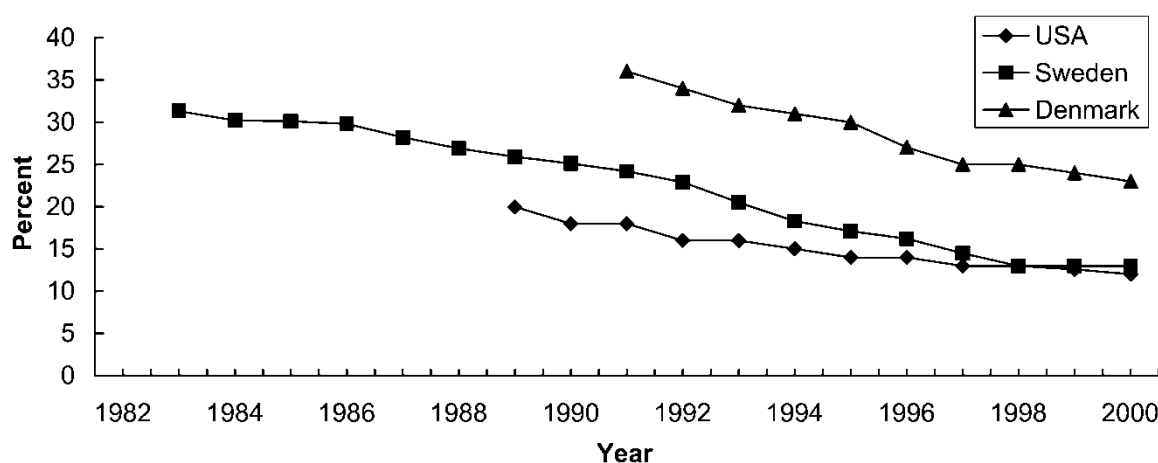
whereas 16% smoked in 2001. In Sweden, smoking is today more common among girls than among boys at a similar age (“Swedish Survey of Living Conditions,” 2002). In Eastern European countries, such as Russia and Hungary, there have been alarming reports of increasing smoking prevalence among girls (European Network for Smoking Prevention, 1999).

### *Smoking behavior during pregnancy*

Estimates of smoking prevalence during pregnancy are usually based on self-reported information. Validation of such information, using biochemical markers such as cotinine, has shown repeatedly that pregnant women may conceal their smoking (Ford, Tappin, Schluter, & Wild, 1997; Klebanoff, Levine, Clemens, DerSimonian, & Wilkins, 1998). Thus, self-reported information of smoking prevalence during pregnancy is probably underestimated. Because negative attitudes toward smoking during pregnancy have increased during recent years, the validity of self-reported smoking information may be a special concern. A Swedish study investigated the association between self-reported smoking in early pregnancy and risk of small-for-gestational-age (SGA) births in the 1980s and early 1990s (Cnattingius, 1997). The prevalence of self-reported smoking in early pregnancy declined from 30% in 1983–1985 to 24% in 1990–1992. The smoking-related relative risks of a SGA birth were virtually identical for pregnancies in 1983–1985 compared with 1989–1992: no differences were found in relative risks related to moderate (1–9 cigarettes per day) or heavy ( $\geq 10$  cigarettes per day) smoking between these time periods.

In the United States, the National Natality Survey reported that 40% of White pregnant women smoked in 1967, compared with only 25% in 1980, whereas corresponding figures among Black women were 33% and 23%, respectively (Kleinman & Kopstein, 1987). Since 1989, information on smoking prevalence during pregnancy is available from the U.S. Standard Certificate of Live Birth. Birth certificate data of live births indicate that in 1989 close to 20% of U.S. pregnant women smoked. Smoking prevalence declined thereafter, and for the last available year (2000), only 12% smoked (USDHHS, 2002) (Figure 2).

In Sweden, the population-based Swedish Medical Birth Register includes self-reported information about smoking at registration to antenatal care, which generally occurs at 8–12 weeks of pregnancy. Registration of smoking habits in the Swedish Medical Birth Register started in 1983. Since then, the prevalence of smoking during pregnancy has declined rapidly. In 1983, 31% of Swedish pregnant women smoked; in 1989, 26% smoked; in 1993, 20% smoked; in 1997, 15% smoked; and in 2000, 13% smoked (P. Otterblad-Olausson, National Board of Health and Welfare, Stockholm, Sweden, personal communication) (see



**Figure 2.** Prevalence of smoking among young women during pregnancy in the United States and Sweden. U.S. data from USDHHS (2002); Swedish data from P. Otterblad-Olausson P, National Board of Health and Welfare, Stockholm, Sweden, personal communication; and Danish data from U. Skovgård Danielsen, National Board of Health and Welfare, Copenhagen, Denmark, personal communication.

Figure 2). Denmark also has experienced a substantial decline in maternal smoking during the past decade (U. Skovgård Danielsen, National Board of Health and Welfare, Copenhagen, Denmark, personal communication).

The decline in smoking during pregnancy in the United States, Sweden, and Denmark is probably due primarily to a decrease in smoking initiation rather than increased smoking cessation before or during pregnancy (Cnattingius, 1997; USDHHS, 2001b; Wisborg, Henriksen, Hedegaard, & Secher, 1996).

Both in the United States and Sweden, smoking prevalence during pregnancy is highly affected by maternal education. For example, in the United States, only 2% of college-educated women reported smoking during pregnancy in 2000, whereas 25% of women who attended but did not complete college smoked (Martin, Hamilton, Ventura, Menacker, & Park, 2002). In Sweden, 3% of highly educated women ( $\geq 15$  years) smoked during pregnancy in 1997, compared with 34% of women with low ( $\leq 9$  years) education (Cnattingius, unpublished data). In the United States, birth certificates also include information about ethnicity. Smoking during pregnancy is most prevalent among Native Americans and Alaskan natives (20% in 2000); in addition, 16% of non-Hispanic Whites, 9% of non-Hispanic Blacks, and 4% of Hispanics smoke (Martin et al., 2002). Heavy smoking during pregnancy has become less common in the United States and Sweden (Cnattingius, 1997; USDHHS, 2001b).

#### *Smoking cessation among pregnant women*

Virtually all pregnant women who stop smoking do so because of concerns about fetal and infant health (Almstrom et al., 1992). Observation studies reported that 20%–40% of smokers quit during pregnancy

(Cnattingius, Lindmark, & Meirik, 1992; Fingerhut, Kleinman, & Kendrick, 1990; Wisborg et al., 1996). Of those who stop smoking, the majority do so in early pregnancy (Cnattingius et al., 1992; Fingerhut et al., 1990; Wisborg et al., 1996). In a Swedish study, 18% of pregnant women stopped smoking before being registered to antenatal care, 11% stopped smoking later during pregnancy, and another 6% stopped smoking temporarily during pregnancy (Cnattingius et al.). Similarly, Fingerhut et al. found that 39% of pregnant women stopped smoking during pregnancy (27% on learning they were pregnant and 12% later). Also, more recent experiences from Denmark suggest that the majority of smokers who quit smoking do so in early pregnancy (Wisborg et al., 1996). The risk for continued smoking during pregnancy is higher among women who have had previous pregnancies than among nulliparous women, and it is also higher among women with low education compared with those with high education. Women with a low age at onset of smoking, heavy smokers, and women exposed to passive smoking at home or at work also are more likely to continue to smoke during pregnancy (Cnattingius et al.; USDHHS, 2001a; Wisborg et al., 1996). Although the relationship between smoking and cancer and cardiovascular diseases is well-known, most women who quit smoking during pregnancy resume smoking within 6 months after delivery (USDHHS, 2001b).

Given that pregnant women are concerned about fetal well-being, and that pregnant women also repeatedly visit prenatal care clinics during pregnancy, it has been suggested that pregnancy may be an ideal time for smoking intervention. Lumley, Oliver, and Waters (2002) performed a meta-analysis of 34 intervention trials during pregnancy and found that the mean rate of smoking cessation was 16% in the intervention groups and 9% in the control groups.

Similar results were obtained when the meta-analysis was restricted to 19 trials with biochemically validated smoking cessation. In a Danish intervention trial, women who smoked at least 10 cigarettes per day were randomized to receive a nicotine patch or a placebo patch. Patches were used for 11 weeks, and smoking habits were evaluated using salivary cotinine. Compliance was low in both groups, and the authors found no differences in cotinine values between the groups (Wisborg, Henriksen, Jespersen, & Secher, 2000). So far, smoking intervention strategies during pregnancy have had limited success, and no effective methods exist for cost-efficient implementation in routine prenatal care.

### Reproductive outcomes

Smoking has been reported to influence fecundity (ability to conceive) and the risk of infertility, which is commonly defined as the inability to conceive after 12 consecutive months of unprotected intercourse. This section reviews current literature on the association between smoking and pregnancy outcomes: the risk that pregnancy ceases during the first 3 months, either as a spontaneous abortion (miscarriage) or an ectopic pregnancy (a pregnancy located outside the uterus); the risk of placental complications; the risks of other adverse pregnancy outcomes, including fetal growth restriction, preterm birth, fetal or infant death, and congenital malformations; and the associations between smoking during pregnancy and subsequent risks to the child, including risks of hospitalization, behavioral problems, psychiatric diseases, and childhood cancers.

#### *Smoking and risks of infertility and pregnancy complications*

Table 1 summarizes the results from studies of associations between smoking, infertility, and pregnancy complications. The first column reports relative risk, which is defined as the ratio of the risk of disease or death among smokers to the risk of disease or death among nonsmokers. In case-control studies and sometimes in cohort studies, the odds ratio is used as

an approximation of the relative risk. Dose-response associations (second column) refers to whether the smoking-related relative risk increases with amount smoked, or, in the case of pregnancy-induced hypertensive diseases, is reduced with amount smoked. Consistency between studies from different populations (third column) refers to whether most studies report similar findings. Whether smoking cessation influences risk (fourth column) indicates whether a change in exposure (from exposed to unexposed) influences risk but has been investigated with regard to only a few outcomes. If (a) the relative risk is high, (b) a dose-response relationship exists between amount smoked and relative risk, (c) the results are consistent between studies, and (d) smoking cessation influences risk, these findings favor (but do not prove) the hypothesis that smoking causes the complication. For example, the results summarized in Table 1 favor the hypothesis that smoking is causally associated with risk of placental abruption, whereas the associations between smoking and the other outcomes are more uncertain.

*Delayed conception and infertility.* Pregnancy rates over defined periods of time are lower among smokers than among nonsmokers (Florack, Zielhuis, & Rolland, 1994; Olsen, 1991), but conception rates among nonsmokers and former smokers appear to be similar (Curtis, Savitz, & Arbuckle, 1997). In a meta-analysis of 12 studies of infertility, Augood, Duckitt, and Templeton (1998) found that the odds ratio of infertility in smokers vs. nonsmokers was 1.60 (95% *CI*=1.34–1.91). In studies of subfertile women undergoing in vitro fertilization treatment, smoking also appears to be associated with reduced fecundity (Hughes & Brennan, 1996). Smoking appears to have antiestrogenic effects (Baron, La Vecchia, & Levi, 1990), and smokers have, during ovarian stimulation, lower peak serum estradiol levels than do nonsmokers (Gustafson, Nylund, & Carlstrom, 1996). Nicotine and the toxic products of cigarette combustion also may interfere with the formation of corpus luteum, tubal transportation, or implantation (Gindoff & Tidey, 1989).

**Table 1.** Summary of smoking-related risks and pregnancy complications.

	Relative risk <sup>a</sup>	Dose response?	Consistency between findings?	Smoking cessation influences risk?
Infertility	1.2–3.6	?	Most studies	Yes
Ectopic pregnancy	1.5–2.5	?	Most studies	?
Spontaneous abortion	1.0–1.8	?	No	?
Placental abruption	1.4–2.4	Yes	Yes	Yes
Placenta previa	1.5–3.0	?	Yes	?
Preeclampsia	0.5–0.7	No	Most studies	?

<sup>a</sup>Smokers vs. nonsmokers.

*Ectopic pregnancy.* Ectopic pregnancies, usually in the fallopian tube, account for around 10% of all maternal deaths in the United States (Atrash, Hughes, & Hogue, 1986). Pelvic inflammatory disease (PID) is one of the most important risk factors for ectopic pregnancy. Cigarette smoking is associated with increased risk of PID, which explains in part why smoking increases the risk of ectopic pregnancy (USDHHS, 2001b). However, smoking also is associated with an increased risk of ectopic pregnancy independent of PID. If smoking impairs tubal transport of the ovum, this may predispose female smokers to ectopic pregnancies (Phipps et al., 1987).

*Spontaneous abortions.* Although many studies have found a positive modest association between maternal cigarette smoking and risk of spontaneous abortion, dose-response associations have been reported only by some studies, and some studies have been unable to find an association between smoking and risk of spontaneous abortion (USDHHS, 2001b). Cotinine is a metabolite of nicotine that is measurable in many human tissues and is considered to be a more correct measure of tobacco exposure than self-reported tobacco consumption. Ness et al. (1999) found that the risk of spontaneous abortion related to smoking habits is probably substantially underestimated when using self-reports ( $OR=1.4$ ) compared with the use of cotinine in hair samples ( $OR=1.9$ ). Because smoking is generally not associated with fetal anomaly, the smoking-related risk of spontaneous abortion may occur predominantly among spontaneous abortions with normal fetal karyotype (i.e., a fetus with normal chromosomes). This conclusion is supported in part by the findings of Kline et al. (1995). Current smoking, defined as smoking at least 14 cigarettes per day, was increased among women with spontaneous abortions with normal fetal karyotype compared with women with live fetuses ( $OR=1.3$ ; 95%  $CI=1.1-1.7$ ). Current smoking tended to be more common among women with spontaneous abortion with normal fetal karyotype than among women with spontaneous abortion with abnormal fetal karyotype ( $OR=1.2$ ; 95%  $CI=0.8-1.8$ ). The mechanisms underlying a possible association between smoking and risk of spontaneous abortion with normal fetal karyotype may involve toxic effects of nicotine, carbon monoxide, and other constituents of tobacco smoke.

*Placental complications.* Placental abruption (premature separation of the placenta from the uterine wall) occurs in 0.4%–2% of all pregnancies and is one of the most common causes of maternal death and perinatal death, the latter being defined as fetal death occurring at 28 weeks or later or death within the first week of life (Kyrklund-Blomberg, Gennser,

& Cnattingius, 2001; USDHHS, 2001b). In pregnancies with placental abruption, perinatal mortality rates range from about 10% to 25% (Kyrklund-Blomberg et al., 2001). Smoking during pregnancy is repeatedly associated with placental abruption. Compared with nonsmokers, smokers face a twofold increased risk of placental abruption, and the risk increases with amount smoked (Ananth, Smulian, & Vintzileos, 1999; USDHHS, 2001b). The smoking-related risk of placental abruption confers to both single and multiple pregnancies (Ananth, Smulian, Demissie, Vintzileos, & Knuppel, 2001). Moreover, one study reported that women who stop smoking during pregnancy have a lower risk of placental abruption compared with women who continue to smoke (Naeye, 1980). In pregnancies complicated with placental abruption, smoking also has been associated with increased risk of perinatal death (Kyrklund-Blomberg et al., 2001). Smoking can increase the risk of placental abruption by several possible mechanisms. Degenerative and inflammatory alterations of the placenta are found in smokers (Rasmussen, Irgens, & Dalaker, 1999). Women with placental abruption also have decreased levels of blood ascorbic acid, which is important in collagen synthesis. Plasma ascorbic acid levels are lower in smokers than in nonsmokers, which may predispose the placenta to early separation in smokers (Faruque, Khan, Rahman, & Ahmed, 1995). Smoking also is associated with preterm rupture of the membranes, which increases the risk of placental abruption (Kyrklund-Blomberg et al.).

Placenta previa, defined as a placenta that partly or completely covers the internal cervical os, occurs in around 5 per 1,000 deliveries (Iyasu et al., 1993). Women with pregnancies complicated by placenta previa are at increased risk for severe vaginal bleedings before or during delivery, preterm birth, and maternal death; the risk of perinatal death also is increased. Cigarette smoking is associated with placenta previa. Relative risks range between 1.5 and 3.0, and dose-response relationships have generally, but not always, been reported (USDHHS, 2001b). In smokers, levels of carbon monoxide are increased at the expense of oxygen; therefore, smokers usually have less oxygen bound to hemoglobin in the blood, compared with nonsmokers. Smoking-induced chronic hypoxemia has been suggested to result in placental enlargement, which increases the risk that the placenta reaches the cervical os.

*Pregnancy-induced hypertensive diseases.* Preeclampsia is defined as pregnancy-induced hypertension combined with proteinuria. If preeclampsia is complicated with seizures, the condition is called eclampsia. Preeclampsia is the leading cause of maternal mortality in the United States (Berg, Atrash, Koonin, & Tucker, 1996) and

may also cause reduced fetal growth, placental abruption, and perinatal death (Cnattingius, 1997). One surprising and not very well understood finding is that smoking is inversely related to risk of preeclampsia, and most studies find no dose-response relationship between amount smoked and reduction in risk (USDHHS, 2001b). A recent Norwegian study found that the smoking-related reduced risk of preeclampsia was confined to preeclampsia developing at term (Odegard, Vatten, Nilsen, Salvesen, & Austgulen, 2000). If smokers develop preeclampsia, there appears to be a multiplicative effect of smoking and preeclampsia on pregnancy outcomes. Thus, in smokers with preeclampsia, risks of placental abruption, SGA births, and perinatal deaths are substantially increased (Cnattingius, 1997).

Compared with preeclampsia, gestational hypertension (pregnancy-induced nonproteinuric hypertension) is generally associated with lower maternal and fetal risks (Naeye, 1981; Seshadri & Venkataraman, 1997). Whether smoking also reduces the risk of gestational hypertension is less well studied. Most, but not all, studies find a moderate reduction in the risk of gestational hypertension associated with cigarette smoking (Ros, Cnattingius, & Lipworth, 1998).

What are the possible reasons for the reduced risks of preeclampsia or gestational hypertension among smokers? McGillivray (1983) reported that less expansion of plasma volume may occur among smokers than among nonsmokers. Cigarette smoke also includes thiocyanate, which has hypotensive effects (Klonoff-Cohen, Edelstein, & Savitz, 1993). Moreover, nicotine may inhibit the production of thromboxane, which is a potent vasoconstrictor and a platelet aggregation stimulator (Ylikorkala, Viinikka, & Lehtovirta, 1985). Preeclampsia also may lead to a reduction in oxygen levels in placental tissue (placental hypoxia). In preeclamptic pregnancies, vasoconstriction leads to increased arterial blood pressure and uteroplacental resistance, which may cause placental hypoxia (Harris, 1988). If smokers develop preeclampsia, the placental hypoxia may be especially pronounced, leading to substantially increased risks of fetal hypoxia, placental abruption, and fetal death.

### *Smoking and risks of adverse pregnancy outcomes*

Table 2 summarizes the results from studies of smoking and risks of adverse pregnancy outcomes.

*Fetal growth restriction.* Simpson and Linda (1957) reported that infants born to mothers who smoked 10 cigarettes or more per day weighed on average 200 g less than infants born to nonsmokers. Later studies found that the smoking-related reduction in birth weight is mediated primarily by fetal growth restriction (Kramer, 1987). The association between smoking and fetal growth restriction is today regarded as causal. First, findings of an association between smoking and risk of SGA births are consistent in the literature. Second, the risk of SGA births increases with amount smoked. Third, from studies of different design, it has been shown that smoking cessation improves fetal growth. For example, Nordström and Cnattingius (1994) studied smoking habits in two successive births. Among women who smoked during their first pregnancy but quit smoking during their second pregnancy, the second birth weight was the same as among women who never smoked. Among women who stop smoking in early pregnancy, birth weights were reported to be essentially the same as birth weights of infants born to nonsmokers (MacArthur & Knox, 1988). Finally, in a randomized controlled trial of smoking intervention during pregnancy, Sexton and Hebel (1984) found that, compared with controls, women subjected to intense antismoking intervention more often quit smoking and their infants also had higher birth weights.

The effect of smoking on fetal growth also may interact with other factors. For example, a number of investigations have found that the smoking-related risk of SGA births increases with maternal age (Cnattingius, 1989; Fox, Koepsell, & Daling, 1994; Wen et al., 1990). Because only a minority of smokers have growth-restricted infants, Wang et al. (2002) investigated whether genetic factors might modify the smoking-related risk of reduced birth weight. The authors found that certain maternal genotypes

**Table 2.** Summary of smoking-related risks and adverse pregnancy outcomes.

	Relative risk <sup>a</sup>	Dose response?	Consistency between findings?	Smoking cessation influences risk?
Small-for-gestational-age	1.5–2.9	Yes	Yes	Yes
Preterm birth	1.2–1.6	Yes	Yes	Yes
Stillbirth	1.3–1.8	Yes	Yes	Yes
Neonatal mortality	1.2–1.4	?	Yes	?
Congenital malformations				
All	No increase?	NA	No	NA
Oral clefts	1.2–1.6	Yes?	Yes	?

Note. NA = not applicable.

<sup>a</sup>Smokers vs. nonsmokers.

(*CYP1A1* and *GSTT1* genotypes) modified the association between maternal cigarette smoking and infant birth weight, suggesting an interaction between metabolic genes and cigarette smoking with regard to fetal growth.

The contents of tobacco smoke that influence fetal growth are not clear. Nicotine causes contractions of the placental vessels (Suzuki et al., 1971); and carbon monoxide binds to fetal hemoglobin, which results in fetal hypoxemia (Lambers & Clark, 1996). Weight gain during pregnancy also is associated with fetal growth. Smokers gain less weight during pregnancy, compared with nonsmokers. However, even after adjustment for pregnancy weight gain, maternal smoking increased the risk of SGA births (Spinillo, Capuzzo et al., 1994; Wen et al., 1990).

Given its high prevalence, smoking is from a public health perspective the most important risk factor for intrauterine growth restriction in most countries in Europe and North America. For example, in Sweden, 22% of pregnant women smoked in 1990–1992. If these women had stopped smoking and thereby had reduced their risk of SGA births to that of nonsmokers, the overall rate of SGA births in the Swedish population would have been reduced by one fifth (Cnattingius & Haglund, 1997).

**Preterm birth.** Preterm birth is commonly defined as a birth occurring at least 4 weeks before the estimated date of delivery (i.e., the gestational age is less than 37 completed weeks). Preterm birth is the major cause of neonatal mortality and morbidity in developed countries. However, owing to improvements in neonatal care, most deaths occur today among very preterm infants (<32 weeks) (Berkowitz & Papiernik, 1993). Intervention programs, aimed at preventing preterm births, have not been successful (Goldenberg & Andrews, 1996), and focusing on potentially preventable risk factors such as smoking may be a way to reduce the incidence of preterm birth. Smoking is repeatedly associated with increased risk of preterm birth, but the smoking-related relative risk of preterm birth is less than the smoking-related risk of SGA births (Chan, Keane, & Robinson, 2001; Zeitlin, Ancel, Saurel-Cubizolles, & Papiernik, 2001). The relative risk of preterm birth among smokers, compared with nonsmokers, generally ranges from 1.2 to 1.6 (USDHHS, 2001b). Smoking appears to increase the risk of having both very (<32 weeks) and moderately (32–36 weeks) preterm infants, but the association seems stronger for very preterm infants (Kyrklund-Blomberg & Cnattingius, 1998; Meyer & Tonascia, 1977; Shiono, Klebanoff, & Rhoads, 1986).

About two thirds of all preterm births occur spontaneously, and one third are electively delivered owing to concerns about fetal or maternal well-being

(Kyrklund-Blomberg & Cnattingius, 1998). Smoking is reported to increase the risk of both spontaneous and elective preterm delivery, but the association is stronger with spontaneous preterm delivery (Kyrklund-Blomberg & Cnattingius, 1998). Spontaneous preterm delivery generally occurs as a result of preterm labor, and smoking is associated with increased risk of preterm labor (Savitz, Blackmore, & Thorp, 1991). Smoking is probably associated with increased risk of intrauterine infection, and signs of impaired maternal immunity and acute inflammation in the umbilical cord and placenta have been observed in mothers who smoke (Naeye, 1978; Nymand, 1974). Smoking also may increase the risk of preterm labor through increased production of prostaglandins in fetal membranes (Hoffman, Romero, & Johnston, 1990). Preterm premature rupture of membranes (preterm PROM) is defined as leakage of amniotic fluid occurring before 37 weeks' gestation. Preterm PROM is the second most common cause of spontaneous preterm delivery and is sometime hard to separate from preterm labor (Spinillo, Nicola, et al., 1994). Smoking has consistently been associated with preterm PROM (Lee & Silver, 2001). When women with preterm PROM are compared with pregnant women at similar time points in their pregnancies, the smoking-related relative risks of preterm PROM range from 2.0 to 3.0 (Hadley, Main, & Gabbe, 1990; Harger et al., 1990). Smoking reduces serum copper and ascorbic acid in blood plasma, which are important for collagen synthesis and maintenance (Hadley et al., 1990). These reductions may result in reduced elastic properties of the fetal membranes, but the smoking-related increased susceptibility to infections also may increase the risk of preterm PROM (Holt, 1987). The smoking-related risk of elective preterm delivery is mediated largely by other smoking-related risks. As stated previously, smoking increases the risk of placental abruption, placenta previa, and fetal growth disturbances, conditions that may require elective preterm delivery.

Although the smoking-related risk of preterm birth is relatively modest, the consistency of findings, the generally obtained dose-response relationships, and the biologically plausible mechanisms favor the hypothesis that smoking may be causally associated with preterm birth. Moreover, women who stop smoking from one pregnancy to another reduce the risk of preterm birth in the subsequent pregnancy to that of nonsmokers in both pregnancies (Cnattingius, Granath, Petersson, & Harlow, 1999). In a randomized controlled trial, infants born to women who stopped smoking during pregnancy had longer gestation periods than did infants whose mothers smoked throughout pregnancy (Li, Windsor, Perkins, Goldenberg, & Lowe, 1993).



*Perinatal mortality.* Perinatal mortality includes fetal deaths occurring at 28 weeks or later and early neonatal deaths (i.e., within the first week of life). Smoking is consistently associated with increased risk of perinatal mortality. In terms of the association between birth weight and risk of perinatal mortality, infants born to smokers appear to have lower perinatal mortality than infants born to nonsmokers if birth weight is below 3 kg, whereas the risk is reversed among heavier infants. However, when standardized birth-weight-specific mortality rates are compared (using a Z-score scale), infants born to smokers have a higher risk of perinatal mortality across all relative birth weights (Wilcox, 1993). Wilcox proposed two pathways for the smoking-related influence on perinatal mortality: one is fetal growth restriction, and the other is that smokers are at higher risk of delivering very small preterm infants. Owing to the close association between fetal growth restriction and stillbirth on one hand, and preterm and neonatal mortality on the other, it seems reasonable to stratify perinatal mortality into stillbirths and early neonatal mortality when investigating smoking-related risks.

*Stillbirth.* When stillbirth is defined as fetal death occurring at 20 gestational weeks or later, 82% of stillbirths occur in the preterm period (i.e., between 20 and 36 gestational weeks; Copper, Goldenberg, DuBard, & Davis, 1994). Also, when stillbirth is defined as a fetal death at 28 weeks or later, the majority of stillbirths are preterm (Stephansson, Dickman, Johansson, & Cnattingius, 2001). Stillbirth is relatively uncommon, and when defined as fetal death at 28 weeks or later, rates range from 3 to 8 per 1,000 in Europe and North America (Andersen, 2001).

Smoking has repeatedly been associated with risk of stillbirth, and a Norwegian study found that smoking was foremost associated with risk of unexplained stillbirth (Froen et al., 2001). Although the smoking-related risk of stillbirth is relatively modest (1.2–1.8), most studies find that the risk increases with amount smoked (USDHHS, 2001b). Smoking appears to influence the risk of primarily preterm stillbirth (Stephansson et al., 2001), and the proportion of growth-retarded stillbirths also is larger among preterm compared with term stillbirths (Gardosi, Mul, Mongelli, & Fagan, 1998).

Biological evidence indicates that smoking may cause stillbirth. The smoking-related fetal hypoxemia and the increase in vascular resistance may partly explain the association between smoking and reduced fetal growth and also may contribute to increased risk of placental abruption (Kramer, 1987; Kramer, Usher, Pollack, Boyd, & Usher, 1997). In a U.S. study, the elevated risk of stillbirth in smokers was due largely to

high rates of placental abruption and placenta previa (Meyer & Tonascia, 1977). Similarly, in a Swedish study, smoking was associated with a 40% increased risk of stillbirth, and this risk was explained entirely by the smoking-related risks of fetal growth restriction and placental complications (Raymond, Cnattingius, & Kiely, 1994). A Danish study found that women who stopped smoking in early pregnancy reduced the risk of stillbirth to that of nonsmokers (Wisborg, Kesmodel, Henriksen, Olsen, & Secher, 2001).

*Neonatal mortality.* Smoking has been associated with increased risk of early neonatal mortality (death of a liveborn infant during the first week of life) as well as neonatal mortality (death during the first 4 weeks of life), and the relative risk generally ranges from 1.2 to 1.4 (USDHHS, 2001b). Meyer and Tonascia (1977) found that the increased risk of neonatal mortality associated with maternal smoking was due to an increased risk of a very early delivery.

*Congenital malformations.* Congenital malformations include a variety of anomalies that may have distinct causes. Most studies have found no association between cigarette smoking during pregnancy and the overall risk of congenital malformations (Malloy, Kleinman, Bakewell, Schramm, & Land, 1989; Shiono, Klebanoff, & Berendes, 1986; Van den Eeden, Karagas, Daling, & Vaughan, 1990).

Maternal smoking during pregnancy has been associated primarily with increased risks of oral-facial clefts. The association between maternal cigarette smoking and risk of oral clefting was summarized in a meta-analysis (Wyszynski, Duffy, & Beaty, 1997). For cleft lip with or without cleft palate, the odds ratio was 1.29 (95% *CI* = 1.18–1.42). For isolated cleft palate, the odds ratio was of similar magnitude (1.32; 95% *CI* = 1.10–1.62). In a Swedish study, based on the largest series of oral cleft cases published to date, the smoking-related risk of cleft palate alone was 1.29 (95% *CI* = 1.08–1.54), whereas the corresponding risk for cleft lip with or without cleft palate was 1.16 (95% *CI* = 1.02–1.32) (Kallen, 1997). It has been suggested that the inconsistencies between studies of maternal smoking and risk of oral clefts may be explained partly by differences in genetic factors. Two studies have reported that the type of allele for transforming growth factor alpha may modify the smoking-related risk of oral clefts (Hartsfield et al., 2001; Hwang et al., 1995). Results regarding possible associations between maternal smoking and other congenital malformations, including limb reductions and cardiac defects, are inconclusive (USDHHS, 2001b).

*Smoking and risks of sudden infant death syndrome and childhood morbidity*

Table 3 summarizes results from studies of associations between smoking, sudden infant death syndrome (SIDS), and childhood morbidity.

*SIDS and childhood morbidity.* SIDS is defined as a sudden unexpected infant death, in which the cause of death remains unexplained after postmortem examinations. The diagnosis of SIDS is usually restricted to unexpected deaths among infants aged 4 weeks to 1 year. During the past decade, SIDS rates have declined in most developing countries. This decline has been attributed primarily to a change from prone to back sleeping position (Mitchell, Thach, Thompson, & Williams, 1999; Willinger, Hoffman, & Hartford, 1994). However, it appears that the prevalence of SIDS continues to decline. For example, SIDS prevalence rates in the United States declined by 7% from 1999 to 2000 (Martin, 2002; Mathews, Menacker, & MacDorman, 2002).

Despite the rapid decline in SIDS rates, it remains the most common cause of postneonatal death in developed countries, and most SIDS deaths occur at 2–3 months of life (USDHHS, 2001b). In the United States, SIDS rates vary substantially by ethnicity. For example, in 2000, SIDS rates per 100,000 live births were 29.4 among Asians and Pacific Islanders, 51.8 among Whites, 120.0 among Native Americans, and 122.1 among Blacks (Mathews et al., 2002). Thus, compared with U.S. Whites, U.S. Blacks and Native Americans face a twofold increased risk of SIDS, whereas the corresponding risk among Asians and Pacific Islanders is reduced substantially. The reasons for these differences are not fully understood, but social and lifestyle factors may play a role (MacDorman, Cnattingius, Hoffman, Kramer, & Haglund, 1997).

Although the decline in SIDS rates during the 1990s has been attributed largely to change in infants' sleeping positions, the decline also coincided in many

countries with declining rates of cigarette smoking during pregnancy. Smoking during pregnancy is consistently associated with SIDS, and dose-response relationships have been reported in studies from different populations (MacDorman et al., 1997; Mitchell et al., 1991; Murphy, Newcombe, & Sibert, 1982). The risk of SIDS among infants of daily smokers is commonly doubled or tripled, compared with non-smokers, and sometimes more than tripled risks have been reported (MacDorman et al.; Malloy, Hoffman, & Peterson, 1992). Most of these studies are retrospective cohort studies or case-control studies, but similar results were reported from a prospective cohort study (Wisborg, Kesmodel, Henriksen, Olsen, & Secher, 2000). In a meta-analysis, Mitchell (1995) estimated the overall odds ratio to be 3.0 (95% CI = 2.8–3.2).

Because smokers differ from nonsmokers with regard to other factors, residual confounding could account for the smoking-related risk of SIDS. Many studies have found that the association between smoking and SIDS has remained essentially unchanged even when measures of socioeconomic status, education, or alcohol were included (Nordström, Cnattingius, & Haglund, 1993; Wisborg, Kesmodel et al., 2000), whereas Malloy, Kleinman, Land, and Schramm (1988) found that the smoking-related risk of SIDS was reduced from 2.9 to 1.9 after adjustments for confounders.

Cooke (1998) has suggested that the smoking-related risk of SIDS may be mediated by the causal association between smoking and reduced fetal growth. A Norwegian study reported reduced fetal growth in both SIDS infants and their surviving siblings, but information about maternal smoking was not available (Oyen, Skjaerven, Little, & Wilcox, 1995). Later, the authors investigated the effect of maternal smoking during pregnancy on birth weight and gestational age in SIDS infants and their surviving siblings. They found that maternal smoking explains some of the association between intrauterine

**Table 3.** Summary of smoking-related risks of sudden infant death syndrome (SIDS) and childhood morbidity.

	Relative risk <sup>a</sup>	Dose response?	Consistency between findings?	Smoking cessation influences risk?
SIDS	2.0–3.0	Yes	Yes	?
Hospitalization of infant or child	1.5–2.0	?	Most studies	?
Psychiatric disorders				
Attention-deficit/hyperactivity disorder	1.0–2.0	?	No	?
Autism	Increased?	?	?	?
Childhood cancers				
All	No increase?	NA	No	NA
Lymphatic leukaemia	No increase?	NA	No	NA
Myeloid leukaemia	Increase?	?	No	?
Non-Hodgkin's lymphoma	Increase?	?	No	?
Brain cancer	No increase?	NA	No	NA

*Note.* NA = not applicable.  
<sup>a</sup>Smokers vs. nonsmokers.

growth retardation and SIDS (Oyen, Haglund, Skjaerven, & Irgens, 1997). A Swedish study found that the smoking-related risk of SIDS was essentially unchanged after controlling for low birth weight (Haglund & Cnattingius, 1990). A British study found that the association between fetal growth and SIDS disappeared when maternal smoking was added to the analysis, suggesting that the effect of fetal growth on SIDS risk was mediated through smoking (Cooke, 1998).

A relationship between smoking and risk of SIDS is observed consistently across various study designs and populations. However, because most women who smoke during pregnancy continue to smoke after birth, it has been debated whether the smoking-related risk of SIDS is mediated by prenatal or postnatal smoking exposure or both. Anderson and Cook (1997) performed a systematic review of the associations between maternal prenatal and postnatal smoking and risk of SIDS. Sixteen studies included information about prenatal smoking and a number of possible confounders, and the summary estimate for the adjusted odds ratios of prenatal smoking was 2.11 (95% *CI*=1.83–2.38). Four studies reported on postnatal smoking after controlling for prenatal smoking. Of these, three studies reported that maternal postnatal smoking increased the risk of SIDS independent of prenatal smoking (Klonoff-Cohen et al., 1995; Mitchell et al., 1993; Ponsonby, Dwyer, Kasl, & Cochrane, 1995; Schoendorf & Kiely, 1992), yielding a pooled odds ratio of 1.94 (95% *CI*=1.55–2.43), and one study found that the association between postnatal smoking and SIDS was not significant (Blair et al., 1996). Mitchell et al. (1997) reported that the risk of SIDS was increased markedly among infants born to mothers who were smokers and also shared a bed with their infants, whereas bedsharing among non-smokers did not influence risk of SIDS. Similar results have been reported by Fleming et al. (1996), although a recently published U.S. study found no evidence of an interaction between smoking status and bedsharing with regard to risk of SIDS (Hauck et al., 2003). Dwyer, Ponsonby, and Couper (1999) performed a prospective cohort study of close to 10,000 infants in a high-risk population, of whom 53 infants subsequently died of SIDS. They found that the cotinine level in the infants' urine was reduced by half if smoking mothers did not smoke in the infants' room, which clearly indicates that smoking in an infant's bedroom influence the infant's exposure to passive smoke. However, this finding was not accompanied by a reduced risk of SIDS. In a study of findings at autopsy, cotinine concentrations in pericardial fluid were analyzed in 67 infants who died from SIDS. About 25% of the SIDS infants had cotinine concentrations exceeding 30 ng/ml, indicating tobacco exposure prior to death (Rajs, Rasten-Almqvist, Falck, Eksborg, & Andersson, 1997). Thus, the conclusive

evidence to date is that both prenatal and postnatal smoking exposure influence risk of SIDS (Anderson & Cook, 1997; Fleming et al.).

*Risks of hospitalization and respiratory disorders during infancy and childhood.* During the first years of life, children of women who smoke during pregnancy are at increased risk of hospitalization (Harlap & Davies, 1974; Rantakallio, 1978; Taylor & Wadsworth, 1987; Weitzman, Gortmaker, Walker, & Sobol, 1990; Wisborg, Henriksen, Obel, Skajaa, & Ostergaard, 1999). Maternal smoking during pregnancy is associated with increased risk of lower respiratory illnesses (Harlap & Davies, 1974; Taylor & Wadsworth, 1987; Wisborg et al., 1999), and one study reported that maternal smoking increased the risk of childhood asthma (Weitzman et al., 1990). Wisborg et al. (1999) also found that smoking was associated with increased risk of hospitalization because of gastrointestinal or dermatologic symptoms. However, it is difficult to determine whether these associations, if causal, are due to smoking exposure before or after birth.

*Behavioral and psychiatric diseases in childhood.* Maternal smoking during pregnancy and fetal growth retardation have been associated with several childhood behavior disorders. For example, Milberger, Biederman, Faraone, Chen, and Jones (1996) found that, compared with infants born to non-smokers, infants born to smokers faced a nearly three-fold increased risk of attention-deficit/hyperactivity disorder (ADHD), and this positive association remained significant after adjusting for socioeconomic status, parental IQ, and parental ADHD status (Milberger et al., 1996). In a prospective New Zealand study, children exposed to maternal smoking in utero had higher psychiatric symptoms rates for conduct disorder, alcohol abuse, substance abuse, and depression (Fergusson et al., 1998). Although smoking during pregnancy was associated with other factors, including socioeconomic disadvantage, impaired childrearing behaviors, and family problems, the smoking-related risks of adverse outcomes remained statistically significant after adjustments for these factors. The effect of maternal smoking was more pronounced for male than for female adolescents (Fergusson et al.).

Autistic disorders in children are manifested by impaired social interactions, communication deviance, and stereotypical behavioral patterns. The cause of these disorders is thought to be largely genetically determined (Bailey et al., 1995), but children with autism have been reported to have an increased frequency of pre- and perinatal complications (Burd, Severud, Kerbeshian, & Klug, 1999). In one study, a univariate analysis found that SGA infants had an almost tripled risk (*OR*=2.8) of developing autism

(Hultman, Sparen, & Cnattingius, 2002). However, when smoking was included in multivariate analysis, SGA infants faced a doubled risk of developing infantile autism ( $OR=2.0$ ), and compared with infants born to nonsmokers, those born to women who were daily smokers during pregnancy faced a 40% increased risk of developing autism (Hultman et al., 2002). Although the results from this study suggest that smoking and fetal growth may independently influence risk of autism, these findings require confirmation from other studies.

*Childhood cancers.* Tobacco-specific carcinogenics, such as benzene and nitrosamines, probably pass through the placental barrier to the fetus (Norman, Holly, & Preston-Martin, 1996; Welch et al., 1969). Animal experiments support the hypothesis that tobacco smoke exposure during pregnancy may increase an offspring's risk of developing tumors and hyperplasias (Pershagen, 1989). Animal experiments have shown that nitrosamine exposure during pregnancy may cause cancer in the central nervous system among offspring (Rice & Ward, 1982).

In four studies on risk of childhood cancer, information about smoking during pregnancy was collected before onset of disease (Golding, Paterson, & Kinlen, 1990; Klebanoff, Clemens, & Read, 1996; Neutel & Buck, 1971; Pershagen, Ericson, & Otterblad-Olausson, 1992). Only one of these studies, including 33 cases, found that maternal smoking was associated with an increased risk of childhood cancer (Golding et al., 1990).

Results from case-control studies of smoking during pregnancy and overall risk of childhood cancer are contradictory. In a large case-control study, including 555 cases, McKinney & Stiller (1986) found no association between maternal smoking and childhood cancer risk. John, Savitz, and Sandler (1991) investigated 323 cases and found that smoking during pregnancy was associated with a 30% increased risk of childhood cancer, but the findings were not statistically significant. Schwartzbaum et al. (1991) reported a positive association between smoking during pregnancy and the risk of childhood cancer in a large study including 1,270 cases.

Because tobacco smoke includes leukogenic substances, maternal smoking during pregnancy has been studied primarily with regard to risk of leukemia and other cancers in blood and lymphatic tissue. Most studies have not found that smoking is associated with increased risk of childhood lymphatic leukemia (Tredaniel, Boffetta, Little, Saracci, & Hirsch, 1994). Results from studies on maternal smoking and myeloid leukemia are inconclusive, which may be due primarily to the low number of included cases (Cnattingius et al., 1995; Shu et al., 1988; van Duijn, van Steensel-Moll, Coebergh, & van Zanen, 1994).

Similarly, the association between maternal smoking and risk of childhood non-Hodgkin's lymphoma needs to be addressed in larger studies (Adami et al., 1996).

Most studies have not found an association between maternal smoking and risk of childhood brain cancer (Linet et al., 1996; Norman et al., 1996). In a case-control study of neuroblastoma, Buck, Michalek, Chen, Nasca, & Baptiste (2001) found that smoking may increase the risk of neuroblastoma ( $OR=1.6$ ; 95%  $CI=0.9-2.8$ ).

## Discussion

Besides the causal association between smoking and fetal growth restriction, the growing body of literature suggests that smoking is causally related to risks of preterm birth, stillbirth, and placental abruption. First, increased risks are found in virtually all studies; second, a dose-response-relationship between amount smoked and risks are consistently reported; third, smoking cessation influences risk; and finally, likely biological explanations for these associations exist (Ananth et al., 2001; Cnattingius et al., 1999; Li et al., 1993; Meyer & Tonascia, 1977; Raymond et al., 1994; USDHHS, 2001b). It also has been suggested that smoking may cause SIDS, although it is not entirely clear whether risk of SIDS is due to smoking during pregnancy or to passive exposure to smoking after birth or both (Anderson & Cook, 1997; Dwyer et al., 1999). Most studies also find strong associations between smoking and fertility problems, spontaneous abortions, ectopic pregnancies, and placenta previa (USDHHS, 2001b). The association between smoking during pregnancy and subsequent risks of behavioral disorders and cancers needs to be studied further.

The prevalence of smoking during pregnancy is declining in some industrialized countries, such as the United States and Sweden. However, the prevalence of smoking among adolescents appears to have reached a plateau, indicating that smoking prevalence during pregnancy may not continue to decline. Moreover, in Eastern European countries, Mediterranean countries, and probably many countries in South America, smoking is becoming increasingly common among young women (European Network for Smoking Prevention, 1999). Although smoking today is relatively uncommon among women in developing countries (Mackay & Crofton, 1996), given the nature of the smoking epidemic and tobacco industry marketing, growing concern exists over smoking as a third-world epidemic (Mackay, 1996). Thus, smoking will continue to be one of the most important preventable risk factors for unsuccessful pregnancy outcomes.

Reduction of smoking-related adverse pregnancy outcomes requires that existing primary preventive tools, aimed at prevention of youth smoking and cessation of smoking among women of childbearing age, be used efficiently. Although much can be learned from successful prevention programs in various populations (Task Force on Community Preventive Services, 2001; Wakefield & Chaloupka, 2000), these preventive tools also must be developed and adapted to be implemented successfully in different settings to reduce the health consequences of the worldwide smoking epidemic.

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