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A longitudinal population study of the impact of cataract extraction on sleep quality

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Abstract: *Purpose*: To investigate the longitudinal effects of cataract extraction on sleep quality in two discrete population cohorts. *Methods*: 301 participants who had senile cataract in both eyes at the baseline examination were selected from two large longitudinal epidemiologic studies of age-related eye disease, hearing, olfaction, and cognition. The participants were divided into two groups: one had cataract surgery (CS) in both eyes, and the other had no cataract surgery (NCS) in either eye by the follow up examination. Cataract was graded from photos or digital images using a standardized protocol. The quality of sleep was assessed using a modified Wisconsin Sleep Cohort Study Questionnaire. The NCS and CS groups were compared as to the change in the number of sleep problems reported from the baseline to the follow-up examination, adjusted for systemic co-morbidity data and the SF-36 physical component and mental component summary scores. *Results*: The average (mean ± SD) age was 71.0 ± 8.8 years in the NCS (n = 237) group and 73.4 ± 9.1 years in the CS (n = 64) group. There was no statistically significant difference in the change in the number of sleep problems reported between the NCS and CS groups (mean: −0.068 for NCS and 0.016 for CS, p = 0.57). The multivariable linear regression models, when adjusted for confounders, yielded similar results. *Conclusion*: In this longitudinal, community-based population study, we found

ABOUT THE AUTHORS

As a neuro-ophthalmologist, I diagnose and treatment vision problems associated with a variety of neurologic and systemic diseases. My research focuses on how ocular diseases influence our general health, in particular, non-visual brain behaviors such as sleep and cognition. I use pupil reactivity produced by a special group of retinal photoreceptors, the intrinsically photosensitive retinal ganglion cell (ipRGC), as a biomarker to relate age-related ocular disease to these general health outocome measures. I also research if lighting intervention can help promote sleep, cognition, and work performance. Lines of investigation will add to our understanding of how the viusal system—from the eyes to the brain—works to influence human behavior, and facilitate the development of strategies to overcome the negative impact of age-related ocular diseases on the physical and psychosocial wellbeing of the aging population.

PUBLIC INTEREST STATEMENT

The external ambient light plays an essential role in the regulation of various brain activities, such as sleep, body temperature, and hormonal secretion. Age-related ocular diseases have a significant impact on these physiologic activities by blocking the transmission of the external ambient light to the brain. This perspective article studies whether removal of cataract, an age-related ocular condition that causes reduced light transmission due to yellowing of the crystalline lens, can help improve sleep quality, in a large epidemiologic study of aging, the Beaver Dam Offspring Study. The study found no significant impact of cataract removal on sleep quality. Sleep disruption is common in the elderly and has a negative impact on the physical and psychosocial wellbeing of the aging population. Therefore, further study is needed to assess the relation between age-related ocular disease and sleep which may help with the development of interventional strategies to promote sleep.

no significant impact of cataract extraction on sleep quality. Studies of the effect of cataract extraction on sleep should allow a longer follow up to demonstrate sustainability.

Subjects: General Medicine; Ophthalmology; Sleep Medicine

Keywords: cataract; cataract extraction; sleep; population study; longitudinal

1. Introduction

An increasing body of evidence from experimental animals has suggested that the eye serves a critical role in regulating sleep and rest-activity patterns by conducting external ambient light to the brain sleep center (Alexander et al., 2014; Berson, Dunn, & Takao, 2002; Hattar et al., 2003; Panda et al., 2003). Age-related ocular diseases, such as glaucoma and cataract, have been associated with sleep disruption, presumably due to a deterioration of the eye's ability to transmit external ambient light to the brain (Alexander et al., 2014; Asplund & Ejdervik Lindblad, 2002; Drouyer et al., 2008; Gracitelli et al., 2015; Lanzani et al., 2012; Turner, Van Someren, & Mainster, 2010).

The question remains as to whether the presence of cataract, a reversible age-related blinding disease, can impact sleep quality, and conversely, whether cataract extraction can help promote sleep among the middle-aged and elderly. Evidence supporting the negative impact of cataract on sleep is based on the fact that the age-related increase in crystalline lens light absorption and pupil size reduction, taken together, decreases the photoreception in a healthy aging adult by 50% at age 45 and 90% at age 90 compared to a healthy 10-year-old (Norren & Vos, 1974; Turner & Mainster, 2008). A cross-sectional study (n = 970) among adults aged 30–60 years found that the risk of sleep disturbance was significantly higher when the transmission of blue light was decreased by the aging lens (Kessel, Siganos, Jorgensen, & Larsen, 2011). Furthermore, several studies among patients undergoing cataract extraction surgery found an improved sleep quality following cataract removal (Alexander et al., 2014; Asplund & Ejdervik Lindblad, 2002; Asplund & Lindblad, 2004).

However, in our previous examination of the impact of cataract/cataract extraction in large epidemiologic cohorts (n = 5,070), we did not find a significant association between nuclear sclerosis cataract or cataract extraction with sleep quality after adjusting for potential confounders (Chen et al., in press). The cross-sectional design might have mitigated the strength of the study in demonstrating a relation between cataract and sleep. Hence, we conducted a longitudinal study in the same epidemiologic cohorts to further elucidate the relation between cataract/cataract removal and sleep disruption.

2. Materials and methods

The Epidemiology of Hearing Loss Study (EHLS) is an observational, longitudinal, population-based study of age-related hearing, olfaction, and cognition in the cohort recruited into the Beaver Dam Eye Study (BDES) in Beaver Dam, WI. The baseline examination took place in 1993–1995 (n = 3,753, ages 48–92 years), and the five-year follow-up examination in 1998–2000 (Cruickshanks et al., 2003; Schubert et al., 2002). The Beaver Dam Offspring Study (BOSS) is an observational longitudinal study of age-related sensory disorders among the adult children of the EHLS (Schubert et al., 2012, 2013). The baseline examination was conducted from 2005–2008 (n = 3,296, ages 21–84 years), and the five-year follow-up examination in 2010–2013.

The current study combines cataract assessments from the BDES and sleep questionnaires from the EHLS 1998–2000 (referred to as baseline in the present study) and 2003–2005 (follow-up) examinations and similar data from the 2005–2008 (baseline) and 2010–2013 (follow-up) examinations of the BOSS study. Details about these cohorts have been described in previous reports (Cruickshanks et al., 2003; Klein, Klein, Lee, & Grady, 2006; Schubert et al., 2012). The studies were approved by the University of Wisconsin Institutional Review Board. Written informed consent was obtained from participants prior to the examination.

The cataract assessment in the EHLS was conducted during the participation of the same cohort in the BDES. Film-based photographs of the lens were taken after pupils were dilated with mydriatic eye drops. Slit-lamp photos were taken to grade the degree of nuclear cataract. The degree of nuclear cataract was classified level 1 to 5 using a standardized protocol (Klein, Klein, Linton, Magli, & Neider, 1990). Digital images were obtained in the BOSS and graded following an adaptation of the same cataract grading protocols used in the BDES. Cortical opacities and posterior subcapsular opacities were graded from red reflex images using standardized protocols (Klein et al., 1990). The presence of an intraocular lens was coded for each eye. Cataract was defined as increased opalescence of the lens nucleus and cortical lamellae and decreased discretion of the individual lamellae (Klein et al., 1990).

The EHLS and BOSS collected sleep data using a modified version of the Wisconsin Sleep Cohort Study questionnaire (Schubert et al., 2002; Wetter & Young, 1994). In the EHLS, three sleep questions were used to create a cumulative score to semi-quantify sleep disruption: (1) to what extent have you experienced difficulty getting to sleep, (2) to what extent have you experienced waking up during the night and having a hard time getting back to sleep, and (3) to what extent have you experienced waking up repeatedly during the night? For all three questions, the possible responses were: 0 never, 1 rarely (1/month), 2 sometimes (2–4/month), 3 often (5–15/month), 4 almost always (>16/month). Participants responding “often” or “almost always” were considered to have sleep problem for the purposes of scoring. The number of sleep problems reported was then summed, ranging from 0 to 3. The 2003–2005 EHLS and 2010–2013 BOSS examinations included three additional sleep questions: (1) to what extent have you experienced feelings of excessive daytime sleepiness, (2) to what extent have you experienced falling asleep or dozing momentarily while watching TV, reading, etc., and (3) how often do you take naps during the day? Both the EHLS and BOSS contain eye outcome data using comparable protocols, including the presence of cataract/cataract surgery, age-related macular degeneration (AMD), diabetic retinopathy and glaucoma. Furthermore, the studies included co-morbidity data as potential confounders, including diabetes mellitus, arthritis, obesity, hypertension, cerebrovascular disease (CVD), thyroid disease, tobacco and alcohol use, level of education, and the physical component summary (PCS) score and mental component summary (MCS) score from the SF-36. PCS and MCS are widely used aggregate summary measures concerning individual’s overall physical and mental health (Ware, 1994).

Whereas visual impairment from a variety of blinding ocular diseases may have a negative physical and psychological impact on sleep, we would expect that only those that cause dysfunction of the ipRGCs would lead to disruption of the circadian sleep function, such as glaucoma, optic neuropathy, or advanced AMD. In this study, advanced AMD was present in three, and glaucoma in eighteen participants and excluding these participants did not change the results.

3. Statistical analysis

The participants (n = 301) all had cataract in both eyes at baseline. They were classified into one of two groups: (1) No cataract surgery (NCS, n = 237), defined as the presence of cataract in both eyes at follow-up, and (2) Cataract surgery (CS, n = 64), defined as having had cataract surgery in both eyes by the time of the follow-up examination. The overall significance of the mean change in sleep problems reported for all 301 participants was tested with a paired t-test. The unadjusted difference in the mean change in number of sleep problems reported between the NCS and CS groups (“CS status”) was assessed with a t-test. Age- and sex-adjusted differences in participant characteristics by CS status were tested with t-tests from multivariable linear regression models (for continuous characteristics), and with chi-square tests from logistic regression models (for categorical characteristics). Multivariable linear regression (MLR) models were used to test the association between CS status and reported changes in sleep problems after adjusting for additional potential confounders. Three subanalyses were also conducted. In the first, MLR models were used to test the association between CS status and reported sleep problems at follow-up using an expanded 6-question questionnaire. In the second, MLR models were used to test the association between CS status and change in sleep problems in a subset of 119 participants with nuclear sclerosis levels 4 or 5 at baseline. In the

Table 1. Baseline participant characteristics by subsequent cataract surgery status

Characteristic	No cataract surgery (NCS)		Cataract surgery (CS)		*p*-value[1]
	n	%	*n*	%	
Sex					0.57[2]
Men	79	33.3	19	29.7	
Women	158	66.7	45	70.3	
Education (yrs)					0.49
0–11	51	21.5	12	18.8	
12	106	44.7	39	60.9	
13–15	41	17.3	7	10.9	
16+	39	16.5	6	9.4	
Arthritis	128	54.0	28	43.8	0.10
CVD	44	18.6	14	21.9	0.67
Diabetes	33	14.0	9	14.3	0.80
History of heavy drinking	53	22.4	16	25.0	0.44
Hypertension	156	65.8	41	64.1	0.52
Smoking status					
Never	110	46.4	29	45.3	0.83
Past	104	43.9	32	50.0	
Current	23	9.7	3	4.7	
History of thyroid disease	32	13.5	12	19.1	0.28
	Mean	**SD**	**Mean**	**SD**	
Age	71.0	8.8	73.4	9.1	0.06[3]
BMI	30.1	5.8	30.4	6.4	0.57
MCS	54.7	8.5	53.6	7.6	0.25
PCS	45.3	10.5	44.8	10.0	0.98
Number of sleep problems	0.9	1.1	1.0	1.1	0.90

[1]Adjusted for age and sex.
[2]Adjusted for age.
[3]Adjusted for sex.

third, logistic regression was used to test the association between CS status and reported improvement in sleep among 79 participants reporting at least two sleep problems at baseline.

4. Results

The characteristics of the participants are summarized in Table 1. Cataract and sleep data were collected in a total of 301 participants, including 237 participants in NCS (M:F = 79:158) and 64 participants in CS (M:F = 19:45) group. The average age of the participants was 71.0 ± 8.8 and 73.4 ± 9.1 years (mean ± SD) in NCS and CS group, respectively. There were no significant differences in demographic characteristics (age, sex, BMI), functional status (MCS and PCS), level of education, and systemic comorbidity (arthritis, CVD, Diabetes, history of heavy drinking, hypertension, tobacco use, and history of thyroid disease) between NCS and CS group ($p > 0.05$).

There was no significant change in the number of sleep problems at follow-up compared to the baseline examination among all participants combined (mean −0.05; $p = 0.40$). The mean change in the number of sleep problem (−3 to 3) was −0.068 in NCS and 0.016 in CS group, respectively; there was no statistically significant difference in the mean change in the number of sleep problem between the two groups ($p = 0.57$). The MLR models, when adjusted for age, sex, BMI, arthritis, CVD, diabetes, heavy drinking, hypertension, MCS/PCS, tobacco use, and history of thyroid disease, yielded similar results.

Table 2. Association of cataract surgery with various outcomes[1]

Outcome	*n*	Parameter estimate	*p*-value
Change in # of sleep problems (−3 to 3)	301	0.11[2]	0.44
# of sleep problems reported at follow-up (0–6)	300	−0.08[2]	0.73
Change in # of sleep problems (−3 to 3) among those with nuclear sclerosis levels 4 or 5	119	0.14[2]	0.52
Improvement in sleep among those reporting at least two sleep problems at baseline	79	−0.58[3]	0.43

[1]Results are adjusted for age, sex, hypertension, and MCS score.

[2]From multivariable linear regression model.

[3]From multivariable logistic regression model. Odds ratio = 0.56, 95% CI = (0.13, 2.40).

Additional analyses were conducted to compare between NCS and CS group using the following outcome measures: (1) the number of sleep problems (0–6) at the follow-up examination ($n = 300$), (2) the change in the number of sleep problems among participants who had nuclear sclerosis level 4 or 5 in both eyes at baseline examination ($n = 119$), (3) improvement in sleep, defined as having at least 2 sleep problems at baseline ($n = 79$) and 2 or 3 fewer sleep problems at follow-up (20 of the 79). None of the above analyses demonstrated a statistically significant difference in the outcome measures between the NCS and CS group (Table 2).

5. Discussion

Epidemiologic studies have demonstrated that age-related ocular diseases are associated with declines in quality-of-life measures independent of vision (Broman et al., 2002; Knudtson, Klein, Klein, Cruickshanks, & Lee, 2005). Compelling evidence from the anatomical and physiological studies in experimental animals and observational studies in humans points towards the intrinsically photosensitive retinal ganglion cells (ipRGC) as the core ocular structure involved in the eyes' modulating non-visual physiologic behaviors (Berson et al., 2002; Feigl & Zele, 2014; Gracitelli et al., 2015; Hattar et al., 2003; Lucas, Freedman, Munoz, Garcia-Fernández, & Foster, 1999; Zaidi et al., 2007). The ipRGCs are subjected to the influence of age-related ocular diseases, such as cataract, glaucoma, and AMD (Feigl, Mattes, Thomas, & Zele, 2011; Feigl & Zele, 2014; Kankipati, Girkin, & Gamlin, 2011; Turner & Mainster, 2008). All can reduce the transmission of external ambient light to the brain. Therefore, it is intuitive to hypothesize that interventions to age-related ocular disease would improve ipRGC function and thus promote non-visual health outcomes in which the ipRGCs are playing a role, such as sleep.

Several studies reported that cataract extraction improved sleep quality and the improvement lasted up to 12 months following the cataract surgery (Alexander et al., 2014; Asplund & Ejdervik Lindblad, 2002; Asplund & Lindblad, 2004). However, in our previous cross-sectional, community-based population study, we did not find a significant difference in sleep quality between individuals who underwent cataract extraction and those who did not. Therefore, we conducted the present longitudinal study among the participants of the EHLS and BOSS cohort to seek further evidence about the association between cataract/cataract extraction and sleep quality. In the present study, we only included individuals who had a cataract in both eyes at the baseline examination, and who did not have cataract surgery in either eye or had cataract surgery in both eyes in the follow-up examination. Such a design is to enhance the chance of identifying a positive effect of cataract extraction. The results of the present study agree with the findings of our previous cross-sectional analysis using the same epidemiologic cohorts that there is no significant impact of cataract or cataract extraction on sleep quality.

Several factors may have contributed to the negative impact of cataract/cataract extraction on sleep quality. First, the small sample size ($n = 301$) in the present study may have limited the ability of the present study to identify a significant change in sleep problems following cataract extraction. However, we chose the two groups of subjects who had the most and least severe cataract in the follow up examination, i.e. individuals with cataract in both eyes and no cataract in either eye, respectively. A comparison between these two groups would be most likely to demonstrate a difference in sleep problems; adding subjects who had medium-severity cataract was unlikely to change the outcome. Second, the studies demonstrating an improvement of sleep quality had a relatively short follow up of sleep (12 months) (Alexander et al., 2014; Asplund & Ejdervik Lindblad, 2002). It is possible that cataract extraction may have a temporary impact on sleep, due to either an improved psychologic wellbeing from being able to see better or a promoted sleep physiology because of enhanced light transmission through the eye. Nevertheless, the results from our study do not support a sustainability of this impact. It is prudent to have a longer follow up in studies investigating the effect of an intervention on sleep quality, as sustainability is important in such a quality-of-life measure. Third, it is also possible that despite a reduction in the transmission of the amount of the external ambient light through the eye, cataract does not exert the same negative effect on sleep as other age-related ocular diseases, such as glaucoma and AMD, which cause degeneration of the ipRGCs.

We acknowledge several limitations in the present study: First, in this study, sleep data were collected by questionnaire rather than Actigraphy, and the Modified Wisconsin Sleep Cohort Study Questionnaire used in this study does not specifically address circadian rhythm sleep disruption (Schubert et al., 2002). However, similar sleep questionnaires have been used in previous studies demonstrating sleep problems in a variety of ocular diseases (Asplund & Lindblad, 2004; Kessel et al., 2011; Pressman, Diphillipo, & Fry, 1986; Tabandeh et al., 1998). We would thus expect that individuals suffering from circadian sleep disorder would have more sleep problems as identified by the Modified Wisconsin Sleep Cohort Study Questionnaire. Further study using Actigraphy to assess sleep parameters may provide more quantitative assessment of sleep. Second, the grading of the cataract used in this study is based on photos rather than a direct measure of short-wave length light transmission through the eye (Kessel et al., 2011), although the grading system used in the present study is in line with the other studies and perhaps represents a more practical way to assess cataract when the impact of cataract surgery on sleep is concerned. Third, the exact date of the cataract surgery, and thus the precise interval between the surgery and the follow-up examination is unknown for a given individual. This, however, will over- rather than under-estimate the impact of the cataract extraction on sleep by including those who experienced a temporary improvement in sleep following cataract extraction.

6. Conclusion

In this longitudinal, community-based population study, we found no significant impact of cataract extraction on sleep quality. Studies of the effect of an intervention to improve sleep quality should have longer follow up to ensure any improvement in sleep is not transitory.

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Competing Interest
The authors declare no competing interest.

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