MARTIN KHARRAZI, PHD ■ DAVID EPSTEIN, MA ■ BARBARA HOPKINS, MA
RICHARD KREUTZER, MD ■ GWENDOLYN DOEBBERT, MA ■ ROBERT HIATT, MD PHD ■ SHANNA SWAN, PHD ■ BRENDA ESKENAZI, PHD ■ JAMES L. PIRKLE, MD PHD ■ JOHN T. BERNERT, PHD

Evaluation of Four Maternal Smoking Questions

Dr. Kharrazi, Mr. Epstein, Ms. Hopkins, Dr. Kreutzer, and Dr. Swan are with the Environmental Health Investigations Branch, California Department of Health Services, Oakland. Ms. Doebbert is with the Center for Health Statistics, California Department of Health Services, Sacramento. Dr. Hiatt is with the Division of Research, Kaiser Permanente Medical Care Program, Oakland. Dr. Eskenazi is with the School of Public Health, University of California at Berkeley. Drs. Pirkle and Bernert are with the Division of Environmental Health Laboratory Sciences, Centers for Disease Control and Prevention, Atlanta.

SYNOPSIS

Objective. The authors evaluated four questions about maternal smoking during pregnancy for use on birth certificates.

Methods. Question 1 (yes/no format) and Question 2 (trimester-specific design) were tested among 1171 women who delivered at two Kaiser Permanente medical centers in northern California. Responses to Questions 1 and 2 were compared with smoking information provided by participants in telephone interviews conducted during pregnancy. Question 3 (multiple choice format) and Question 4 (month- and grouped month–specific design) were tested among 900 women who enrolled in a statewide prenatal screening program and who delivered in 20 hospitals in four Central Valley counties. Responses to Questions 3 and 4 were compared with mid-pregnancy serum cotinine levels. The authors evaluated the four questions in terms of conciseness, response rate, data accuracy, and type of data requested.

Results. Questions 1 and 2 were the most concise. Response rates could not be calculated for Questions 1 and 2. Response rates were 86.0% for Question 3 and 74.2% for Question 4. Sensitivity was 47.3% for Question 1, 62.1% for Question 2, 83.8% for Question 3, and 86.7% for Question 4. The types of data requested by Questions 2 and 4 seem to best satisfy the needs of the broad audience of birth certificate users.

Conclusions. No single question was clearly superior. The authors propose a combination of Questions 2 and 4, which asks about average number of cigarettes smoked per day in the three months before pregnancy and in each trimester of pregnancy.

Address correspondence to:
Dr. Kharrazi, Environmental Health Investigations Branch, CA Dept. of Health Services, 1515 Clay St., 17th Fl., Oakland CA 94612; tel. 510-622-4500; fax 510-622-4505; e-mail <mkharraz@hw1.cahwnet.gov>.

Data on maternal smoking during pregnancy are required for many important public health activities related to tobacco consumption, including surveillance, identification of women at high risk for smoking, program evaluation, and analytic epidemiologic research. In the United States, the vital registration system provides one mechanism for obtaining population-based data on smoking during pregnancy. In 1996, birth certificates from 49 states, the District of Columbia, and New York City included specific questions about maternal smoking during pregnancy (Personal communication, Stephanie J. Ventura, MA, Research Statistician, National Center for Health Statistics [NCHS], 1998).

The wording of smoking questions on birth certificates or other data gathering instruments can affect response rates and the accuracy of responses.[1-3] Potentially threatening questions, such as those about smoking, may be more honestly answered when the question assumes the behavior and asks about frequency or details instead of asking for a yes or no answer about whether the behavior occurred.[4] Also, yes/no questions about smoking during pregnancy can be confusing to the respondent because it is common for women's behavior to change during the course of pregnancy, with some cutting down on the number of cigarettes smoked and others quitting altogether.[5-7]

The utility of a smoking question also depends on the type of data requested. Two of the most important smoking variables affecting pregnancy outcomes are the quantity of cigarettes smoked and the timing of the exposure. Dose-response relationships have been observed between smoking and low birth weight,[8-11] preterm birth[10,12-15] and fetal and infant mortality.[16] The timing of smoking has been shown to be related to low birth weight and certain congenital anomalies. For example, studies have found smoking in the latter half of pregnancy to be more strongly associated with low birth weight than smoking only in the first half of pregnancy.[10,17-19] Shaw et al. found that maternal smoking for a four-month period starting one month before pregnancy was more strongly associated with orofacial clefts than smoking for a shorter duration of time prior to the completion of palate and lip formation and closure.[20]

California, which accounted for approximately 13.9% of all live births in the United States in 1996[21] (including 44.6% of the nation's births to women of Mexican background and 35.1% of all births to Asian women,[21] two groups for whom national smoking data are poor), does not include questions on maternal smoking during pregnancy on its birth certificate. In this paper, we evaluate four different maternal smoking questions. We first summarize the findings of two investigations, conducted in California, in which the questions were tested for accuracy. We then assess the four questions on the basis of conciseness, response rate, data accuracy, and the type of information elicited.

The four smoking questions were chosen to represent a range of question formats, complexity, and detail of information requested.

Question 1, a yes/no-type question, came from the 1989 U.S. Standard Certificate of Live Birth[22] and is currently used by 44 states, the District of Columbia, and New York City (Personal communication, George C. Tolson, Statistician, NCHS, 1998).

Q1. Tobacco use during pregnancy **Yes ☐ No ☐**
Average number cigarettes per day ____

We developed Question 2, a trimester-specific question, after reviewing the US Standard Certificate of Live Birth[22] and the questionnaires used in two epidemiologic studies.[23-24]

Q2. Cigarette smoking during pregnancy (PLEASE ANSWER FOR EACH TIME PERIOD LISTED)

	Average number cigarettes per day (IF NONE, ENTER "0")
First three months	_____
Second three months	_____
Third three months	_____

Question 3, a multiple choice question, was adapted from the work of Mullen et al.[25]

Q3. Which of the following statements best describes your cigarette smoking? (CHECK ONE)

☐ **(1.) I smoke daily now, about the same amount as before finding out I was pregnant.**
☐ **(2.) I smoke daily now, but I've cut down since I found out I was pregnant.**
☐ **(3.) I smoke every once in a while.**
☐ **(4.) I quit smoking since finding out I was pregnant.**
☐ **(5.) I wasn't smoking around the time I found out I was pregnant and I don't currently smoke.**

We derived Question 4 from questions used in three studies of pregnancy outcomes.[20,23,26]

Q4. How many cigarettes did you smoke each day during the... (IF NONE, WRITE IN 0. 1 PACK = 20 CIGARETTES)

	Average number cigarettes smoked per day
1–3 months BEFORE pregnancy?	___ per day
1st month of pregnancy?	___ per day
2nd month of pregnancy?	___ per day
3rd month of pregnancy?	___ per day
4th month of pregnancy?	___ per day
5th month of pregnancy?	___ per day
6th–9th months of pregnancy?	___ per day

Questions 2, 3, and 4—unlike Question 1—assume the smoking behavior and allow the respondent to indicate changes in that behavior. Questions 1, 2, and 4 request specific information on dose, and Questions 2 and 4 request specific information on timing.

METHODS

We conducted two investigations, one of Questions 1 and 2 and the other of Questions 3 and 4. See the Appendix for more detailed information on methods.

In the first investigation, we tested Questions 1 and 2 among 1171 English-speaking women who delivered infants from September 13, 1990, to February 8, 1992 , at two northern California facilities of the Kaiser Permanente Medical Care Program (KPMCP). These study subjects were drawn from a larger group of women who had earlier participated in a prospective epidemiologic study of pregnancy outcomes conducted by the California Department of Health Services and KPMCP's Division of Research.[27] Study subjects answered either Question 1 or Question 2.

In the second investigation, we tested Questions 3 and 4 among 900 women who enrolled in a statewide prenatal screening program in April 1992 and who delivered between July 1 and October 31, 1992 , at 20 hospitals in four contiguous Central Valley, California, counties. Each woman received both Questions 3 and 4, with Question 4 asked immediately after Question 3.

To examine data accuracy, we compared responses to Questions 1 and 2 to self-reported smoking information from prenatal telephone interviews, and responses to Questions 3 and 4 with cotinine levels (a biochemical marker of cigarette smoking)[28] in serum drawn from women during their 15th through 19th weeks of pregnancy. We calculated the following accuracy statistics for each smoking question: sensitivity, specificity, positive predictive value, kappa, and smoking misclassification rate (percentage of reported nonsmokers who actually were smokers, or 100% minus the negative predictive value). We performed each of these calculations for any smoking on Questions 1 and 2, for three definitions of smoking on Question 3, and for smoking during each month or grouped set of months on Question 4.

In addition, for Questions 1 and 2, we examined whether sensitivity was related to the timing of smoking during pregnancy. Also, we examined how reliably the timing of smoking was reported for women who indicated that they smoked in Question 2. For these analyses, data limitations reduced the number of participants.

RESULTS

Questions 1 and 2. In total, 616 women answered Question 1 and 555 women answered Question 2. Both groups consisted primarily of non-teenage women and women with at least a high school education (Table 1).

Response rates for Questions 1 and 2 could not be determined because the number of women asked to participate is unknown. Study participants constituted an estimated 50% of potential recruits (data not shown), and the estimated potential and actual study populations for each question were demographically similar (data not shown).

Altogether, 8.8% of respondents to Question 1 reported that they had smoked during pregnancy, while 18.2% of respondents to Question 1 were classified as smokers according to the prenatal interview (Table 2). Overall, 11.9% of respondents to Question 2 reported smoking during pregnancy, while 18.6% of Question 2 respondents were classified as smokers according to their prenatal interviews. The sensitivity of Question 1 was 47.3% compared with 62.1% for Question 2 ($P = 0.03$ for difference in sensitivity rates). Both questions had specificity levels and positive predictive values of at least 97.0%. We found a higher kappa level and a lower smoking misclassification rate for Question 2 than for Question 1 (Table 3).

Based on data from a subsample of 83 women (see Appendix), the likelihood that a woman reported herself as a smoker on Question 1 or Question 2 was related to the timing of smoking during pregnancy. Women who smoked into the third trimester, as self-reported in prenatal interviews, were much more likely to identify themselves as smokers when responding to Questions 1 or 2 (sensitivity = 100%) than women who smoked only in the first trimester (sensitivity = 28.6% for Question 1 and 41.7% for Question 2) (Table 4). For the small number of women who reported in the prenatal interviews that they stopped smoking prior to the third trimester, Question 2 achieved higher sensitivity (48.1%) than Question 1 (32.0%).

Table 1. Respondents to four maternal smoking questions, by age and education level

Characteristic	Question 1 n = 616		Question 2 n = 555		Question 3 n = 899		Question 4 n = 775	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Age at time of delivery (years)								
<20	8	1.3	15	2.7	148	16.5	123	15.9
20–29	323	52.4	305	55.0	521	58.0	450	58.1
≥30	285	46.3	235	42.3	230	25.6	202	26.1
Education level[a]								
Less than high school graduate	25	4.1	29	5.2	282	31.4	238	30.7
High school graduate	196	31.8	169	30.5	326	36.3	279	36.0
More than high school	395	64.1	357	64.3	291	32.4	258	33.3

NOTES: Questions 1 and 2 were administered to 1171 English-speaking women who delivered infants from September 13, 1990, to February 8, 1992, at two northern California facilities of the Kaiser Permanente Medical Care Program. Questions 3 and 4 were administered to 900 women who enrolled in a statewide prenatal screening program in April 1992 and who delivered between July 1 and October 31, 1992, at 20 hospitals in four contiguous Central Valley, California, counties. Percentages may not add to 100 due to rounding errors.

[a] Education level at first trimester for Questions 1 and 2, and at time of birth for Questions 3 and 4

Table 2. Smoking status as self-reported in prenatal telephone interviews, by smoking status self-reported in response to Questions 1 and 2

Smoking status self-reported in prenatal interviews	Smoking status self-reported on Question 1 n = 616						Smoking status self-reported on Question 2 n = 555					
	Smoker		Nonsmoker		Total		Smoker		Nonsmoker		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Smoker	53	8.6	59	9.6	112	18.2	64	11.5	39	7.0	103	18.6
Nonsmoker	1	0.2	503	81.7	504	81.8	2	0.4	450	81.1	452	81.4
Total	54	8.8	562	91.2	616	100.0	66	11.9	489	88.1	555	100.0

NOTE: Percentages may not add to 100 due to rounding errors.

Data were available on 28 women to examine the timing of smoking reported in Question 2 (see Appendix). Agreement between Question 2 and the prenatal interviews on whether smoking occurred was 89.3% for the first trimester, 82.1% for the second trimester, and 89.3% for the third trimester.

Questions 3 and 4. Of a total of 900 respondents, 774 answered both Questions 3 and 4, 125 answered Question 3 only, and one woman answered Question 4 only. Respondents to Questions 3 and 4 were more diverse in terms of age and education than respondents to Questions 1 and 2 (Table 1). Response rates were 86.0% for Question 3 and 74.2% for Question 4.

Question 3. Thirteen percent of Question 3 respondents had cotinine levels in the fourth to fifth months of pregnancy consistent with cigarette smoking. According to Question 3, 9.0% to 18.6% were defined as smokers, depending on which definition of smoking was used (see Table 5). The best overall agreement with cotinine levels (kappa = 73.1%) was achieved with the intermediate smoking definition (responses 1–3). The highest specificity level (98.8%) and positive predictive value (88.9%) were found with the most restrictive smoking definition (responses 1 and 2), and the highest sensitivity level (83.8%) and lowest rate of smoking misclassification (2.6%) were obtained with the broadest smoking definition (responses 1–4) (Table 6).

Question 4. Approximately 13.5% of Question 4 respondents had cotinine levels consistent with cigarette smoking in the fourth to fifth months of pregnancy (Table 7). The percentage of women who described themselves as smokers in response to Question 4 generally decreased for each successive month of pregnancy or grouped set of months from 18.2% during the one to three months before pregnancy to

Table 3. Selected statistical findings: investigation of Questions 1 and 2

Statistic	Question 1 Percent	Question 2 Percent
Sensitivity	47.3	62.1
Specificity	99.8	99.6
Positive predictive value	98.1	97.0
Kappa	59.0	71.6
Smoking misclassification rate	10.5	8.0

11.8% during months 6–9 of pregnancy. The highest kappas were achieved for responses about smoking during the third, fourth, and fifth months of pregnancy. The highest specificity levels and positive predictive values were found for responses about smoking during the fourth and fifth months of pregnancy. The highest sensitivity level and the lowest smoking misclassification rate were observed for responses about smoking during the three months before pregnancy (Table 8).

Kappa levels, specificity, and positive predictive value were all greatest for responses about smoking during the fourth and fifth months of pregnancy (Table 8), the period when the blood specimens were drawn, providing evidence that the women accurately recalled the timing of smoking in mid-pregnancy.

DISCUSSION

In what follows, we evaluate the four smoking questions and propose a new smoking question for future study and possible use.

Conciseness. Physical space limitations on birth certificates, costs associated with data entry and storage, and time to complete smoking questions are practical concerns. The relative conciseness of Questions 1 and 2 gives them an advantage over Question 3 and especially Question 4. This advantage could be tempered, however, by the use of universal worksheets so that only space for responses would be needed on birth certificates, or by electronic registration of births.

Response rate. Evidence suggests that response rates tend to decrease as questions increase in complexity.[29] Thus, Question 1 might be expected to have the highest response rate, Question 2 the next highest, followed by Question 3, and Question 4 the lowest.

Response rates could not be calculated for our investigation of Questions 1 and 2. In 1996 national data, the overall response rate for 46 states, the District of Columbia, and New York City, nearly all of which used Question 1, was 98.4%.[21]

We found a higher response rate for Question 3 (86.0%) than for Question 4 (74.2%). To some extent the difference may be due to Question 3 having been asked immediately before Question 4. It is possible that Question 3 respondents thought they had already provided enough smoking information and thus chose not to answer Question 4.

Response rates for Questions 3 and 4 may have been adversely influenced by the questions' position on the questionnaire. Questions 3 and 4 followed seven other questions on topics such as weight, language spoken at home, and months of pregnancy working outside the home. Response rates would probably have been higher if either of the smoking questions had been an actual part of the birth certificate, but this remains to be tested.

Table 4. Timing of smoking during pregnancy as self-reported in prenatal telephone interviews and sensitivity rates for Questions 1 and 2

Timing of smoking as self-reported in prenatal interviews	Question 1 n = 43 Number of smokers[a]	Question 1 n = 43 Sensitivity Percent	Question 2 n = 40 Number of smokers[a]	Question 2 n = 40 Sensitivity Percent
First trimester only[b]	21	28.6	24	41.7
First and second trimesters only[c]	4	50.0	3	100.0
First, second and third trimesters[d]	18	100.0	13	100.0

[a] As self-reported in prenatal telephone interviews
[b] All or part of the first trimester
[c] All or part of the first and part of the second trimester
[d] All or part of the first trimester, all of the second trimester, and all or part of the third trimester

We found evidence of response bias in Question 4. There was a larger percentage of women who were quitters according to Question 3 (14%) among those who answered Question 3 but not Question 4 than among those who answered both questions (5%, $P < 0.001$). By the time that serum specimens were drawn from the women in mid-pregnancy, cotinine distributions were similar for those who did and did not respond to Question 4. Together, these findings indicate that women who quit smoking in the first trimester may be less likely to respond to Question 4 than other types of smokers and nonsmokers.

We expect that response rates in the Questions 1 and 2 investigation, had they been possible to obtain, would be higher than in the Questions 3 and 4 investigation given the older maternal age and greater educational attainment of those responding to Questions 1 and 2.

Data accuracy. Misclassification of smoking is likely to go in only one direction—underreporting of smoking (smokers falsely identifying themselves as nonsmokers). The most accurate smoking question exhibits the highest level of sensitivity and the lowest smoking misclassification rate, and thus identifies the highest prevalence of smoking in the population. Unfortunately, we cannot compare the four smoking questions to assign an accuracy ranking because factors that could affect the results, including criteria standards (self-reports on prenatal telephone interviews and serum cotinine levels), test sites, and study populations, were not uniform across the two investigations. Instead, we make separate comparisons of Questions 1 and 2 and of Questions 3 and 4.

Both Questions 1 and 2 had low sensitivity. This translates into substantial underreporting for both questions, although the percentage of smokers who underreported was greater for Question 1 (52.7%) than for Question 2 (37.9%).

Sensitivity levels were similar for the broadest definition of smoking in Question 3 and smoking in the three months before pregnancy in Question 4. These translate into moderate levels of underreporting (16.2% for Question 3 and 13.3% for Question 4). Underreporting was higher for the

Table 5. Smoking status according to serum cotinine levels, by smoking status self-reported in response to Question 3 for three definitions of smoking

Smoking status per serum cotinine levels	*Smoking status self-reported on Question 3*				*Total*	
	Smoker		*Nonsmoker*			
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*
	Smoker = Responses 1–4; Nonsmoker = Response 5					
Smoker (>10 ng/mL)	98	10.9	19	2.1	117	13.0
Nonsmoker	69	7.7	713	79.3	782	87.0
Total	167	18.6	732	81.4	899	100.0
	Smoker = Responses 1–3; Nonsmoker = Responses 4–5					
Smoker (>10ng/mL)	86	9.6	31	3.4	117	13.0
Nonsmoker	22	2.4	760	84.5	782	87.0
Total	108	12.0	791	88.0	899	100.0
	Smoker = Responses 1–2; Nonsmoker = Responses 3–5					
Smoker (>10 ng/mL)	72	8.0	45	5.0	117	13.0
Nonsmoker	9	1.0	773	86.0	782	87.0
Total	81	9.0	818	91.0	899	100.0

NOTE: Percentages may not add to 100 due to rounding errors.

Response 1 = I smoke daily now, about the same amount as before finding out I was pregnant.

Response 2 = I smoke daily now, but I've cut down since I found out I was pregnant.

Response 3 = I smoke every once in a while.

Response 4 = I quit smoking since finding out I was pregnant.

Response 5 = I wasn't smoking around the time I found out I was pregnant and I don't currently smoke.

Table 6. Selected statistical findings, by definition of smoking: investigation of Question 3

Statistic	Definition of smoking: Smoker = Responses 1–4 Nonsmoker = Response 5	Smoker = Responses 1–3 Nonsmoker = Responses 4–5	Smoker = Responses 1–2 Nonsmoker = Responses 3–5
	Percent	Percent	Percent
Sensitivity	83.8	73.5	61.5
Specificity	91.2	97.2	98.8
Positive predictive value	58.7	79.6	88.9
Kappa	63.4	73.1	69.5
Smoking misclassification rate	2.6	3.9	5.5

Response 1 = I smoke daily now, about the same amount as before finding out I was pregnant.

Response 2 = I smoke daily now, but I've cut down since I found out I was pregnant.

Response 3 = I smoke every once in a while.

Response 4 = I quit smoking since finding out I was pregnant.

Response 5 = I wasn't smoking around the time I found out I was pregnant and I don't currently smoke.

other Question 3 smoking definitions and for the other time periods asked about in Question 4 (range 18.3% to 38.5%).

Three published studies provide additional information about Question 1. Sensitivity ranged from 73.5% to 78.0% in a Tennessee study[30] and was 86.0% in a North Carolina investigation.[31,32] In a Georgia study, the prevalence of smoking during pregnancy was 17.7% using Question 1 and estimated to be 25.6% based on additional information.[33] The low sensitivity in the Tennessee investigation and the large difference in prevalence rates in the Georgia study suggest a high degree of underreporting of smoking in these studies.

From the Questions 1 and 2 investigation, there is evidence, although based on small numbers, that Question 2 was more sensitive than Question 1 among women who stopped smoking prior to the third trimester. When given the opportunity to do so, some quitters may note that they have quit, thereby portraying themselves favorably, instead of either not responding or misclassifying themselves as nonsmokers in answer to a yes/no question. Unlike Question 1, Questions 2, 3, and 4 provide women the opportunity to show that they have quit smoking. Questions 2, 3, and 4 also provide nonquitters the opportunity to show that they have cut down on their smoking during pregnancy.

Questions 2, 3 and 4 also may be advantageous because their wording assumes the smoking behavior. In a Missouri time trend study, pregnant women's self-reported smoking rate declined faster than expected when the smoking question changed from "Cigarettes smoked per day?" (followed by three choices of amount smoked) to Question 1.[34] Mullen et al. found that a version of Question 3 used at the first prenatal visit increased smoking disclosure by 40% in a multi-specialty group practice compared with a yes/no-type smoking question.[25]

The criteria standards we used in evaluating the smoking questions for reporting accuracy were not ideal. In the Questions 1 and 2 investigation, smokers may have identified themselves as nonsmokers during prenatal telephone interviews. If so, the sensitivity levels reported here for Questions 1 and 2 are overestimates and the smoking misclassification and underreporting rates are underestimates. In the Questions 3 and 4 investigation, the usefulness of a single cotinine value obtained from serum drawn in the fourth to fifth month of pregnancy is limited by the relatively short half-life of cotinine. Women who quit or who smoked once in a while or who happened not to smoke for a number of days prior to the blood draw may not have been identified as pregnant smokers according to their cotinine values. Describing themselves as smokers would have lowered the specificity and positive predictive value of Questions 3 and 4. This can be seen from the low positive predictive values obtained for the broadest definition of smoking for Question 3 (responses 1–4) and for smoking in the three months before pregnancy for Question 4. If women who quit, smoked once in a while, or happened not to smoke for a number of days prior to the blood draw described themselves as nonsmokers, this would have spuriously inflated the sensitivity and lowered the rates of smoking misclassification and underreporting for the smoking question.

In the Questions 3 and 4 investigation, sensitivity levels may have been overestimated and smoking misclassification and underreporting rates may have been underestimated for Question 4 because it followed Question 3. The combination of Questions 3 and 4 may yield a higher sensitivity level and lower smoking misclassification rate than Question 4 alone because the design of Question 3 may have encouraged reluctant smokers to respond affirmatively to being a smoker.

Type of information elicited. Effective planning and evaluation of public health programs and population-based research require information not only on smoking prevalence but also on dose and timing. For example, an evaluation of interventions aimed at stopping smoking in pregnant women would be aided greatly by knowledge about patterns of quitting and quantities of cigarettes smoked over the course of the pregnancy. Additionally, estimates of the

Table 7. Smoking status according to serum cotinine levels, by smoking status self-reported in response to Question 4

Smoking status per serum cotinine levels	Smoking status self-reported on Question 4: Smoker, Number	Smoker, Percent	Nonsmoker, Number	Nonsmoker, Percent	Total, Number	Total, Percent
During 3 months before pregnancy						
Smoker (>10 ng/mL)	91	11.7	14	1.8	105	13.5
Nonsmoker	50	6.5	620	80.0	670	86.5
Total	141	18.2	634	81.8	775	100.0
During month 1 of pregnancy						
Smoker (>10 ng/mL)	85	11.0	19	2.5	104	13.5
Nonsmoker	35	4.5	632	82.0	667	86.5
Total	120	15.6	651	84.4	771	100.0
During month 2 of pregnancy						
Smoker (>10 ng/mL)	81	10.6	22	2.9	103	13.4
Nonsmoker	22	2.9	641	83.7	663	86.6
Total	103	13.4	663	86.6	766	100.0
During month 3 of pregnancy						
Smoker (>10 ng/mL)	81	10.6	21	2.7	102	13.4
Nonsmoker	15	2.0	647	84.7	662	86.6
Total	96	12.6	668	87.4	764	100.0
During month 4 of pregnancy						
Smoker (>10 ng/mL)	81	10.6	22	2.9	103	13.5
Nonsmoker	11	1.4	651	85.1	662	86.5
Total	92	12.0	673	88.0	765	100.0
During month 5 of pregnancy						
Smoker (>10 ng/mL)	79	10.4	23	3.0	102	13.4
Nonsmoker	9	1.2	651	85.4	660	86.6
Total	88	11.5	674	88.5	762	100.0
During months 6–9 of pregnancy						
Smoker (>10 ng/mL)	75	9.8	27	3.5	102	13.4
Nonsmoker	15	2.0	647	84.7	662	86.6
Total	90	11.8	674	88.2	764	100.0

NOTE: Percentages may not add to 100 due to rounding errors.

strength of association between smoking and adverse pregnancy outcomes and of population attributable risks are most precise if information on dose and timing of smoking is available. As well, detailed smoking data could be cost-effectively linked with data from birth defect or cancer registries.

Only Questions 2 and 4 request specific information on dose and timing; thus they provide more useful information than Questions 1 and 3. An additional advantage of Question 4 is its inquiry into smoking in the three months before pregnancy. By asking about smoking in the three months before pregnancy it may be possible to obtain valuable information about smoking early in pregnancy from women who otherwise might not report smoking during pregnancy. Of the 14 women who reported in response to Question 4 that they were smokers in the one to three months before pregnancy but not during their pregnancies, 13 (92.9%)

Table 8. Selected statistical findings: investigation of Question 4

Statistic	3 months before pregnancy	Month 1 of pregnancy	Month 2 of pregnancy	Month 3 of pregnancy	Month 4 of pregnancy	Month 5 of pregnancy	Months 6–9 of pregnancy
	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Sensitivity	86.7	81.7	78.6	79.4	78.6	77.5	73.5
Specificity	92.5	94.8	96.7	97.7	98.3	98.6	97.7
Positive predictive value	64.5	70.8	78.6	84.4	88.0	89.8	83.3
Kappa	69.2	71.8	75.3	79.1	80.6	80.8	75.0
Smoking misclassification rate	2.2	2.9	3.3	3.1	3.3	3.4	4.0

said in response to Question 3 that they had quit smoking since finding out they were pregnant. This suggests that they are likely to have been smokers during the first few weeks of pregnancy, important information in an investigation of the effects of smoking on organogenesis.

Our results suggest that women who identified themselves as smokers generally reported reliably on the timing of their smoking in response to Question 2 and validly on smoking in mid-pregnancy in response to Question 4. However, the amount smoked may not be accurately dated. For example, the correlation between number of cigarettes smoked and cotinine values was highest for the third month of pregnancy, not for the fourth or fifth month, when the serum was drawn (data not shown). Further validation studies of cigarette dose and timing are indicated.

Proposed new question. Our evidence suggests that the accuracy of data on maternal smoking during pregnancy can be enhanced by questions that: (*a*) give women who stop smoking during pregnancy the opportunity to show their change in behavior, (*b*) inquire about smoking before the pregnancy, and (*c*) ask about smoking by assuming the behavior. An ideal smoking question would include these features and also be concise, achieve high response rates, and provide accurate information on dose and timing.

None of the four smoking questions was ideal, but some were better than others. First, we found Question 2 to be superior to Question 1. When we compared them, we found less underreporting of smoking with Question 2 than with Question 1. In addition, Question 2 obtains reliable information on timing of smoking, which is unavailable from Question 1. Although we could not assess the response rate for Question 2, the question appears to be sufficiently simple and concise to elicit a high response rate.

Despite potentially acceptable levels of underreporting, both Questions 3 and 4 are unlikely candidates for inclusion on the birth certificate. One problem is that they require too much space. This problem could be overcome to a large degree by the previously suggested remedies; however, even if the space problem were solved, the questions have other limitations. Question 3 does not provide enough detail on dose and timing. (Question 3 might be acceptable if the goal of the birth certificate question is limited to identifying the mother as a smoker or nonsmoker during pregnancy.) Question 4 has the potential for a low—and possibly biased—response rate.

While Question 2 has many advantages, its low sensitivity prevents us from recommending it for use on the birth certificate. However, modifying Question 2 as follows, by incorporating the first part of Question 4, which asks about smoking in the three months before pregnancy, might reduce underreporting.

Cigarette Smoking Before and During Pregnancy
(PLEASE ANSWER FOR EACH TIME PERIOD LISTED)

	Average number cigarettes per day (IF NONE, ENTER "0." 1 pack = 20 cigarettes)
Three months before pregnancy	_____
First three months of pregnancy	_____
Second three months of pregnancy	_____
Third three months of pregnancy	_____

This proposed question is moderate in complexity, is designed to maximize ascertainment, and provides information on the timing of smoking during pregnancy and number of cigarettes smoked. Currently, at least two states include aspects of the proposed question on their birth certificates. Massachusetts requests information on smoking for the one year prior to pregnancy, and Utah requests trimester-specific smoking information.

Before its implementation on the birth certificate or shortly thereafter, this proposed smoking question should

be evaluated in culturally diverse populations with differing smoking prevalence rates using the best possible criteria standards. In addition, the accuracy of dose information should be assessed, which was not done here.

Questions 1 and 2. The authors thank the Medical Records Department supervisors and birth recorders from the participating Kaiser Permanente Medical Centers for their cooperation in testing the smoking questions, and Julie Von Behren and Geraldine Lee and her staff for additional data collection.

Questions 3 and 4. Lynn Goldman, George Cunningham, Robert Haas, and Enid Satariano were co-investigators on this project. Theresa Saunders assisted with preparation of training and questionnaire materials. Birth recorders and supervisors in the 20 participating hospitals collected questionnaire data. Staff from the California Office of State Registrar, led by David Mitchell and Michael Davis, and from the Fresno, Kern, Kings, and Tulare County Registrars' Offices processed the supplemental questionnaires.

This project was aided by Reproductive Hazards in the Workplace, Home, Community, and Environment Research Grant Nos. 15-FY92-0078 and 15-FY93-0662 from the March of Dimes Birth Defects Foundation to the Public Health Institute.

References

1. Bradburn NM, Sudman S, Blair E, Locander W, Miles C, Singer E, Stocking C. Improving interview method and questionnaire design: response effects to threatening questions in survey research. San Francisco: Jossey-Bass; 1979.
2. Sudman S, Bradburn NM. Asking questions: a practical guide to questionnaire design. San Francisco: Jossey-Bass; 1988.
3. Starzyk, PM. Data quality: 1989 revision of the Washington State Birth Certificate. Olympia: Washington State Department of Health, Health Information Division; 1991 Oct.
4. Sheatsley PB. Questionnaire construction and item writing. In: Rossi PH, Wright JD, Anderson AB, editors. Handbook of survey research. New York: Academic Press; 1983. p. 215-16.
5. Prager K, Malin H, Spiegler D, Natta PV, Placek PJ. Smoking and drinking behavior before and during pregnancy of married mothers of live-born infants and stillborn infants. Public Health Rep 1984;99:117-27.
6. Johnson SF, McCarter RJ, Ferencz C. Changes in alcohol, cigarette, and recreational drug use during pregnancy: implications for intervention. Am J Epidemiol 1987;126:695-702.
7. Fingerhut LA, Kleinman JC, Kendrick JS. Smoking before, during and after pregnancy. Am J Public Health 1990;80:541-4.
8. Abel EL. Smoking during pregnancy: a review of effects on growth and development of offspring. Hum Biol 1980;52:593-625.
9. Kleinman JC, Madans JH. The effects of maternal smoking, physical stature, and educational attainment on the incidence of low birth weight. Am J Epidemiol 1985;121:843-855.
10. McDonald AD, Armstrong BG, Sloan M. Cigarette, alcohol, and coffee consumption and prematurity. Am J Public Health 1992;82:87-90.
11. Ventura SJ, Martin JA, Taffel SM, Mathews TJ, Clarke SC. Advance report of final natality statistics, 1993. Monthly Vital Statistics Report Vol. 44, No. 3 (Suppl). Hyattsville (MD): National Center for Health Statistics (US); 1995.
12. Fedrick J, Anderson ABM. Factors associated with spontaneous pre-term birth. Br J Obstet Gynaecol 1976;83:342-50.
13. Meyer MB, Jonas BS, Tonascia JA. Perinatal events associated with maternal smoking during pregnancy. Am J Epidemiol 1976;103:464-76.
14. Berkowitz GS, Holford TR, Berkowitz RL. Effects of cigarette smoking, alcohol, coffee, and tea consumption on preterm delivery. Early Hum Dev 1982;7:239-50.
15. Shiono PH, Klebanoff MA, Rhoads GG. Smoking and drinking during pregnancy: their effects on preterm birth. JAMA 1986;255:82-4.
16. Kleinman JC, Pierre MB, Jr, Madans JH, Land GH, Schramm WF. The effects of maternal smoking on fetal and infant mortality. Am J Epidemiol 1988;127:274-82.
17. Butler N, Goldstein H, Ross E. Cigarette smoking in pregnancy: its influence on birth weight and perinatal mortality. BMJ 1972;2:127-30.
18. Rush D, Cassano P. Relationship of cigarette smoking and social class to birth weight and perinatal mortality among all births in Britain, 5-11 April 1970. J Epidemiol Comm Health 1983;37:249-55.
19. Hebel JR, Fox NL, Sexton M. Dose-response of birth weight to various measures of maternal smoking during pregnancy. J Clin Epidemiol 1988;41:483-9.
20. Shaw GM, Wasserman CR, Lammer EJ, O'Malley CD, Murray JC, Basart AM, Tolarova MM. Orofacial clefts, parental cigarette smoking, and transforming growth factor-alpha gene variants. Am J Hum Genet 1996;58:551-61.
21. Ventura SJ, Martin JA, Curtin SC, Mathews TJ. Report of final natality statistics, 1996. Monthly Vital Statistics Report Vol. 43, No. 11 (Suppl). Hyattsville (MD); National Center for Health Statistics (US); 1998.
22. National Center for Health Statistics (US). U.S. Standard Certificate of Live Birth. Revision 1/89. Washington: Department of Health and Human Services; 1989.
23. Deane M, Swan SH, Harris JA, Epstein DM, Neutra RR. Adverse pregnancy outcomes in relation to water contamination, Santa Clara County, California, 1980–1981. Am J Epidemiol 1989;129:894-904.
24. Wrensch M, Swan S, Lipscomb J, Epstein D, Fenster L, Claxton K, et al. Pregnancy outcomes in women potentially exposed to solvent-contaminated drinking water in San Jose, California. Am J Epidemiol 1990;131:283-300.
25. Mullen PD, Carbonari JP, Tabak ER, Glenday MC. Improving disclosure of smoking by pregnant women. Am J Obstet Gynecol 1991;165:409-13.
26. Lemasters GK. Female reproductive health history. Cincinnati (OH): Kettering Laboratory, Department of Environmental Health, University of Cincinnati College of Medicine; 1983.
27. Fenster L, Schaefer C, Mathur A, Hiatt RA, Pieper C, Hubbard AE, Von Behren J, Swan SH. Psychologic stress in the workplace and spontaneous abortion. Am J Epidemiol 1995;142:1176-83.
28. Benowitz NL. Pharmacologic aspects of cigarette smoking and nicotine addiction. N Engl J Med 1988;319:1318-30.
29. Bailey KD. Methods of social research. New York: Free Press; 1978.
30. Piper JM, Mitchel EF Jr, Snowden M, Hall C, Adams M, Taylor P. Validation of 1989 Tennessee birth certificates using maternal and newborn hospital records. Am J Epidemiol 1993;137:758-68.
31. Buescher PA, Taylor KP, Davis MH, Bowling JM. The quality of the new birth certificate data: a validation study in North Carolina. Am J Public Health 1993;83:1163-5.
32. Buescher PA. Smoking in pregnancy in North Carolina: maternal characteristics and trends, 1988–1994. N C Med J 1997;58:356-60.
33. Dietz P, Adams M, Rochat R, Mathis M. Does the accuracy of prenatal smoking on Georgia birth certificates vary by infant birth weight? Am J Epidemiol 1997;145(11 Suppl):S39.
34. Stockbauer JW, Land GH. Changes in characteristics of women who smoke during pregnancy: Missouri, 1978-88. Public Health Rep 1991;106:52-8.
35. Benowitz NL, Jacob P. Daily intake of nicotine during cigarette smoking. Clin Pharmacol Ther 1984;35:499-504.
36. Bernert JT Jr, Turner WE, Pirkle JL, Sosnoff CS, Akins JR, Waldrep MK, et al. Development and validation of sensitive method for determination of serum cotinine in smokers and nonsmokers by liquid chromatography/atmospheric pressure ionization tandem mass spectrometry. Clin Chem 1997;43:2281-91.■

APPENDIX
TESTING THE SMOKING QUESTIONS

Questions 1 and 2. We tested Questions 1 and 2 among 1171 English-speaking women who delivered infants from September 13, 1990, to February 8, 1992 , at two northern California facilities of the Kaiser Permanente Medical Care Program (KPMCP). Respondents had earlier participated in a prospective study of pregnancy outcomes (POS) conducted by the California Department of Health Services (CDHS) and the KPMCP Division of Research.[27]

For POS, respondents were interviewed by telephone during the first trimester of pregnancy by the Survey Research Center at the University of California at Berkeley. Participants were queried about frequency of smoking during the seven days that began with the first day of their last menstrual period (LMP) and during the seven days prior to the interview.

CDHS and KPMCP staff conducted second telephone interviews with a sample of those participating in the first telephone interviews during the sixth month post-LMP or later, usually prior to delivery. The second interview asked about smoking behavior for each month of pregnancy thus far completed.

All respondents to Question 1 or 2 had first interviews, and second interviews were conducted with 37.7% of Question 1 respondents and 38.2% of Question 2 respondents.

Question 1 or 2 was administered, along with questions about weight gain and use of medications during pregnancy, while the women were still in the hospital. With few exceptions, responses were obtained within one day after delivery. Hospital birth recorders read the questions to participants or distributed questionnaires to study subjects for self-administration. The birth recorders attached copies of the birth certificates to the completed questionnaires.

We calculated sensitivity, specificity, positive predictive value, kappa, and the smoking misclassification rate using smoking information from the first interview as the criteria standard for smoking status during pregnancy. A woman was classified as a smoker if she reported smoking during either or both seven-day periods, and as a nonsmoker if she reported not smoking during both periods. For the analysis of sensitivity and timing of smoking (Table 4) and the examination of timing reported in Question 2, the criteria standard for each participant was a smoking history covering the entire pregnancy. The history was based on smoking data from the first and second interviews, with precedence given to the first interview for first trimester smoking information. We assumed that the woman's smoking behavior at the time of the second interview continued until delivery.

The analysis of sensitivity and timing of smoking was limited to the 83 women for whom a smoking history was available and who reported having smoked during pregnancy. The examination of timing reported on Question 2 was limited to the 28 women who reported any smoking on Question 2 and for whom a smoking history was available.

The demographic data in Table 1 for Questions 1 and 2 were based on information from POS and birth certificates.

Questions 3 and 4. We tested Questions 3 and 4 among 900 women who enrolled in a statewide prenatal screening program in April 1992 and who delivered between July 1 and October 31, 1992 , at 20 hospitals in four contiguous Central Valley, California, counties. This investigation was part of a population-based study of the mothers of approximately 13,000 infants delivered during the study period.

Of a total of 1463 women from the four counties who enrolled in California's statewide maternal serum alpha-fetoprotein prenatal screening program in April 1992, a total of 1287 could be linked to a live birth certificate. Of these, 1045 completed one or more questions on the study questionnaire and were residents of the four-county study region at the time of delivery. For this paper, the final study population consisted of 900 (86.1%) enrollees who responded to one or both of the smoking questions.

The questionnaire was one page in length and bilingual (one side in English and the other side in Spanish). Birth recorders administered the questionnaire soon after the birth when data were collected for the birth certificate. As in the Questions 1 and 2 investigation, birth recorders read the questions to the women or the women completed the questionnaire in writing. The birth recorders attached the completed questionnaires to the birth certificates before they were filed with county registrars.

The demographic data in Table 1 for Questions 3 and 4 were based on information from birth certificates.

As the criteria standard, we used cotinine levels in maternal serum drawn between 15 and 19 weeks gestation for the prenatal screening program. Cotinine is a principal metabolite of nicotine with an average serum half-life of 20 hours. Cotinine concentrations reflect an individual's daily consumption of nicotine.[35] Maternal blood was obtained via venous puncture in serum separator tubes, banked at –20 degrees Centigrade for up to four years, and the serum then laboratory analyzed for cotinine. Cotinine analyses were conducted by the Division of Environmental Health Laboratory Sciences, Centers for Disease Control and Prevention, Atlanta, Georgia, using a highly sensitive isotope dilution high performance liquid chromatographic-atmospheric pressure chemical ionization tandem mass spectrometry method developed by the Division.[36] Serum specimens were analyzed in runs of 50, which included two water blanks and two quality control pool sera. Eleven per cent of the specimens were randomly selected for repeat analysis, and excellent agreement was found. The limit of detection, calculated as three times the limiting standard deviation from repetitive standards analyses, was 0.05 nanogram (ng) cotinine per milliliter (mL) serum. We calculated sensitivity, specificity, positive predictive value, kappa, and the smoking misclassification rate using a 10 ng cotinine per mL serum cutoff point to define smokers and nonsmokers. Increasing or decreasing the cutoff point by 5 ng per mL did not change the study findings.