Smoking and Its Association with Cataract: Results of the Andhra Pradesh Eye Disease Study from India

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Purpose. To investigate the associations between tobacco smoking and various forms of cataracts among the people of a state in India.

Methods. A population-based cross-sectional epidemiologic study was conducted in the south Indian state of Andhra Pradesh (AP). A total of 10,293 subjects of all ages from one urban and three rural areas, representative of the population of AP, were interviewed, and each underwent a detailed dilated ocular evaluation by trained professionals. Data were analyzed for 7416 (72%) of the subjects aged >15 years.

Results. Increasing age was significantly associated with all cataract types and history of prior cataract surgery and/or total cataract. In multivariate analyses, after adjusting for all demographic factors and for history of smoking, females, illiterate persons, and those belonging to the extreme lower socioeconomic status group were found to have a significantly higher prevalence of any cataract, adjusted odds ratio (OR) = 1.60 (95% confidence interval [CI]: 1.24–1.96), 1.46 (95% CI: 1.17–1.70), and 1.92 (95% CI: 1.14–3.24), respectively. After adjustment, cigarette and cigar smokers had a significantly higher prevalence of any cataract, adjusted OR = 1.51 (95% CI: 1.10–2.06) and 1.44 (95% CI: 1.12–1.84), respectively, compared with those who had never smoked ("never-smokers"). A significantly higher prevalence of nuclear, cortical cataract, and history of prior cataract surgery and/ or total cataract was found among cigarette smokers. A dose–response relationship was seen with respect to cigarette and cigar smoking. After adjustment, compared with never-smokers, cigarette smokers who smoked heavily (>14 "pack-years" of smoking) had a significantly higher prevalence of nuclear cataract (OR = 1.65; 95% CI: 1.10–2.59), cortical cataract (OR = 2.11; 95% CI: 1.38–3.24), and history of prior cataract surgery and/or total cataract (OR = 2.10; 95% CI: 1.05–4.22). Nuclear cataract was significantly higher in cigar smokers (adjusted OR = 1.55; 95% CI: 1.16–2.01) and in cigar smokers who smoked heavily (>21 person-years of smoking; OR= 1.50; 95% CI: 1.10–1.95), compared with never-smokers.

Conclusions. Consistent with other studies, tobacco smoking was strongly associated with a higher prevalence of nuclear and cortical cataracts and history of prior cataract surgery in this population. These findings suggest yet another need to educate the community on the importance of cessation of tobacco smoking and perhaps incorporating an antismoking message into school health programs. (*Invest Ophthalmol Vis Sci.* 2005;46:58–65) DOI:10.1167/iovs.04-0089

Cataract is a major cause of avoidable blindness and visual impairment throughout the world. The challenges are to prevent or delay cataract formation, and treat that which does occur.[1] Although safe and effective technologies are available that could restore normal vision to a large number of those affected, the cataract burden continues to increase annually, because of the backlog of patients to be operated on, and the growing number of cataract cases, due to increased life expectancy. Although surgery is the only effective treatment option available, identifying risk factors may help to establish preventive measures and appropriate strategies at the level of primary or primordial prevention. The World Health Report, published in 1998, estimated that there were 19.34 million people who were bilaterally blind (visual acuity <3/60 in the better eye) due to age-related cataract.[2] In the Andhra Pradesh Eye Disease Study (APEDS) conducted by our institute, it has been reported that cataract alone contributes to 44% of the total blindness in India.[3] Intervention against cataract blindness has received priority attention in the global initiative called VISION 2020: The Right to Sight.[4–6]

Cigarette smoking is an established risk factor for nuclear cataract, and there is growing epidemiologic evidence that smoking is also a risk factor for posterior subcapsular cataract.[7] It has been shown to be a risk factor for many common and severe eye diseases, such as age-related macular degeneration, glaucoma, and cataract, which can lead to irreversible blindness.[8] Several studies[9–19] have investigated and reported the significant relationship between cigarette smoking and an increased risk of cataract development. Despite the multifactorial etiology of these ocular syndromes, smoking is an independent risk factor that has dose–response effects. It causes morphologic and functional changes to the lens and retina due to its atherosclerotic and thrombotic effects on the ocular capillaries. In addition, evidence exists that cigarette smokers are more at risk of development of cataract at an earlier age than are nonsmokers.[11,12]

We focus attention on habitual tobacco smoking in men and women in the state of Andhra Pradesh (AP, population ~65 million) in India, and the connection between smoking and cataract in this population. India is the second largest tobacco producer in the world, and the state of AP accounts for almost 40% of the country's tobacco production. The practice of smoking, particularly home-rolled cigars called chutta, is highly prevalent among its people, rural and urban, women and men. As part of the comprehensive APEDS, we have attempted for this article to investigate the association between tobacco smoking and various forms of cataract in AP.

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Subjects and Methods

The details of various aspects of design of the APEDS have been described previously.[3,20–22] Approval of the Ethics Committee of the Institute was obtained for the study design, which was conducted during the 5-year period 1996 to 2000, in compliance with the tenets of the Helsinki Declaration.

Briefly, a multistage sampling procedure was used to select the study sample of 10,000 persons, with 5,000 each older and younger than 30 years based on the assumption that a 0.5% prevalence of an eye disease in either of these groups may be of public health significance. One urban and three rural areas from different parts of AP were selected. Approximately 2950 persons were sampled in each of the four areas with the intent of including ~2500 participants in each area, so as to reflect the urban–rural and socioeconomic distribution of the population of this state. These four areas were located in Hyderabad (urban, stratified by socioeconomic status and religion), the West Godavari district (economically well off, rural), and the Adilabad and Mahabubnagar districts (poor, rural). To obtain a sample representative of the entire population of the city of Hyderabad, we stratified the urban blocks by socioeconomic status and religion, because these variables might influence ocular morbidity. Because details of socioeconomic status were not available, we stratified blocks based on our knowledge of Hyderabad gained from various sources, including a surveyor with 27 years' field experience in Hyderabad. The socioeconomic strata were extreme low (monthly income per person, ≤ 200 rupees (US$ 4.31), low (201–500 rupees), middle (501–2000 rupees), and high (>2000 rupees). We assumed that 0.7% of the Hyderabad population was homeless (no accurate data were available) and included those people in the lowest socioeconomic stratum. We stratified blocks by two major religious groups, Hindu and Muslim, based on location, because people of the same religion tend to live in the same areas. For practical purposes, we assumed that socioeconomic status and religion were homogeneous within each block. We chose 23 blocks (clusters) and one cluster of homeless people by stratified random sampling with an equal probability of selection. The selected blocks were mapped, and the number of households listed. We randomly selected every third to fifth household depending on the total number of households in each block, to obtain a similar number of households in all blocks. We selected 2954 people from Hyderabad with the purpose of achieving a recruitment rate of at least 85% from these blocks.

From three rural areas in different parts of the state, 70 rural clusters were selected with the purpose of having a study sample representative of the socioeconomic distribution of the rural population of the state. We sampled 8832 subjects from these three rural areas, of whom 7771 participated in the study. The major difference between the urban and rural samples was that the former was selected from blocks stratified by socioeconomic status and religion, whereas the latter were selected from villages stratified by four different castes (forward caste, backward caste, scheduled caste, and scheduled tribe) assuming that the different castes roughly reflect the different socioeconomic strata in these rural areas.

Interview

The volunteers were interviewed in detail by trained field investigators.[20] A structured questionnaire was used to collect the information on current and prior status of cigarette, *beedi* (a leaf-rolled cigarette), *hookah* (the "hubble-bubble" or the flexible, water-filtered smoking pipe) ,and *chutta* (a home-rolled cigar sold and used extensively in the state) smoking. The first question related to smoking was on the current status of smoking (yes/no). If the response was yes, the volunteer was asked how long he/she had been smoking (years) and current level (in terms of number per day for cigarettes/*beedies*/*chuttas*; hours per day for the *hookah*) of smoking. Similar information was also obtained from those who were once smokers but had since given up (i.e., prior smokers). In addition, data on cooking status was ascertained from each volunteer as part of the structured questionnaire. The first question related to cooking status asked was, "Do you cook regularly?" If yes, the participant was asked about the type of fuel mainly used for cooking.

Ophthalmologic Examination

Two ophthalmologists and two optometrists, specially trained in the procedures used in this study, performed the examinations. Distance and near visual acuity, both presenting and best corrected after refraction, were measured under standard distance and lighting conditions using logarithm of minimum angle of resolution (logMAR) charts[23] obtained from Australian Vision Charts (Forest Hill, Australia). English alphabet charts were used for literate subjects and E-type charts for illiterate subjects. If visual acuity was worse than 6/6, objective refraction was performed with a streak retinoscope (Heine Optotechnik, Herrsching, Germany), followed by assessment of subjective acceptance by the subject. External eye examination, assessment of pupillary reaction, and anterior segment examination with a slit-lamp biomicroscope (Haag-Streit, Koeniz, Switzerland) were performed. Intraocular pressure was measured with a Goldmann applanation tonometer (Clement Clarke International, Harlow, UK) in those children who could not sit at the slit lamp or in debilitated subjects who were examined at home. Gonioscopy was attempted on all subjects with an NMR-K two-mirror lens (Ocular Instruments, Bellevue, WA), and the angle was graded as open, occludable, or occluded according to Scheie's classification based on the extent of visible angle structures.[24] If gonioscopy was not possible with a particular patient, the van Herick technique was used to grade the angle with the slit lamp.[25]

Dilated Examination

All subjects had their pupils dilated unless contraindicated due to risk of angle closure. Tropicamide 1% and phenylephrine 2.5% were used for subjects >15 years of age, and tropicamide 1% and cyclopentolate 1% were used in subjects ≤15 years of age. Phenylephrine was not used if contraindicated. An attempt was made to obtain a pupillary diameter of 8 mm for lens and posterior segment examination.[20] After the dilatation, the size of the pupil and intraocular pressure were recorded again. The lens was examined under the slit lamp, and nuclear opacity was graded according to the Lens Opacities Classification System III (LOCS III)[26]: cortical and posterior subcapsular cataracts were graded using the Wilmer Classification.[27] Inter-rater reliability was determined between the study principal investigator (Lalit Dandona) and the clinicians who were specially trained for slit-lamp grading of cataract with LOCS III and Wilmer classifications.[20] The details of training and other procedures have been reported elsewhere.[20] Those who graded lens status were masked to the interview data and also the investigators who administered the questionnaire in the field were masked to the clinical findings. The possible etiology of cataract was also documented. If the crystalline (natural) lens was absent, the presence of any lens (aphakia) or the presence of an intraocular lens (pseudophakia) was determined and documented. The absence, presence, and clarity of the posterior lens capsule were determined in aphakic and pseudophakic eyes. Subjects who were physically unable to come to the clinic were examined at home with portable equipment.

Data Analysis

Smoking Status. For this analysis, subjects were categorized as never-smokers (never smoked) and ever-smokers (current and prior smokers). Current and prior smokers (ever smokers) were those for whom smoking had become a habit and who had smoked for a minimum of at least 1 year. Subjects who had been smoking for less than 1 year were considered to be non–tobacco smokers (never-smokers).

Cumulative Smoking Dose. For this analysis, cigarette and cigar smokers were classified into light and heavy smokers. Cigarette smoking subjects were classified based on cigarette pack-years. Pack-

year is a way to measure the amount a person has smoked over a long period. Cigarette pack-years were calculated by multiplying the number of packs of cigarettes smoked per day by the number of years the person had smoked. For example, 1 pack-year is equal to smoking one pack per day for 1 year, and so on. In this analysis, subjects were considered to be light smokers if they had <15 cigarette pack-years of smoking (median cigarette pack-years smoked) and heavy smokers if they had 15 years or more cigarette pack-years. Cigar-smoking subjects having cigar person-years of smoking ≥21 years (median cigar person years smoked) were considered to be heavy smokers.

Definitions of Cataract. We defined the presence of nuclear cataract (NC) as at least one eye showing nuclear opalescence of grade 3.0 or higher on LOCS III.[28] Cortical cataract (CC) was considered to be present if at least one eye had a Wilmer grade ≥2. Posterior subcapsular cataract (PSC) was considered to be present if at least one eye had a Wilmer grade ≥1.

Any Cataract. Any cataract (cataract of any type) was defined as (1) the presence in at least one eye of significant nuclear, cortical, or posterior subcapsular cataract, as just defined; (2) the presence of bilateral total cataract; (3) the presence of unilateral total cataract with phthisis bulbi in the other eye; (4) a history of prior bilateral cataract surgery (pseudophakia or aphakia); and (5) a history of prior unilateral cataract surgery (pseudophakia or aphakia) with combination of total cataract or phthisis bulbi in the other eye.

Of the total 10,293 examined subjects, data were analyzed for the 7,416 (72%) subjects who were aged ≥16 years, after excluding from analysis 11 subjects who had traumatic cataract and 4 who had bilateral phthisis bulbi. A total of 2862 subjects, aged ≤15 years, were excluded from the analysis. Of the 7416 subjects, it was possible to grade lens status for 7248 (97.7%) of them. Lens status was not gradable for 168 subjects because of ungradable lens opacities or a history of prior cataract surgery. Among these, 85 had bilateral cataract surgery (pseudophakia or aphakia), 7 had bilateral total cataract, 49 had unilateral cataract surgery (pseudophakia or aphakia) combined with total cataract in the other eye, 4 had unilateral cataract surgery (pseudophakia or aphakia) with phthisis bulbi in the other eye, 1 had total cataract with combination of phthisis bulbi in the other eye, 19 subjects had pupils that could not be dilated because of the risk of angle closure, and 1 patient did not agree to have her pupils dilated for religious reasons. Lens grading data were missing for two subjects for unknown reasons.

Statistical Analysis. The prevalence of NC, CC, and PSC and other estimates in our sample were adjusted for the estimated age and sex distribution of the population in India during 2000 (http://www.census.gov). The 95% confidence intervals were calculated by assuming a Poisson distribution[29] for prevalence <1%, and normal approximation of binomial distribution for prevalence of >1%. The confidence intervals were adjusted for the design effect of the sampling strategy, which was based on the rates in each cluster.[30] The association between each cataract type and smoking, age, sex, socioeconomic status, and education was assessed with the χ^2 test or Fisher exact test for univariate analyses, followed by multivariate analyses with multiple logistic regression. All statistical analyses were performed on computer (SPSS ver.12.0 for Windows; SPSS, Chicago, IL). We considered a two-tailed $P < 0.05$ to be statistically significant for this analysis.

Results

Of a total of 11,786 subjects sampled for APEDS, 10,293 (87.3%) participated in the study. The participation rate was 85.4% in the urban area (Hyderabad) and 84.6%, 91.6%, and 87.7% in the rural areas of West Godavari, Adilabad, and Mahabubnagar districts, respectively. Data were analyzed for 7416 (72%) subjects who were ≥16 years of age, after excluding from the analysis 11 subjects who had traumatic cataract and 4 with bilateral phthisis bulbi. A total of 4027 (54.3%) were females, 3865 (52.1%) were illiterate persons, and 631 (8.5%) were cigar smokers. Any cataract was present in 1482 subjects, with an age-gender-area–adjusted prevalence of 14.4% (95% CI: 13.6–15.2). A total of 901 subjects had NC ≥3 (with or without other types, an age-gender-area–adjusted prevalence of 9.2% [95% CI: 8.5–9.9]); 541 subjects had CC (alone or with other types, an age-gender-area–adjusted prevalence of 5.5% [95% CI: 5.2–6.2]); and 569 subjects had PSC, an age-gender-area–adjusted prevalence of 6.0% (95% CI: 5.4–6.5). Table 1 shows the prevalence of all grades of nuclear, cortical, and poster subcapsular lens opacities and pure and mixed types of opacities. The univariate distribution of type of cataract and prevalence of prior cataract surgery and/or total cataract for the demographic variables, history of various forms of smoking, and mixed smoking is shown in Table 2. The multivariate logistic regression analysis assessing the association with any cataract and specific cataract types is shown in Tables 3 and 4, respectively. A history of prior cataract surgery and/or total cataract was present in 146 (1.97%) of the subjects, including 85 (1.15%) persons in whom bilateral prior cataract surgery (pseudophakia or aphakia) had been performed. The presence of history of prior cataract surgery and/or total cataract increased significantly with increasing age (Table 2). All types of cataracts were seen to increase significantly with increasing age and decreasing socioeconomic status. The univariate associations of NC, CC, and PSC were significantly higher among mixed smokers of one form or more than one form of smoking compared with never-smokers.

Table 1. Prevalence of Lens Opacities among Subjects Aged 16 Years or More by Type of Cataract and Severity

Type of Cataract/Lens Grade	Subjects *n* (%)
Nuclear opacity	
0.00	894 (12.3)
0.50	2287 (31.6)
1.00	1426 (19.7)
1.50	691 (9.5)
2.00	575 (7.9)
2.50	474 (6.5)
3.00	328 (4.5)
3.50	416 (5.7)
4.00	114 (1.6)
4.50	26 (0.4)
5.00	17 (0.2)
Cortical opacity	
0.00	6454 (89.0)
1.00	240 (3.3)
2.00	248 (3.4)
3.00	232 (3.2)
4.00	61 (0.8)
Posterior subcapsular opacity	
0.00	6668 (91.9)
1.00	300 (4.1)
2.00	207 (2.9)
3.00	62 (0.9)
Pure nuclear	454 (6.3)
Pure cortical	214 (3.0)
Pure posterior subcapsular	125 (1.7)
Mixed cataract*	543 (7.5)
Total population†	7248 (100.0)

n = 7248.

* Mixed cataract includes a combination of nuclear, cortical, or posterior subcapsular cataract. Pure nuclear, cortical, and posterior subcapsular cataract subgroups have isolated cataracts without the presence of the other types. The opacity grade of the worse eye was considered for analysis.

† Data were analyzed for persons ≥16 years of age with gradable cataracts.

TABLE 2. Univariate Effect of Demographic Variables and Type of Smoking on Nuclear, Cortical, Posterior Subcapsular Cataract, Prior Cataract Surgery, and/or Total Cataract

Demographic Factors, Smoking Status	Total Population (n = 7416)*	Nuclear Cataract†	Cortical Cataract†	Posterior Subcapsular Cataract†	Prior Cataract Sx and/or TC
Age (y)‡					
16–29	1843	1/1842 (0.1)	4/1842 (0.2)	4/1842 (0.2)	0/1843 (0.0)
30–39	1859	5/1849 (0.3)	11/1848 (0.6)	17/1848 (0.9)	6/1859 (0.3)
40–49	1420	49/1404 (3.5)	58/1403 (4.1)	48/1403 (3.4)	13/1420 (0.9)
50–59	1043	218/1016 (21.5)	151/1014 (14.9)	139/1015 (13.7)	22/1043 (2.1)
60–69	899	423/832 (50.8)	222/829 (26.8)	248/829 (30.0)	61/899 (6.8)
≥70	352	205/305 (67.2)	95/299 (31.8)	113/300 (37.7)	44/352 (12.5)
Sex§					
Male	3389	405/3319 (12.2)	216/3314 (6.5)	252/3312 (7.6)	63/3389 (1.9)
Female	4027	496/3929 (12.6)	325/3921 (8.3)	317/3925 (8.1)	83/4027 (2.1)
Female‖					
LPG, biogas, and kerosene	906	49/889 (5.5)	47/888 (5.3)	34/888 (3.8)	13/906 (1.4)
Use of cheaper cooking fuel	2255	353/2255 (15.7)	142/2229 (6.4)	128/2228 (5.7)	19/2255 (0.8)
Socioeconomic status¶					
≤200	898	120/875 (13.7)	53/875 (6.1)	92/875 (10.5)	21/898 (2.3)
201–500	3630	483/3554 (13.6)	267/3549 (7.5)	279/3550 (7.9)	63/3630 (1.7)
501–2000	2474	263/2409 (10.9)	190/2402 (7.9)	174/2403 (7.2)	60/2474 (2.4)
>2000	290	15/287 (5.2)	21/286 (7.3)	14/286 (4.9)	2/290 (0.7)
Education#					
Illiterate	3865	654/3763 (17.4)	357/3758 (9.5)	399/3758 (10.6)	92/3865 (2.4)
Literate	3543	245/3477 (7.0)	181/3469 (5.2)	168/3471 (4.8)	54/3543 (1.5)
Cigarette smoker**					
Never a smoker	6860	843/6709 (12.6)	491/6697 (7.3)	533/6700 (8.0)	131/6860 (1.9)
Ever smoker	556	58/539 (10.8)	50/538 (9.3)	36/537 (6.7)	15/556 (2.7)
Cigar smoker††					
Never a smoker	6785	723/6637 (10.9)	473/6627 (7.1)	486/6630 (7.3)	132/6785 (1.9)
Ever smoker	631	178/611 (29.1)	68/608 (11.2)	83/607 (13.7)	14/631 (2.2)
Beedi smoker‡‡					
Never a smoker	6288	719/6149 (11.7)	458/6137 (7.5)	454/6138 (7.4)	119/6288 (1.9)
Ever smoker	1128	182/1019 (16.6)	83/1098 (7.6)	115/1099 (10.5)	27/1128 (2.4)
Hookah smoker§§					
Never a smoker	7413	899/7245 (12.4)	540/7232 (7.5)	569/7234 (7.9)	146/7413 (1.9)
Ever smoker	3	2/3 (66.7)	1/3 (33.3)	0/3 (0.0)	0/3 (0.0)
Mixed smoking‖‖					
Never a smoker	5311	524/5201 (10.1)	360/5193 (6.9)	360/5196 (6.9)	98/5311 (1.8)
Only one form of smoking	1931	351/1878 (18.7)	166/1873 (8.9)	193/1872 (10.3)	43/1931 (2.2)
More than one form of smoking	174	26/169 (15.4)	15/169 (8.9)	16/169 (9.5)	5/174 (2.9)

Data are expressed as the number of persons/total group (percentage of total group). Sx, surgery; TC, total cataract.

* Data were analyzed for n = 7416 subjects and excluded the data from 11 subjects who had a diagnosis of traumatic cataract and from 4 subjects who had bilateral phthisis bulbi.

† Data were analyzed for n = 7248 subjects ≥16 years of age with gradable cataracts. Data on 13 subjects for CC and 11 subjects for PSC were not available (unknown reason).

‡ χ^2 test: $P < 0.0001$ for NC, $P < 0.0001$ for CC, $P < 0.0001$ for PSC, and $P < 0.0001$ for any prior cataract Sx and/or TC.

§ Fisher exact test: $P = 0.592$ for NC, $P = 0.005$ for CC, $P = 0.483$ for PSC, and $P = 0.616$ for any prior cataract Sx and/or TC.

‖Fisher exact test: $P < 0.0001$ for NC, $P = 0.280$ for CC, $P = 0.032$ for PSC, and $P = 0.167$ for any prior cataract Sx and/or TC. Data on type of fuel mainly used for cooking were available for 3161 (78.5%) of the female population. Cheaper cooking fuels include wood, coal, cow dung, and others.

¶ χ^2 test: $P < 0.0001$ for NC, $P = 0.359$ for CC, $P = 0.004$ for PSC, and $P = 0.084$ for any prior cataract Sx and/or TC. Socioeconomic status was defined according to monthly per capita income in Indian rupees: ≤200, extreme lower; 201–500 lower; 501–2000, middle; and >2000 upper. Data on socioeconomic status were not available for 124 subjects.

Fisher exact test: $P < 0.0001$ for NC, $P < 0.0001$ for CC, $P < 0.0001$ for PSC, and $P = 0.012$ for any prior cataract Sx and/or TC. Data on education were not available for eight subjects.

** Fisher exact test: $P = 0.248$ for NC, $P = 0.105$ for CC, $P = 0.359$ for PSC, and $P = 0.205$ for any prior cataract Sx and/or TC.

†† Fisher exact test: $P < 0.0001$ for NC, $P < 0.0001$ for CC, $P < 0.0001$ for PSC, and $P = 0.112$ for any prior cataract Sx and/or TC.

‡‡ Fisher exact test: $P < 0.0001$ for NC, $P = 0.901$ for CC, $P = 0.001$ for PSC, and $P = 0.296$ for any prior cataract Sx and/or TC.

§§ Fisher exact test: $P = 0.042$ for NC, $P = 0.208$ for CC, $P = 1.000$ for PSC, and $P = 1.000$ for any prior cataract Sx and/or TC.

‖‖ χ^2 test: $P < 0.0001$ for NC, $P = 0.018$ for CC, $P < 0.0001$ for PSC, and $P = 0.602$ for any prior cataract Sx and/or TC.

Multivariate logistic regression analysis revealed that, after adjusting for demographic factors and for history of smoking, the prevalence of any cataract significantly increased with increasing age and was significantly higher in females, in the extremely low socioeconomic group, and in illiterate persons (Table 3). The prevalence of any cataract was significantly higher in cigarette and cigar smokers but not in beedi and hookah smokers.

The results of four separate multivariate logistic regression models after adjusting for demographic factors are presented in Table 4. We found that cigarette smoking was significantly associated with cortical cataract and history of prior cataract surgery and/or total cataract, adjusted OR = 2.10 (95% CI: 1.35–2.91) and 1.98 (95% CI: 1.05–3.70), respectively. An adjusted OR of 1.55 (95% CI: 1.16–2.01) for cigar smokers was noted, compared with never-smokers (Table 4).

TABLE 3. Adjusted Effect of Demographic Variables with Smoking Status on Any Cataract by Multivariate Logistic Regression Analysis

Demographic Factors, Smoking Status	Total Population*	Any Cataract† *n* (%)	Odds Ratio (95% CI) for Any Cataract	*P*
Age (y)				
16–29	1843	8 (0.4)	1.00	
30–39	1859	32 (1.7)	3.28 (1.55–6.91)	0.002
40–49	1420	133 (9.4)	20.07 (10.16–39.64)	<0.0001
50–59	1043	391 (37.5)	111.75 (57.21–218.31)	<0.0001
60–69	899	615 (68.4)	400.14 (204.12–784.39)	<0.0001
70+	352	303 (86.1)	1234.47 (596.1–2556.48)	<0.0001
Sex				
Male	3389	653 (19.3)	1.00	
Female	4027	829 (20.6)	1.60 (1.24–1.96)	<0.0001
Female‡				
LPG, biogas, and kerosene	906	106 (11.7)	1.00	
Use of cheaper cooking fuel	2255	353 (15.7)	1.01 (0.51–1.70)	0.896
Socioeconomic status§				
Extreme lower	898	198 (22.0)	1.92 (1.14–3.24)	0.014
Lower	3630	734 (20.2)	1.42 (0.87–2.29)	0.156
Middle	2474	486 (19.6)	1.38 (0.85–2.23)	0.189
Upper	290	38 (13.1)	1.00	
Education‖				
Illiterate	3865	1012 (26.2)	1.46 (1.17–1.70)	<0.0001
Literate	3543	467 (13.2)	1.00	
Smoking status¶				
Never smokers	5311	914 (17.2)	1.00	
Ever smokers	2105	568 (27.0)	1.17 (0.95–1.47)	0.150
Cigarette smokers				
Never smokers	6860	1372 (20.0)	1.00	
Ever smokers	556	110 (19.8)	1.51 (1.10–2.06)	0.013
Cigar smokers				
Never smokers	6785	1234 (18.2)	1.00	
Ever smokers	631	248 (39.3)	1.44 (1.12–1.84)	0.004
Beedi smokers				
Never smokers	6288	1210 (19.2)	1.00	
Ever smokers	1128	272 (24.1)	0.81 (0.55–1.00)	0.052
Hookah smokers				
Never smokers	7413	1480 (20.0)	1.00	
Ever smokers	3	2 (66.7)	6.26 (0.19–211.97)	0.307
Mixed smokers				
Never a smoker	5311	914 (17.2)	1.00	
Only one form of smoking	1931	525 (27.2)	1.18 (0.94–1.51)	0.140
More than one form of smoking	174	43 (24.7)	1.15 (0.67–1.94)	0.622

* Data were analyzed for $n = 7416$ subjects and excluded from analysis on 11 subjects who had a diagnosis of traumatic cataract and on 4 subjects with bilateral phthisis bulbi.

† Nuclear, cortical, or posterior subcapsular cataracts, including 85 subjects with bilateral prior cataract surgery (pseudophakic or aphakic), 7 with bilateral total cataract, 53 with unilateral cataract surgery (pseudophakic or aphakic) combined with total cataract or phthisis bulbi in the other eye, and 1 with total cataract combined with phthisis bulbi in the other eye.

‡ Data on type of fuel mainly used for cooking were available for 3161 (78.5%) of the female population, and this variable was replaced in the multivariate analysis adjusting for age, socioeconomic status, smoking status, and education. Cheaper cooking fuels used include wood, coal, and cow dung.

§ Socioeconomic status defined according to monthly per capita income in Indian rupees: ≤200, extreme lower; 201–500, lower; 501–2000, middle; and >2000, upper. Data on socioeconomic status were not available for 124 subjects.

‖ Data on education were not available for eight subjects.

¶ Smoking of cigarette, beedi, cigar, or hookah. Variables: cigarette, cigar, beedi, and hookah smoking were replaced respectively with any smoking variable in the logistic regression model.

Table 4 points to the association of cumulative smoking dose with the risk of specific cataract type, after adjusting for age, gender, socioeconomic status, and education. There was evidence of a dose–response pattern for cigarette and cigar smoking. Corresponding to the cumulative smoking dose, the odds of NC, CC, and a history of prior cataract surgery and/or total cataract were seen to be significantly higher among cigarette smokers who smoked heavily (adjusted OR for NC = 1.65. 95% CI: 1.10–2.59; for CC = 2.11, 95% CI: 1.38–3.24; and for prior cataract surgery and/or total cataract = 2.10; 1.05–4.22). We also found the prevalence of NC to be significantly higher among cigar smokers who smoked heavily (adjusted OR = 1.50, 95% CI: 1.10–1.95) compared with never-smokers. Higher odds of CC were noted in heavy smokers of cigarettes and cigars, but did not reach statistical significance in the multivariate analyses.

DISCUSSION

Types of Cataract and Etiology

Accurate population-based data on the risk factors and various features of blindness are necessary, particularly in a country such as India, which has a large cataract burden. Our results showed a significantly higher prevalence of NC in this population, and approximately 78% of this prevalence was in the

TABLE 4. Association of Smoking History with Nuclear, Cortical, and Posterior Subcapsular Cataracts and Prior Cataract Surgery and/or Total Cataract by Multivariate Logistic Regression Analysis

Smoking History	Total Population*	OR (95% CI) for NC†	OR (95% CI) for CC†	OR (95% CI) for PSC†	OR (95% CI) for Prior Cataract Sx and/or TC*
Cigarette smokers					
Never-smokers	6860	1.00	1.00	1.00	1.00
Ever-smokers	556	1.25 (0.85–1.84)	2.10 (1.35–2.91)	1.01 (0.66–1.53)	1.98 (1.05–3.70)
Cumulative smoking dose‡					
Never-smokers	6860	1.00	1.00	1.00	1.00
Light smokers	262	0.60 (0.24–1.23)	1.68 (0.83–3.34)	0.85 (0.38–1.84)	1.57 (0.46–5.40)
Heavy smokers	294	1.65 (1.10–2.59)	2.11 (1.38–3.24)	1.09 (0.69–1.73)	2.10 (1.05–4.22)
Cigar smokers					
Never-smokers	6785	1.00	1.00	1.00	1.00
Ever-smokers	631	1.55 (1.16–2.01)	0.92 (0.70–1.23)	1.00 (0.73–1.32)	0.62 (0.33–1.15)
Cumulative smoking dose‡					
Never-smokers	6785	1.00	1.00	1.00	1.00
Light smokers	202	1.69 (0.99–2.88)	1.33 (0.74–2.36)	0.93 (0.50–1.75)	0.50 (0.20–1.99)
Heavy smokers	429	1.50 (1.10–1.95)	0.89 (0.56–1.15)	1.00 (0.79–1.40)	0.65 (0.35–1.10)

ORs and 95% CIs were adjusted for age, gender, socioeconomic status, and education. Sx, surgery; TC, total cataract.

* Data were analyzed for $n = 7416$ subjects and excluded from analysis on 11 subjects who had a diagnosis of traumatic cataract and on four subjects with bilateral phthisis bulbi.

† Data were analyzed for $n = 7248$ subjects ≥16 years of age with gradable cataract lens. Data on 13 subjects for CC and on 11 subjects for PSC were not available (unknown reason).

‡ This variable was replaced with the respective smoking status variable in the multivariate logistic regression model.

rural areas (data not shown). These results suggest that after adjustment for demographic factors, any cataract significantly increased with increasing age. There was a significantly higher prevalence of any cataract in females, illiterate persons, the extremely low socioeconomic group, and cigarette and cigar smokers (Table 3). Several population-based studies have found a higher prevalence of both nuclear and cortical opacities in women.[31–33] The association between education and cataract has also been one of the most consistently reported observations in the epidemiologic studies of cataract.[9,34–37] Our study results suggest that low socioeconomic status is a risk factor for cataract. This finding of an association between low socioeconomic status and lens changes has been supported by other studies.[38–42]

There is a growing consensus that smoking increases the risk of nuclear cataract. Association between cigarette smoking and cortical cataract also has recently been reported.[37,43,44] Our study is consistent with previous studies in finding that cigarette and cigar smokers are at a higher risk of development of nuclear and cortical cataract. Consistent with other studies, our data suggest that NC is more strongly associated with cigar smoking.[8] Contradictory to some studies,[9,36,45] but favoring others,[37,43,44] our study showed that prevalence of CC is significantly higher in the subjects with history of cigarette smoking (Table 4).

Our study showed that the cumulative smoking dose of cigarettes plays a significant role in accounting for higher prevalence of NC and CC in this population. The finding of a higher prevalence of CC in heavy cigarette smokers is in accordance with previous findings from India.[37] We also found a higher prevalence of prior cataract surgery to be significantly associated with lifelong cigarette smokers who smoked heavily compared with never-smokers. However, heavy cigar smoking was more strongly associated with NC but not with other types. Higher prevalence of PSC was present in both heavy cigarette and cigar smoking, but it did not reach statistical significance.

The situation with beedi smoking was less clear, because there were more beedi smokers than cigarette smokers (23.9% vs. 13.3%) and yet the cataract risk for the former appeared to be less. The odds ratio was almost significant for a reduced effect (OR = 0.81). We speculate that this difference may have to do with the relative inhalation dosages. A typical beedi smoker smokes a pack of 24 beedis per day. Each beedi weighs approximately 0.36 g and contains 0.15 g of tobacco loosely wrapped in a leaf that weighs ~0.16 g. In contrast, a typical cigarette smoker smokes a pack of 20, each weighing approximately 0.82 g and containing 0.70 g of tobacco wrapped in paper. The daily inhalation dosage for a cigarette smoker is thus four to five times higher. Local cigars (*chutta*) are bits of tobacco wrapped tightly with tobacco leaves, weighing approximately 2 to 3 g each, and a typical smoker smokes five a day. The inhalation dose is approximately the same as that of cigarettes and far higher than that of beedis.

Mechanisms of Smoke Action

The mechanisms by which smoking may damage the lens are becoming increasingly clear. Damage appears not to be related to the nicotine in tobacco, but more generally and commonly, to any form of smoke and partially pyrolyzed organic material from tobacco, coal, wood, cooking fuel, or automobile fuel. Our earlier studies[14] suggest the major damaging mechanism to be oxidative stress brought about by reactive oxygen species (ROS) generated by smoke constituents both in the dark and in light. Damage is more likely to occur through systemic absorption of smoke constituents that reach the lens and generate ROS endogenously through photodynamic action. This effect would depend on the amount of such photoactive material in the lens and is therefore thought to be dose-dependent (heaviness and period of smoke inhalation). In prior smokers who have overcome the habit, such deposition of photodynamic material would have ceased, rendering this mode of oxidative stress inoperative. This would explain why quitting smoking reduces this risk factor.[46,47]

That oxidative stress by smoke is generated in dark conditions, as suggested by reports[15,16,48,49] on the accumulation of metals such as Cd and Fe and the reduction in levels of vitamin C in the lens and blood of smokers (and smoke-exposed rats). Oxidative stress occurs through a metal-catalyzed Fenton reaction that produces ROS and by modulating the role of metallothioneins. Partial relief of the condition by the administration of the antioxidant vitamin E and the iron-chelator deferoxamine[48,49] adds support to the idea that oxidative stress is

imposed by smoke. The recent French Age-Related Eye Diseases (POLA) study[31] implicates the role of antioxidant enzymes in the etiology of PSC in lifelong heavy smokers.

Possible Causes of Gender-Based Differential Risk

Our study shows that the prevalence of NC, CC, and PSC is higher among females compared with males, in accordance with some earlier reports.[32,34,50–54] It is quite possible that this higher prevalence of cataract in women in the present instance is related to gender-based differences in exposure to the environment and/or to hormonal influences associated with menopause.[55,56] It could also be because most rural women tend to use cheap cooking fuels (e.g., dried wood, twigs and sticks, leaves, cow dung), which produce a lot of smoke. Prolonged exposure to this smoke (particularly in ill-ventilated spaces) would serve as an additional and cumulative source of oxidative damage to the eye. That such cooking smoke could be a risk factor has been alluded to earlier.[14,57] Added to this is the fact that most women in AP, particularly in rural areas, are anemic,[58] and of subnormal nutritional status,[57] which too may be confounding factors in increasing the risk of cataract.

This study has a few limitations as well as strengths. Because this was a cross-sectional study, there may be a potential for recall bias that might have affected the results. Cataract is a multifactorial disease and, as we did not study all other confounding factors, such as presence of diabetes, steroid intake, exposure to sunlight, and diet, we may have underestimated the adjusted effect of smoking on the risk of cataract. In contrast, a strength of the study is that we had a participation rate of more than or equal to 85% in all the selected areas, which means the sample roughly represents the entire the population of AP.

In summary, the findings of this study indicate that prevalence of cataract increased with increasing age and was more common among females, illiterate persons, and the extremely low socioeconomic group. Our results confirmed previous findings of higher prevalence of NC and CC in those who smoke cigarettes heavily and also suggest that there is a higher prevalence of NC in cigar smokers. Our results also proved that a higher prevalence of history of prior cataract surgery occurred more commonly among those with a history of heavy cigarette smoking, suggesting that an early onset of cataract may be possible in those who had a lifelong habit of heavy cigarette smoking. Our results suggest that because smoking remains a modifiable risk factor for cataract, an effective antismoking program in India may decrease the large burden of cataract blindness to some extent. In addition, it would have a potentially beneficial impact on respiratory and cardiovascular health. It would make sense to extend the antismoking awareness program to schools. Educating about the ill effects of tobacco smoking may go a long way in promoting healthy behavior among the general population, in particular the younger generation, with a view toward reducing tobacco-related ailments, including cataract.

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