The authors investigated the association of smoking and smoking cessation with the incidence of cataract extraction in a population-based prospective cohort study. A total of 34,595 women aged 49–83 years in the Swedish Mammography Cohort were followed from September 1997 through June 2002. Information on smoking, diet, and other lifestyle factors was collected through a self-administered questionnaire. A total of 2,128 cases of age-related cataract extraction were identified. Relative risks were estimated as rate ratios using Cox proportional hazards models. The authors observed a significant dose-response association between intensity of smoking and risk of cataract extraction (among current smokers, \( p \) for trend = 0.02; among past smokers, \( p \) for trend = 0.0002).

After cessation of smoking, the risk decreased with time. Among women with a moderate lifetime smoking intensity (6–10 cigarettes/day), the relative risk was not significantly different from the risk among never smokers 10 years after smoking cessation. Among women who had smoked more intensively (>10 cigarettes/day), after 20 years of nonsmoking the increased risk became small and no longer statistically significant in comparison with never smokers (for trend over time, \( p < 0.0001 \)). This prospective study confirmed smoking as a risk factor for cataract, with a dose response for smoking intensity. Smoking cessation predicts reduced risk over time, but a longer period of time is needed with a higher smoking intensity.

cataract; cohort studies; smoking; smoking cessation

Abbreviations: CI, confidence interval; RR, rate ratio.

Cataract is highly prevalent in the elderly, with social consequences involving decreased vision and deteriorated quality of life. It is the most common cause of blindness in the world (1). The only currently available treatment is surgical extraction of the lens.

Epidemiologic studies have shown that the etiology of cataract is multifactorial and that incidence increases with advancing age (2–13). Oxidative damage to lens proteins is suggested to be of importance (14).

Cigarette smoking, which potentially increases oxidative stress in the lens, has been associated with an increased risk of cataract in the majority of cross-sectional (5, 10, 11), case-control (8, 12, 15), and cohort studies (2, 7, 9, 13, 16–22), although the findings are not entirely consistent (23, 24). The effect of smoking cessation on cataract development is not clear. Some studies (25–27), but not all (21), have shown that former smokers have a decreased risk of cataract in comparison with current smokers. However, to our knowledge, none of the previous studies evaluated the effect of smoking cessation and time since quitting smoking on the risk of cataract in comparison with never smokers.

To address further whether any benefit is obtained from quitting smoking, we examined prospectively the associations of smoking and time since quitting smoking with...
incidence of cataract extraction in a population-based cohort of 34,595 women aged 49–83 years.

MATERIALS AND METHODS
The Swedish Mammography Cohort

Between March 1987 and December 1990, women living in two counties in central Sweden were recruited to enter the Swedish Mammography Cohort. All women living in Uppsala County who were born between 1914 and 1948 and all women living in Västmanland County who were born between 1919 and 1948 received an invitation, by mail, to participate in a population-based mammography screening program and to fill in a self-administered questionnaire regarding diet, height, weight, parity, and educational level. The questionnaires were completed prior to mammography, and answers were obtained from 74 percent of the source population. After exclusion of women with a previous cancer diagnosis, the Swedish Mammography Cohort included 61,433 women at baseline in 1987–1990.

In September 1997, a follow-up questionnaire was mailed to 56,030 women who remained in the cohort after exclusion of those who had died or permanently moved out of the study area. The questionnaire included 350 items concerning cigarette smoking, diet, alcohol consumption, vitamin supplement use, physical activity, weight, height, reproductive factors, use of some medications, educational level, and diagnosis of hypertension and diabetes. Reminder letters were mailed to nonrespondents in November 1997 and February 1998. A total of 39,227 women (70 percent) returned the questionnaire (219 women were too sick to fill in the questionnaire, 548 refused to answer, and 16,036 did not respond at all). We excluded women whose questionnaires contained incorrect or missing personal identification numbers (n = 243); this yielded an identifiable cohort of 38,984 women. For this analysis, we excluded all women with a diagnosis of cancer (other than nonmelanoma skin cancer) (n = 1,738) and those who had undergone cataract extraction (n = 88) before the start of follow-up (September 15, 1997). Furthermore, we excluded women who moved into or out of the study area between 1987 and September 15, 1997 (n = 1,788), because information about cataract extraction during the period of living outside the study area was not available. Women with missing data on smoking status (n = 775) were also excluded from the analysis. The final study cohort included 34,595 women at the start of follow-up for cataract extractions in September 1997.

Assessment of smoking status

The women in the cohort were classified as never, past, or current smokers on the basis of self-report in the 1997 questionnaire. The number of cigarettes smoked per day was reported on the questionnaire for several periods in life: ages 15–20 years, each decade thereafter, and the present.

Other exposures

The self-administered questionnaire collected information on possible risk factors for cataract, including diagnoses of diabetes and hypertension, use of steroid medication, alcohol consumption (frequencies and amounts of different beverages were converted into grams of alcohol and divided into quartiles), use of vitamin supplements, height and weight (body mass index was defined as weight in kilograms divided by the square of height in meters), and educational level.

Identification of cases and follow-up of the cohort

Between September 1997 and June 2002, 2,128 incident cases of extraction of age-related cataracts occurred among women in the cohort. These cases were identified through computerized registers of diagnoses of cataract extraction in the two counties. The registers were linked to the study population using personal identification numbers. We matched the cohort against the International Classification of Diseases, Tenth Revision, code for age-related cataract extraction (H25). Cataracts considered to be congenital or secondary to ocular trauma or intraocular inflammation and previous intraocular surgery were not included in the matching. According to the Swedish National Cataract Register, which covers more than 93 percent of all cataract extractions in Sweden (28), preoperative visual acuity in the operated-upon eye was less than 0.6 during the study period. Visual acuity less than 0.6 implies difficulty in driving. Mean visual acuity in the operated-upon eye was 0.3, which means difficulty in reading the newspaper, and more than one third of the patients were socially blind (visual acuity <0.1; difficulty in walking and eating) because of cataract.

The dates of deaths occurring in the cohort were ascertained through the Swedish Death Register, and information about dates of moving out of the study area was obtained by matching the cohort with the Swedish Population Register. These registers are nearly 100 percent complete.

The study was approved by the ethical committee at the Karolinska Institutet (Stockholm, Sweden), and informed consent was obtained from the participants.

Statistical analysis

Follow-up ceased on the date of cataract extraction, death, migration out of the study area, or the end of follow-up (June 30, 2002), whichever came first. We examined risk of cataract extraction according to the mean number of cigarettes smoked per day during the period of smoking and according to age at starting smoking. The mean number of cigarettes smoked per day during the smoking period was calculated for both current and past smokers.

We used the Cox proportional hazards model to estimate relative risks as rate ratios, with 95 percent confidence intervals (29), using the PHREG procedure in SAS (version 8.2; SAS Institute, Inc., Cary, North Carolina). Relative risks were estimated for the average number of cigarettes smoked per day and the duration (years) of smoking. Risk estimates were also calculated for past smokers who had quit smoking less than 10 years, 10–20 years, or more than 20 years before the start of follow-up in 1997. All relative risks were adjusted for potential risk factors, including age, diabetes, hypertension, use of steroid medication, alcohol...
consumption, use of vitamin supplements, body mass index, and educational level. We tested for trends by using the median value of each category to create a single continuous variable. All p values shown are two-sided.

RESULTS

At the start of follow-up of the cohort in 1997, 54 percent of the women were never smokers, 23 percent were past smokers, and 23 percent were current smokers. We examined smoking status in relation to potential confounders (table 1). Smoking behavior differed by age. Women younger than age 60 years reported a higher level of smoking; among them, 14.9 percent smoked more than 10 cigarettes/day, on average, in comparison with 3.7 percent among women aged 70 years or older. Past smokers had a higher smoking intensity than current smokers. Among women with cataract extraction, there were twice as many women who smoked more than 20 cigarettes/day before age 50 years among past smokers as among current smokers. Compared with never smokers, ever smokers, particularly current smokers, reported higher alcohol consumption.

In age-adjusted analysis, ever smokers had a 22 percent increased risk of cataract extraction as compared with never smokers (RR = 1.19, 95 percent CI: 1.06, 1.34), and current smokers had a 14 percent increased risk (RR = 1.14, 95 percent CI: 1.01, 1.29).

There was a positive association between intensity of cigarette smoking, measured as the average number of cigarettes smoked per day during one’s smoking lifetime, and risk of cataract extraction. Table 2 presents risk estimates for smoking intensity among past and current smokers. Smoking more than 20 cigarettes/day was rare; only 283 women in the cohort had ever smoked more than 20 cigarettes/day, on average.

In analysis stratified by smoking duration, smoking intensity seemed to be more important than smoking duration. Among women who had smoked for 15 years or longer, the risk in multivariate analysis was not significantly increased if they had smoked 10 or fewer cigarettes/day (RR = 1.06, 95 percent CI: 0.94, 1.19) in comparison with never smokers. If women had smoked more than 10 cigarettes/day, they had a significantly increased risk (RR = 1.36, 95 percent CI: 1.18, 1.57). In the multivariate model including intensity and duration of smoking simultaneously, only intensity was statistically significantly associated with increased risk of cataract extraction. The risk estimate for a smoking duration of more than 25 years was 0.96 (95 percent CI: 0.80, 1.15).

When we examined the association between age at starting smoking and risk of cataract extraction, we found no significant relation after adjusting for smoking intensity (data not shown).

To examine the association between time since quitting smoking and risk of cataract extraction, we stratified the data by smoking intensity, as measured by the mean number

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TABLE 1. Age-adjusted* prevalence of baseline characteristics by smoking status in the Swedish Mammography Cohort, 1997

<table>
<thead>
<tr>
<th></th>
<th>Never smokers (n = 18,774)</th>
<th>Past smokers (n = 7,867)</th>
<th>Current smokers (n = 7,954)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of cataract extractions</td>
<td>1,348</td>
<td>406</td>
<td>374</td>
</tr>
<tr>
<td>Mean age (years)</td>
<td>64.0 (9.4)†</td>
<td>59.3 (8.4)</td>
<td>59.2 (8.4)</td>
</tr>
<tr>
<td>Diabetes (%)</td>
<td>4.5</td>
<td>3.6</td>
<td>3.5</td>
</tr>
<tr>
<td>Hypertension (%)</td>
<td>22.9</td>
<td>19.4</td>
<td>19.3</td>
</tr>
<tr>
<td>Corticosteroid use (%)</td>
<td>14.1</td>
<td>13.5</td>
<td>13.5</td>
</tr>
<tr>
<td>Mean alcohol consumption (g/day)</td>
<td>5.4 (6.3)</td>
<td>7.7 (8.4)</td>
<td>8.1 (13.1)</td>
</tr>
<tr>
<td>Vitamin supplement use (%)</td>
<td>44.7</td>
<td>45.4</td>
<td>45.4</td>
</tr>
<tr>
<td>Mean body mass index ‡</td>
<td>25.2 (4.0)</td>
<td>25.3 (4.1)</td>
<td>24.4 (3.9)</td>
</tr>
<tr>
<td>More than 12 years of education (%)</td>
<td>16.0</td>
<td>21.0</td>
<td>21.0</td>
</tr>
<tr>
<td>Mean age (years) at starting smoking</td>
<td>19.6 (5.8)</td>
<td>20.3 (7.0)</td>
<td></td>
</tr>
<tr>
<td>Mean age (years) at quitting smoking</td>
<td>41.8 (12.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of cataract extractions among those who smoked &gt;20 cigarettes/day before age 50 years</td>
<td>19</td>
<td>9</td>
<td></td>
</tr>
</tbody>
</table>

* All values (except age) were standardized to the age distribution in the study population.
† Numbers in parentheses, standard deviation.
‡ Weight (kg)/height (m)².
of cigarettes smoked per day during one’s smoking lifetime (1–5, 6–10, 11–15, or >15 cigarettes/day). There were too few women with cataract extraction who had smoked more than 15 cigarettes/day (n = 40) to analyze them separately; therefore, we present the results in three categories (table 3). Among women who had smoked 6–10 cigarettes/day, the relative risk of cataract extraction decreased with time since quitting smoking; compared with never smokers, past smokers who had quit smoking more than 10 years before baseline no longer had a significantly increased risk. Among women who had smoked more intensively (>10 cigarettes/day), after 20 years of nonsmoking the risk became small and no longer statistically significant; the trend analysis of risk estimates over time since quitting smoking was highly significant (p < 0.0001). In a small subgroup of women who had smoked even more intensively (>15 cigarettes/day), the multivariate risk estimate was 1.23 (95 percent CI: 0.66, 2.30) more than 20 years after quitting smoking (10 cases).

**DISCUSSION**

In this population-based prospective cohort study, we observed a positive association between cigarette smoking and cataract extraction, with a significant dose response for intensity of smoking. Smoking intensity was more important as a risk factor for cataract extraction than was smoking duration. Among women who had smoked for 15 years or longer, the relative risk of cataract extraction was not significantly increased unless they had smoked more than 10 cigarettes/day. Smoking cessation was associated with decreasing risk with increasing time since stopping smoking. For women with a moderate intensity of smoking (6–10 cigarettes/day), the relative risk after 10 years since smoking cessation decreased to the same level as that among never smokers. Risk among women with a higher smoking intensity (>10 cigarettes/day) also decreased significantly with time, and 20 years after quitting smoking, the risk was no longer significantly increased in comparison with never smokers. Our results show that with a higher intensity of smoking, it takes longer for the lens to “recover” from the effects.

The association of smoking with cataract has been considered in numerous previous epidemiologic studies (2, 5, 7–13, 15–24). Although relative risk estimates vary across studies, most studies have reported a positive association between smoking and cataract (2, 5, 7–13, 15–24). Intensity of smoking, measured by the number of cigarettes smoked per day, and its association with cataract has been investigated in the Nurses’ Health Study (16) and the City Eye Study (21). Both studies found a positive association with increasing intensity of smoking.

The effect of smoking cessation on the risk of cataract has been considered in a few studies (21, 25–27). Risk estimates differ between studies, depending on whether the reference...
group is current smokers or never smokers. In a cross-sectional study of 838 Maryland watermen, West et al. (27) found a 33 percent decreased risk of nuclear opacity in past smokers as compared with current smokers 10 years after quitting smoking. In the City Eye Study, no reduction in risk was noted among past heavy smokers (>25 cigarettes/day) compared with never smokers; however, time since quitting smoking was not taken into account. There was no increased risk for past light smoking (<15 cigarettes/day) (21). In a prospective study of 19,698 men, Christen et al. (26) found a 25 percent decreased risk of cataract surgery within 10 years after quitting smoking in comparison with current smokers, with no additional reduction being observed more than 20 years after quitting smoking. In a recent analysis of women in the Nurses’ Health Study and men in the Health Professionals Follow-up Study, past smokers who had quit smoking 25 or more years previously had a 20 percent decreased risk of cataract extraction in comparison with current smokers after adjustment for intensity of smoking, but the risk did not decrease to the level of never smokers (25).

The main strengths of our study are the population-based design and the high response rate. The prospective design excluded the risk of recall bias in the self-reports of cigarette smoking and other potential risk factors, because information on presumed risk factors was recorded before cataract extraction. Furthermore, follow-up of the cohort through computerized registers of cataract extraction that contained data collected from eye clinics in the study area, without knowledge of exposure status, reduced the likelihood of nonrandom misclassification. The large number of women with cataract extractions allowed us to examine associations within subgroups with reasonable statistical power. However, our study also had some potential limitations. No international standard exists for the definition of cataract. In our study, we focused on cataract severe enough to cause visual impairment and require lens extraction, thus being of the greatest clinical and public health importance. Use of cataract surgery as the endpoint decreased the risk of misclassification of disease diagnosis. There might be random misclassification if female smokers with cataract were less likely to undergo cataract extraction, which would lead

### TABLE 3. Relative risk of cataract extraction among past smokers, by smoking intensity and time since quitting smoking, in the Swedish Mammography Cohort, 1997–2002

<table>
<thead>
<tr>
<th>Smoking intensity (no. of cigarettes smoked/day) and years since quitting smoking</th>
<th>No. of women in the cohort*</th>
<th>No. of cataract extractions*</th>
<th>Age-adjusted RR†</th>
<th>95% CI†</th>
<th>Multivariate RR‡</th>
<th>95% CI‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>1–5 cigarettes/day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never smokers</td>
<td>18,774</td>
<td>1348</td>
<td>1.0§</td>
<td>1.0§</td>
<td>1.0§</td>
<td>1.0§</td>
</tr>
<tr>
<td>Years since quitting smoking</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;10</td>
<td>329</td>
<td>11</td>
<td>0.77</td>
<td>0.43, 1.40</td>
<td>0.75</td>
<td>0.41, 1.36</td>
</tr>
<tr>
<td>10–20</td>
<td>657</td>
<td>30</td>
<td>1.06</td>
<td>0.73, 1.52</td>
<td>0.95</td>
<td>0.66, 1.39</td>
</tr>
<tr>
<td>&gt;20</td>
<td>1,039</td>
<td>69</td>
<td>1.23</td>
<td>0.96, 1.56</td>
<td>1.16</td>
<td>0.90, 1.49</td>
</tr>
<tr>
<td>p for trend</td>
<td></td>
<td></td>
<td></td>
<td>0.49</td>
<td>0.97</td>
<td></td>
</tr>
<tr>
<td>6–10 cigarettes/day</td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Never smokers</td>
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<td>1.0§</td>
</tr>
<tr>
<td>Years since quitting smoking</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;10</td>
<td>703</td>
<td>44</td>
<td>1.61</td>
<td>1.19, 2.17</td>
<td>1.52</td>
<td>1.12, 2.06</td>
</tr>
<tr>
<td>10–20</td>
<td>984</td>
<td>52</td>
<td>1.28</td>
<td>0.96, 1.68</td>
<td>1.18</td>
<td>0.88, 1.56</td>
</tr>
<tr>
<td>&gt;20</td>
<td>973</td>
<td>38</td>
<td>0.91</td>
<td>0.66, 1.26</td>
<td>0.89</td>
<td>0.64, 1.23</td>
</tr>
<tr>
<td>p for trend</td>
<td></td>
<td></td>
<td></td>
<td>0.008</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>&gt;10 cigarettes/day</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Never smokers</td>
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<tr>
<td>Years since quitting smoking</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;10</td>
<td>1,037</td>
<td>53</td>
<td>1.77</td>
<td>1.34, 2.34</td>
<td>1.63</td>
<td>1.23, 2.16</td>
</tr>
<tr>
<td>10–20</td>
<td>1,024</td>
<td>50</td>
<td>1.59</td>
<td>1.20, 2.12</td>
<td>1.49</td>
<td>1.12, 1.99</td>
</tr>
<tr>
<td>&gt;20</td>
<td>625</td>
<td>27</td>
<td>1.30</td>
<td>0.89, 1.91</td>
<td>1.20</td>
<td>0.81, 1.77</td>
</tr>
<tr>
<td>p for trend</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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</tr>
</tbody>
</table>

* Numbers do not add up to the totals because of missing values.
† RR, rate ratio; CI, confidence interval.
‡ Adjusted for age (5-year age groups; ≤52, 53–57, 58–62, 63–67, 68–72, 73–77, ≥78), diabetes, hypertension, steroid medication use, alcohol consumption (in quartiles), vitamin supplement use, body mass index (<20, 20–<25, 25–30, >30 kg/m²), and education.
§ Reference category.
to underestimation of the true association between cigarette smoking and cataract extraction. Standardized eye examination of all women in this large population-based cohort was not possible. Information on cataract type was not assessed in a standardized manner at different eye clinics, and documentation of subtypes in the medical records was too incomplete for us to obtain sufficient data for analysis.

The estimates of lifetime cigarette smoking were based on retrospective recall. Because data on smoking status were collected only at baseline, random misclassification of current and past smoking could occur because of women underestimating their smoking habits. This would lead to underestimation of the true association between cigarette smoking and cataract extraction. Improper inclusion of failed quitters as past smokers would lead to a reduced estimate of the benefit of smoking cessation. The suggestion of higher risk estimates among past smokers than among current smokers in our study may be due to a different smoking pattern among past smokers, as indicated by a greater proportion of women with a higher smoking intensity, or residual confounding, which we were not able to adjust for.

Smoking increases oxidative stress in the lens by generating free radicals and reduces plasma concentrations of several antioxidants and proteolysis enzymes important for the removal of damaged proteins from the lens (14). Cadmium is also found to be accumulated in the cataractous lenses of smokers. Cadmium may hasten cataractogenesis by affecting lens enzymes such as superoxide dismutase and glutathione peroxidases, thereby weakening defense against oxidative damage (30, 31).

Our findings confirm those of previous studies showing that cigarette smoking increases the risk of cataract requiring surgical extraction in women. The effect of smoking cessation on the decreased risk of cataract extraction was observed earlier among women smoking less intensively than among women smoking more heavily. It seems that in the latter group, a much longer period of time is needed. However, even in the latter group, smoking cessation lowered the risk over time, indicating that the lens has an ability to repair protein damage with time.

The increasing proportion of smokers among young women in some populations may lead to a potentially growing number of women at risk of developing cataract in the future. Increased risk of cataract is yet one more reason to encourage women to never start smoking or to quit smoking early, since so many serious diseases are related to smoking.

ACKNOWLEDGMENTS

This work was supported by the Swedish Research Council/Longitudinal Studies, the Swedish Research Council/Medicine, the Swedish Council for Working Life and Social Research, the Crown Princess Margaret’s Foundation, the Carmen and Bertil Regné Foundation, Synframidsjandet in Stockholm, and the Västernorrland County Council.

Conflict of interest: none declared.

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