Correlation between UVB Irradiation and the Proportion of Cataract
—An Epidemiological Study Based on a Nationwide Patient Survey in Japan—

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Abstract: Among the multiple factors affecting the human eye in work environment, ultraviolet B irradiation (UVB) has received much attention recently. To provide a clear information for the association between cataract and UVB irradiation, the prevalence data from the Patient Survey and UVB estimates in all the 47 prefectures in Japan were used to examine the relationship between cataract and UVB. In analyzing the relationship, we controlled possible effect modifiers; which were aged, that is 65 years old (yo.) or older, population per ophthalmologist, proportions of all the patients among the aged population and proportion of very elderly population (75 yo. or older) among the aged population. A sex-specific logistic regression analysis revealed that the adjusted odds ratio in women was 1.118 with a 95% confidence interval of 1.058-1.183. However, the adjusted odds ratio in men was not statistically significant (1.048 with 95% confidence interval 0.968-1.135). The unstable results of this study may be largely due to the non-definitive estimation of UVB exposure that this kind of study should be repeated when more valid UVB estimates is available.

Key words: UVB, Cataract, Patients Survey, The Japanese islands, Proportion of all the patients among aged population, Aged population per ophthalmologist, Proportion of 75 yo. or older among aged population (65 yo. or older)

Introduction

There are multiple factors in work environment affecting the human eye and giving rise to occupational ocular diseases. Among them, non-ionizing radiation, such as ultraviolet B irradiation (UVB), has received much attention as a cause of cataract1-3. UVB is emitted from arc welding, laser, and some other medical and dental equipments4-6. However, the sun is the largest source of UVB and people working outdoors, such as farmers, may be the largest exposed group. It has been reported that outdoor workers are more liable to cataract than indoor workers5-7. Also, it has been demonstrated that UVB induces cataract formation in experimental animals8-10. The proof of dose response relationship might have important implications for formulating an effective plan for cataract prevention. However, to establish the dose-response relationship of UVB and cataract, further investigation based on a general population is required. This type of investigation has a larger sample size and higher statistical power, providing information suitable for a quantitative information analysis. There are several population-based epidemiological investigations of the relationship between cataract and UVB. However, the results have not been in agreement. It has
been pointed out that there were several sources of biases in these studies, such as the motivation of subjects to participate in the investigation\(^{11}\). The personal history of UV exposure and residential region\(^{12}\) could also influence the results of the investigations. When existing health statistics are used, because cataract is not a fatal disease, the number of patients with cataract may be influenced by both the accessibility to medical care and the variable diagnostic criteria of the physicians. All of these may cause both selection and information bias as well as random misclassification in an epidemiological study on cataract.

Considering these difficulties in an epidemiological study on the association of cataract and UVB irradiation, Japan seems to provide a better foundation from which to perform an epidemiological analysis on this subject. Firstly, people with dark iris, such as the Japanese, have been reported to have higher prevalence of cataract\(^{13-15}\). This is contrary to the case of skin cancer which is more common among white people. Secondly, Japan’s health insurance system provide universal coverage, allowing patients with cataract high and homogeneous access to medical care. In addition, there are several nationwide health statistics suitable for the estimation of the prevalence of cataract, which is not readily existent in many countries. Finally, Japan lies through the latitudes of 24° to 45° and the range of UVB irradiation varies fairly widely from the northern to the southern parts of Japan. Thus, we analyzed the results of the 1993 Patient Survey of Japan\(^{16}\), one of the latest nationwide statistical survey for cataract, which is not readily existent in Japan (Sapporo, Tsukuba, Kagoshima and Naha) between October, which was relatively homogeneous in many countries. The personal history of UV exposure and residential region\(^{12}\) could also influence the results of the investigations. When existing health statistics are used, because cataract is not a fatal disease, the number of patients with cataract may be influenced by both the accessibility to medical care and the variable diagnostic criteria of the physicians. All of these may cause both selection and information bias as well as random misclassification in an epidemiological study on cataract.

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Materials and Methods

Sources of data

1) Proportion of patients with cataract among 65 years old (yo.) or older. Every three years in Japan, the Statistics and Information Department, Ministry of Health and Welfare performs the Patient Survey, a medical care institution based survey. The data collection was done in September and October, which was relatively homogeneous in meteorological condition nationwide in Japan to control the variation on accessibility to medical care. Among medical care institutions of 47 prefectures in Japan, 6,865 hospitals (sampling rate 70/100) and 5,884 clinics (sampling rate 7.5/100) were selected as samples by stratified randomized sampling. The number and characteristics (sex, age, and diagnosis) of patients under medical care by hospitals and clinics were investigated on a designated day (outpatients visited from October 19 to 21, 1993 and inpatients discharged from September 1 to 30, 1993). If a patient had more than one diagnosis, the major disease was enumerated as “primary disease” and a less major one was enumerated as “secondary disease”. The number of patients under medical care were estimated by the formula shown below:

\[
\text{Number of patients under medical care} = \text{inpatients} + \text{outpatients (first visit)} + \text{outpatients (following visit)} \times \text{average interval since last visit} \times \text{adjust (6/7)}
\]

We collected only the information of the “primary disease” and used the estimated number of patients under medical care. Only those who were 65 yo. or older were included in this study as it has been reported that the prevalence of cataract increases sharply over the 7th decade\(^{17}\) and the population of those who are 65 yo. or older has been generally categorized as “aged people”. Traditionally in Japan, most cataract patients are followed for certain period of time by medication before surgical treatment is indicated. Therefore, the patients with cataract listed in the Patient Survey includes patients under both medical and surgical treatments. The numerator of the proportion of patients with cataract was defined as the estimated number of patients under treatment for cataract who are 65 yo. or older (including the patients who have cataract presently and those who are followed up for operated cataract), and the denominator was defined as total population of 65 yo. or older in each prefecture. This ratio was used as a surrogate for the prevalence rate of cataract.

2) Amount of UVB irradiation. For the amount of UVB irradiation in 47 prefectures in Japan, we used the estimation of ultraviolet irradiation reported by Japan Meteorological Agency in 1994\(^{18}\). This estimation was based on the following information: i) A satellite information of the ozone column, ii) Daily integrating UVB irradiation of 4 locations in Japan (Sapporo, Tsukuba, Kagoshima and Naha) between 1991 and 1992. Radiation in wavelength of 290-325nm was measured every hour during daytime by Brewer spectrophotometer. iii) Daily integrating sunlight hours of 67 locations in Japan between 1982 and 1992.

3) Possible effect modifiers\(^{19}\). To investigate the independent relationship between cataract and UVB, we calculated the following variables as possible effect modifiers. Proportion of all the patients among 65 yo. or older. It is known that patients visit their hospitals more frequently in some areas than others, and thus the apparent different prevalence rates may be partly due to the health behavior of residents rather than real differences in the extent and severity...
of the diseases. For this reason, the proportion of all the patients, which was calculated by dividing the total patient number (including all diseases) of 65 yo. or older by the total population of 65 yo. or older in each prefecture, was controlled as a possible effect modifier.

**Aged population per ophthalmologist.** Medical resources such as the number of medical care institutions and physicians may also influence the proportion of diagnosed patients. To control for these factors, the aged population per ophthalmologist, defined as the population of 65 yo. or older in each prefecture divided by the number of the ophthalmologists in each prefecture, was used. The latter information was based on the Membership Directory of Japan Association of Ophthalmology.

**Proportion of 75 yo. or older among 65 yo. or older.** As it has been demonstrated that prevalence of cataract increases with age, age should be controlled as an effect modifier. In this study, the proportion of 75 yo. or older among 65 yo. or older was calculated for each prefecture. This proportion was used as a surrogate for the averaged age of 65 yo. or older population.

**Method of analysis**

Considering the large variation in the population size of 47 prefectures, the proportion of patients with cataract was weighted by the population of each prefecture throughout the following analysis. At first, we performed an univariate logistic analysis by using the proportion of patients with cataract among 65 yo. or older (ranges between 0 and 1) for the dependent variable and the estimated UVB irradiation for the independent variable.

To assess the independent effects of UVB irradiation on the proportion of patients with cataract among 65 yo. or older, a multiple logistic regression analysis was performed for both men and women by controlling for (1) the proportion of all the patients among 65 yo. or older; (2) aged population per ophthalmologist in each prefecture and (3) proportion of 75 yo. or older among 65 yo. or older. All the denominators and numerators were used as continuous variables in the regression model.

To investigate the sex difference in the proportion of patients with cataract in the whole Japan, stratified analysis with a 5-year age interval was performed by Cochran-Mantel-Haenszel chi-square test. The differences of proportions of all the patients and 75 yo. or older among 65 yo. or older between men and women were performed by paired t-test.

The PC-SAS was used to compute the logistic regression analysis with a 95% confidence interval.

## Results

As shown in Table 1, the proportion of total patients with cataract among women was always higher than that of men across the 5-year age stratum. The result of Cochran-Mantel-Haenszel chi-square test showed a significant difference between men and women.

Table 2 shows the basic characteristics of the variables in 47 prefectures which include the estimated UVB irradiation; the proportion of patients with cataract among 65 yo. or older; the proportion of all the patients among 65 yo. or older; the proportion of all the patients among 65 yo. or older; the aged population per ophthalmologist; the proportion of 75 yo. or older among 65 yo. or older. Due to the extended latitude stretch of islands, the estimated UVB irradiation in the highest UVB exposed prefecture (Okinawa, 20 kJ/m²) was almost double compared to that in the lowest UVB exposed prefecture (Hokkaido, 11 kJ/m²), although there was small discordance between UVB and latitude due to sunlight hours and other meteorological factors. The proportion of patients with cataract among 65 yo. or older in women was twice as high as that in men. In the population of 65 yo. or over, the number of women was 50% more than that of men. Also the proportion of all the patients and population of 75 yo. or older among 65 yo. or older were significantly higher in women than men.

By the univariate analysis, crude odds ratios for an increase of UVB irradiation of 1 kJ/m² to the proportion of patients with cataract were 1.019 (95% confidence interval of 0.955–1.088) in men and 1.034 (95% confidence interval of 0.995–1.076) in women (Table 3). After controlling for the possible effect modifiers by the multiple regression analysis, the adjusted odds ratio in women increased to 1.118 with a 95% confidence interval of 1.058–1.183. Although the adjusted odds ratio in men also increased to 1.048, it was not

<table>
<thead>
<tr>
<th>age (yrs)</th>
<th>population (in thousands)</th>
<th>cataract* (%)</th>
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<tbody>
<tr>
<td></td>
<td>men</td>
<td>women</td>
</tr>
<tr>
<td>65–69</td>
<td>2763</td>
<td>3229</td>
</tr>
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<td>70–74</td>
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<td>1374</td>
</tr>
<tr>
<td>≥85</td>
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<td>942</td>
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*proportion of patients with cataract. \(x^2_{om}=101.8, \ p<0.001\)
The effects of possible effect modifiers which are adjusted in the analysis are shown in Table 4.

Discussion

In this study, we have investigated the association between UVB irradiation and the proportion of patients with cataract. The result of multiple logistic regression analysis in women shows that the UVB irradiation is moderately related to the proportion of patients with cataract after controlling for the aged population per ophthalmologist, proportions of all the patients and 75 yo. or older among 65 yo. or older. In men, the point estimate of odds ratio was above the unity and increased further after controlling for the possible effect modifiers, but was still not statistically significant. Quantitatively, the chance to see a doctor for cataract increases by 11.8% for each 1 kJ/m$^2$ of UVB irradiation in women. As the range of UVB irradiation in Japan is 11–20 kJ/m$^2$, we can estimate that the women living in the highest UVB exposed prefecture in Japan (Okinawa) may have about a 120% higher chance to see a doctor for cataract than those living in the lowest UVB exposed prefecture (Hokkaido). However, this estimation is under a hypothesized situation where only the effect of UVB irradiation is considered. The Chesapeake Bay Waterman Study\textsuperscript{20}, which investigated the personal exposure to the detail, also revealed a 60% increase in cataract with doubling of UVB exposure. Javitt and...
Taylor\textsuperscript{21} reported a comparable result using an analysis of the data from the Medicare program in the USA. The Medicare program provides health insurance for nearly all Americans who are above 65 years old of age and pays for 85\% of cataract operation performed in the USA. They controlled several possible effect modifiers including medical resources. Their results suggested that the probability of having surgery for cataract in the USA increases by 3\% for each degree decrease of latitude. Latitude correlates with UVB irradiation because the incident angle of the sun determines the atmospheric penetration of ultraviolet radiation. The Medicare data has similar characteristics to our data which may accompany similar limitations as ours. The limitation of this kind will be further discussed later.

On the contrary, in an survey conducted in Australia, Hollows \textit{et al.}\textsuperscript{12} reported that cataract prevalence was associated with geographic areas in Aborigines but not in non-Aborigines in Australia. Sasaki \textit{et al.}\textsuperscript{11} also reported that cataract prevalence in a southern village (in Okinawa) was not higher than that in a northern village (in Ishikawa) in Japan. However, the authors of these two studies acknowledged that the result of no association between cataract and UVB could be due to biases. In the former study, as the subjects were measured as same exposure in one geographic area and the non-Aborigines may not have as much uniform lifestyle as the Aborigines, the authors presumed that the association was weakened in non-Aborigines. In the latter, as the investigation of cataract prevalence among residents had been performed several times in the northern village, the authors presumed that the higher motivation of these residents might have influenced the result.

A study in Nepal\textsuperscript{22} reported the correlation between average daily sunlight and cataract both in men and women. The Beaver Dam Eye Study\textsuperscript{23} reported the association between personal exposure to UVB and cataract only in men but not in women, however, the authors explained that the information concerning personal exposure might be biased by the current presence of cataract, and we suppose that the bias may be stronger in women because of the higher prevalence of cataract in women in this study. In our study, the association between cataract and UVB irradiation was significant only in women. We presume that the association also exists in men but did not reach a statistically significant level, because of the following reason. As the aged population and the proportion of patients with cataract were both higher among women than that among men (2:3 and 1:2, respectively), the smaller power of statistics in men rather than women might have affected to this difference. From these findings, we believe that there is an association between UVB irradiation and cataract both in women and men, although it is necessary to investigate further the differential effect of UVB on cataract formation in women and men.

There have been studies which reported that the chance to see a doctor for cataract was higher in women than in men\textsuperscript{24-26}. These authors discussed that this difference may be due to social reasons (women live longer and men accept a lower visual acuity before seeking medical assistance) and biological factors (sex hormone may be a synergist to factors which cause cataract\textsuperscript{27}). However, whether the incidence of cataract is really higher in women or not needs further investigation.

In spite of our effort to control the possible effect modifiers which is considered to affect the relation between cataract and UVB irradiation, there still remains several limitations in the present study.

Firstly, the proportion of patients with cataract is 6.0\% in this study which is lower than that of other epidemiological studies in Japan\textsuperscript{17}. It has been reported that only 29.4\% of cataract patients were diagnosed by ophthalmologists in one area in Japan\textsuperscript{28}. Moreover, the number of patients with cataract in this study (data from the Patient Survey) did not include those who had been diagnosed as having cataract but had not been recently followed up for cataract. Furthermore, as only “primary disease” was enumerated in the Patient Survey, patients with cataract as “secondary disease” were not included in this study. This may account for the cause of the lower proportion of cataract in this study. However, as we have controlled for the proportion of all the patients in this study, the regional difference of probability to see a doctor for cataract among cataract patients may not influence the result of this study.

Secondly, there is a limitation in validity of the estimation of UVB exposure. The estimated UVB irradiation was based on the satellite information of ozone column and daily integrating UVB irradiation of 4 locations. The estimated UVB irradiation is considered to be reproducible as the UVB irradiation was integrated everyday in two years and the sunlight hours in 67 locations were integrated in 11 years. However, the estimate should be further validated as the number of integrating places was too small (only 4 locations). Moreover, the reflection of UVB irradiation and personal difference of exposure could not be incorporated into the analysis due to the lack of detailed information (such as occupation, outdoor activity habit, residential circumstances, moving, etc). We also need to consider whether or not the subjects customarily used glasses, hats or sun umbrellas.
In this study, the residents of the same prefecture were assumed to have been exposed to the same UVB irradiation, despite individual differences. However, all these factors are presumed to weaken the correlation between UVB and cataract. Without these factors, the true value of correlation should have been stronger than what we obtained in this study.

The results of the study suggest that UVB exposure is one of the major causes of cataract and the chance to see a doctor for cataract increases by 11.8% for each 1 kJ/m² of UVB irradiation in women. However, due to the limitations described above, the quantitative result needs further verification when it is applied to formulate a plan for cataract prevention in the workplace. If there were more valid UVB estimates in the future, it is warrant that the correlation between UVB irradiation and the proportion of patients with cataract should be repeated with the same methods as this study. Moreover, it should not be forgotten that people are exposed to sunlight not only in their workplace but also in leisure outdoors. Thus, when investigating the influence of UVB exposure in work environment, particular consideration should be paid on the location of the workplace and residence.

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References


