Rejuvenation Effects of Cataract Surgery with Ultraviolet Blocking Intra-Ocular Lens on Circadian Rhythm and Gait Speed

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Abstract

Background: Previously, we reported improvements in sleep quality and gait speed after implantation of a yellow-colored, blue light-blocking intra-ocular lens (IOL). This study evaluated systemic health parameters for 7 months after cataract surgery with implantation of a clear, ultraviolet (UV)-blocking IOL.

Methods: A total of consecutive 71 patients (average age 74.1 years) underwent cataract surgery with the implantation of a clear, UV-blocking IOL. Participants were evaluated using the Pittsburgh Sleep Quality Index (PSQI) and the National Eye Institute Visual Function Questionnaire (VFQ-25) before and at 2 and 7 months after surgery. Four-meter gait speed was also determined. The metabolic parameters of serum glycated hemoglobin (HbA1c), triglycerides (TGs), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C) were tested.

Results: The pre-operative and post-operative (2 and 7 months after surgery) results were 66.4 ± 16.5 , 79.5 ± 12.6 , and 81.0 ± 13.0 for VFQ-25 score, 5.7 ± 3.5 , 5.1 ± 3.1 , and 4.8 ± 2.9 for PSQI, and 0.90 ± 0.22 , 0.91 ± 0.22 , and 0.92 ± 0.22 meters/sec for gait speed. Significant improvements following surgery were noted in the VFQ-25 score for all cases and in the PSQI for poor sleepers (preoperative PSQI > 5.5) ($P < 0.05$, paired *t*-test). The gait speed and metabolic parameters showed no significant changes.

Conclusions: Cataract surgery with implantation of an UV-blocking clear IOL has the potential for improving circadian rhythm and systemic health parameters.

Introduction

CATARACT SURGERY IS CONSIDERED advantageous in older adults for improving life expectancy, recognition, and depression.^{1–3} Previously, we reported enhanced gait speed and sleep quality after cataract surgery with implantation of yellow-colored, blue light-blocking intra-ocular lens (IOL).⁴ The clear, ultraviolet (UV)-blocking and the yellow-colored IOLs currently available show similar properties in terms of visual function with the exception of vision in mesopic or scotopic light conditions.^{5–9} Glare reduction is an additional advantage of yellow-colored IOL, although concerns have been raised that the blue light-blocking effects of such a lens might disturb normal circadian rhythms^{10,11} because intrinsically photosensitive retinal ganglion cells mediate melatonin secretion by photoreception of blue light.^{12–14} On the contrary, clear IOLs do not block visible light transmission and thus offer no protection to the retina from the potentially damaging effects of bright light,^{15–20} although the protective effect of a blue light-

blocking IOL is elusive.¹⁰ In addition to this analysis of ocular risk/benefit, it is important to clarify the systemic effects of clear IOLs using the same indices used to assess yellow-colored IOLs.

Visual function and physical stature are closely related,²¹ and visual recovery contributes to mortality and physical performance. Cataract surgery is recognized to both reduce the risk of falls, a serious injury in older adults,^{22–29} and improve driving safety^{30,31} probably due to the remarkable improvement in visual recognition after surgery. Therefore, gait speed is a useful health index to evaluate the systemic effects of cataract surgery,³² and we previously developed an estimation of remaining years of life based on gait speed in cataract patients.³³

In this study, we evaluated cataract surgical cases implanted with clear, UV-blocking IOLs by measuring quality of life, sleep quality, and gait speed. We also monitored changes in metabolic parameters to determine whether increased gait speed and improved quality of life might contribute to normalizing these parameters.

Methods

This study was approved by the institutional review board of Mita Hospital, International University of Health and Welfare, and all patients provided written informed consent prior to participation in the study.

A total of 71 consecutive patients indicated for unilateral or bilateral cataract surgery were enrolled, and all of them agreed to participate in the study. Regarding the unilateral/bilateral surgery issue, there was a washout period of >6 months after the first eye surgery for second eye surgery in unilateral cases ($n=47$, 66%), and it was also an exclusion criterion. The study was done in the Tokyo area of Japan, latitude 35.68N, where photoperiods vary from 4 hr to 6 hr of daylight over the year, the average from 1981 to 2010 reported by Japan Meteorological Agency. The time frame of surgery was May, 2012, to June, 2013, with the follow-up assessment running from July, 2012, to September, 2013.

Patients were asked to complete two validated questionnaires as part of the study: the National Eye Institute Visual Function Questionnaire (VFQ-25; Japanese version 1.4)³⁴ and the Japanese version of the Pittsburgh Sleep Quality Index (PSQI).³⁵ Both questionnaires were self-administered. Sub-scales of the PSQI were retrieved for analysis of correlation with the severity of nuclear cataract.

Gait speed was evaluated in patients before and after cataract surgery using a digital stopwatch to time how long it took patients to walk 4 meters. All patients were asked to walk at their usual pace from a standing start with a cane(s) or walker, as needed. Gait speed was also measured in 129 age-matched controls with normal visual acuity (>20/25) in both eyes and who visited our clinic without any walking aid. Additional systemic variables included sex, age, body mass index (BMI; kg/m²), systolic blood pressure (SBP), and the metabolic parameters of serum glycated hemoglobin (HbA1c) (normal range, 4.0%–5.6%; Japanese Diabetes Society), triglycerides (TGs) (normal range, 30–150 mg/dL), low-density lipoprotein cholesterol (LDL-C) (normal range, 60–160 mg/dL), and high-density lipoprotein cholesterol (HDL-C) (normal range, 40–100 mg/dL). A registered nurse obtained patient data regarding major medical co-morbidities during face-to-face interviews with patients (*e.g.*, diabetes, hypertension, neurological disease, psychological disease, musculoskeletal disease, cardiopulmonary disease, and cancer).

Specialized ophthalmic evaluations were performed by certified orthoptists and board-certified ophthalmologists. Cataracts were diagnosed based on confirmation of microscopic crystalline lens opacity corresponding to decreased visual acuity. Cataracts were classified as posterior/anterior sub-capsular, central cortical opacities in the visual axis, or grade ≥ 3 (Emery–Little classification) nuclear sclerosis. For statistical analyses, visual acuity values were converted to the logarithm of the minimum angle of resolution (log-MAR). Refractive errors were classified as hyperopic (either eye $\geq +3.00^D$), moderate ($-2.75^D < \text{both eyes} < +2.75^D$), myopic ($-5.75^D < \text{either eye} \leq -3.00^D$), or highly myopic (either eye $\leq -6.0^D$).

The surgical procedures for cataract surgery and IOL insertion consisted of phacoemulsification and aspiration, followed by IOL fixation of a clear, UV-blocking lens (SA60AT; Alcon Laboratory, Fort Worth, TX) under topical anesthesia. All surgeries were performed by an experienced ophthalmologist, and patients with major intra- or post-operative complications were excluded from subsequent analyses.

Where appropriate, data are given as the mean $\pm$ standard deviation (SD). Data were analyzed using analysis of variance (ANOVA), *t*-tests, and the Mann–Whitney test, as appropriate. Correlations were evaluated using the Pearson test and stepwise multiple regression analysis. Sub-analyses were performed regarding preoperative value of the VFQ-25 and PSQI, sub-scales of PSQI, and severity of nuclear sclerosis to explore possible contributing factors to the main outcome of health indices. All analyses were performed using StatFlex (Atech, Osaka, Japan) and SPSS (SPSS Inc., Chicago, IL) 21, with $P < 0.05$ considered significant.

Results

Table 1 details the patient demographics and health-related characteristics. All patients [71 (100%), 30 males and 41 females] returned for evaluation 2 months after surgery and 53 patients (74.6%, 23 males and 30 females) returned 7 months after surgery. Two patients died during the follow-up period.

Table 2 lists the results of pre- and post-operative ophthalmic examinations. Posterior/anterior sub-capsular cataracts, nuclear cataracts (grade ≥ 3), and central cortical cataracts accounted for 36.8%, 36.8%, and 44.7% of cases, respectively. There was a marked improvement in visual acuity and refractive error after surgery.

In the post-operative analyses of VFQ-25 score and PSQI, patients were classified as either “healthy or normal sleeper” (VFQ-25 score ≥ 60 ; PSQI ≤ 5.5) or “less healthy or poor sleeper” (VFQ-25 score < 60 ; PSQI > 5.5) groups to account for the influence of a patient’s preoperative status on post-operative course (Table 3). In general, most patients in the healthy group maintained their health status after surgery, whereas those in the less healthy group exhibited improvements in all indices at 2 and 7 months after surgery, despite the initial and subsequent scores being worse than those of the healthy group. Significant improvements following surgery were noted in the VFQ-25 score for all of sub-groups and in PSQI for poor sleepers (preoperative PSQI > 5.5) ($P < 0.05$, paired *t*-test) at both 2 and 7 months after surgery (Figs. 1 and 2). Table 4 summarizes the PSQI sub-scales and severity of nuclear sclerosis results. The severe nuclear cataract cases achieved better post-operative scores in many PSQI sub-scales compared to the mild cases,

TABLE 1. PATIENT DEMOGRAPHICS AND HEALTH-RELATED CHARACTERISTICS

No. cases	71
No. men/women	30/41
Age (years)	74.1 $\pm$ 8.8
Height (cm)	157 $\pm$ 9
Weight (kg)	57 $\pm$ 13
BMI (kg/m ²)	22.8 $\pm$ 3.5
% Diabetic (HbA1c $> 5.8\%$, JDS)	33.7

Unless indicated otherwise, data are given as the mean $\pm$ standard deviation (SD).

BMI, body mass index; HbA1c, glycated hemoglobin; JDS, Japanese Diabetes Society.

TABLE 2. RESULTS OF OPHTHALMIC EXAMINATIONS BEFORE AND AT 2 MONTHS AFTER SURGERY

<i>Visual acuity and refractive error</i>	<i>Before surgery (n=71)</i>	<i>2 months after surgery (n=71)</i>
LogMAR visual acuity of better eye	0.10±0.34	-0.05±0.09*
LogMAR visual acuity of worse eye	0.69±1.00	0.14±0.70*
Refractive error		
% Hyperopic (either eye $\geq +3.00^D$)	15.4	4.2*
% Moderate error ($-2.75^D < \text{both eyes} < +2.75^D$)	54.9	90.1*
% Myopic ($-5.75^D < \text{either eye} \leq -3.00^D$)	7.0	5.7
% Highly myopic (either eye $\leq -6.0^D$)	22.7	0*

Unless indicated otherwise, data are given as the mean±standard deviation (SD).

* $p < 0.001$ compared with before surgery.

LogMAR, logarithm of the minimum angle of resolution.

including significant improvements in sleep latency. Figure 3 is a scatter plot showing the pre- versus post-operative PSQI. The PSQI of most poor sleepers improved after surgery compared with that of normal sleepers.

There was no significant difference by paired *t*-test in mean gait speed (meters/sec) across the cataract patients before and at 2 and 7 months after surgery: 0.90 ± 0.22 ($n=68$), 0.91 ± 0.22 ($n=66$), and 0.92 ± 0.22 ($n=53$), respectively (Fig. 2). Gait speed in the age-matched controls with normal visual acuity ($n=129$, 52 males and 77 females, 75.0 ± 6.1 years) was 0.89 ± 0.26 meters/sec, which was also not significantly different from the speeds in cataract patients before and at 2 and 7 months after surgery, respectively (Mann-Whitney test).

Measurement of metabolic parameters revealed no significant differences between preoperative values and those taken 7 months after surgery, as follows: 5.59 ± 0.59 and $5.69 \pm 0.53\%$ for HbA1c, 145 ± 72 and 137 ± 65 mg/dL for TGs, 113 ± 39 and 112 ± 24 mg/dL for LDL-C, and 58 ± 23 and 56 ± 18 mg/dL for HDL-C, respectively. There was also no statistically significant change among diabetic cases only (paired *t*-test). Systemic health parameters were not correlated with visual acuity or refractive error.

Stepwise multiple regression analyses of changes in health indices and related parameters before and at 2 months after surgery revealed correlations between Δ VFQ-25 and preoperative VFQ-25, Δ PSQI, BMI, and the presence of

posterior sub-capsular cataracts (Table 5). Δ PSQI was correlated with preoperative PSQI, Δ gait speed, and Δ VFQ-25, whereas Δ gait speed was correlated with pre-operative gait speed, systolic blood pressure, and the presence of posterior sub-capsular cataracts.

Discussion

In this study, VFQ-25 scores improved 2 months after cataract surgery compared to preoperative values, and then further improved 7 months after surgery. Visual acuity improved shortly after surgery in all patients and it was strongly correlated with improvements in vision-related quality of life (Table 5). Therefore, the VFQ-25 score may reflect the patient's general satisfaction with surgery. Although no significant changes in gait speed were observed following the cataract surgery, Δ gait speed was closely correlated with pre-operative gait speed, indicating that the surgery was predominantly effective in this respect for the slower walkers. Walking is an essential daily activity in these patients because many (approximately 80%) do not drive. It is notable that gait speed did not decrease during the 7 months after surgery because there is a strongly negative correlation between gait speed and age,^{32,36} although we speculated gait speed of visually impaired cataract patient may worsen with time without surgery. The characteristics of a study population may also affect the

TABLE 3. POSTOPERATIVE HEALTH INDICES IN THE HEALTHY AND LESS HEALTHY GROUPS^a

<i>Healthy/less healthy before surgery</i>	<i>Before surgery</i>	<i>After surgery</i>	
		<i>2 months</i>	<i>7 months</i>
Visual function questionnaire (VFQ-25)			
Total	66.4±16.5 (62)	79.5±12.6* (61)	80.6±14.3* (41)
Healthy (score ≥ 60)	75.1±7.6 (44)	82.0±9.1* (44)	85.8±7.4* (31)
Less healthy (score < 60)	45.1±12.4 (18)	72.5±17.5* (17)	70.1±14.9* (10)
Pittsburgh sleep quality index (PSQI)			
Total	5.7±3.5 (64)	5.1±3.1 (64)	4.9±2.9 (40)
Normal sleepers (≤ 5.5)	3.3±1.5 (35)	3.3±1.7 (35)	3.4±2.1 (23)
Poor sleepers (> 5.5)	8.8±2.9 (27)	7.6±2.9* (27)	6.8±2.7* (17)

Data are given as the mean±standard deviation (SD), with the number of subjects in each group given in parentheses.

^aClassified according to the preoperative status of each index.

* $p < 0.05$ compared with before surgery (paired *t*-test).

VFQ-25, Visual Function Questionnaire; PSQI, Pittsburgh Sleep Quality Index.

FIG. 1. Pittsburgh Sleep Quality Index (PSQI) before and at 2 and 7 months after cataract surgery. Statistically significant improvements were found in poor sleepers (preoperative PSQI >5.5). (*) $P < 0.05$ compared with before surgery (paired t -test); (closed triangles with solid line) poor sleepers; (closed triangles with dotted line) all cases; (open triangles) normal sleepers; (vertical bar) standard error.

FIG. 2. Visual Function Questionnaire 25 (VFQ-25) and gait speed before and at 2 and 7 months after cataract surgery. Statistically significant improvements were found in VFQ-25 of all patients at 2 and 7 months after surgery. It is also notable that gait speed did not worsen, and even improved, after surgery. (*) $P < 0.05$ compared with before surgery (paired t -test); (circles) gait speed in meters/sec; (squares) VFQ-25 scores; (vertical bar) standard error.

TABLE 4. PRE- AND POSTOPERATIVE SLEEP QUALITY AND SEVERITY OF CATARACT

Subscale value of PSQI and preoperative severity of nuclear sclerosis cataract	PSQI global score	Sleep efficacy (%)	Sleep duration (hour:min)	Sleep latency (score)	Sleep difficulty (score)	Subjective sleep quality (score)	Medication (score)	Daytime dysfunction (score)
All cases ($n = 65$)	5.8/5.2	91.2/91.9	6:57/6:59	1.2/0.9*	0.9/0.8*	1.1/1.0	0.9/0.9	0.4/0.5
Severe (grade ≥ 3 , $n = 22$)	6.0/4.8	90.4/92.5	7:07/7:07	1.1/0.7*	1.0/0.8	1.1/0.9	0.9/0.9	0.5/0.4
Mild (grade < 3 , $n = 43$)	5.7/5.4	91.6/91.6	6:52/6:55	1.3/1.0	0.9/0.7	1.1/1.0	0.8/0.9	0.4/0.5

* $p < 0.05$, compared with before surgery, paired t -test.

Data are given as the mean of before/2 months after surgery unless indicated. Subscale scores were retrieved from the itemized questions in PSQI. Sleep efficacy (%) was calculated as [(sleep duration)/(sleep latency + sleep duration)] $\times 100$. PSQI, Pittsburgh Sleep Quality Index.

FIG. 3. Scatter plot showing Pittsburgh Sleep Quality Index (PSQI) before and at 2 months after surgery in cataract patients. The PSQI of most poor sleepers in the study (PSQI >5.5) improved after surgery compared with that of normal sleepers (PSQI <5.5), as segmented by the dotted lines. Each plot may represent multiple cases.

gait speed results. For instance, cataract patients might consider surgery only when they could physically and mentally tolerate surgery.

Special attention was paid to the sleep quality results because poor sleepers significantly improved at 2 and 7

months after surgery, whereas our previous results showed improvement only at 2 months after surgery.⁴ Visual improvement and relief from stress after surgery could have contributed to the improved sleep because depression or stress is an exacerbation factor for sleep quality. Other investigators reported mental improvement with Cataquest or SF-36 after implantation of clear IOL for 145 cases.³⁷ In that study, the mental effect was transient after surgery, although visual acuity or visual function remained improved for a year post-surgically, and the authors speculated that the elevated spirit immediately after surgery was an effect of the significant changes in vision. However, even with a remarkable visual recovery, other functions may not be sustainable in older persons. Specifically in Japan, the significant earthquake and tsunami disaster in March, 2011, and the resultant nationwide depression might have also affected sleep quality during the study period.³⁸ Nevertheless, sleep quality improved continuously and was correlated with gait speed in the present study. We speculate that our study patients were highly motivated to enjoy a better life after surgery because many of them were still involved in business or social activities.

Yellowing of the crystalline lens, generally present with nuclear sclerosis cataracts, and the chromatic properties of IOL are important factors for photo-entrainment both before and after cataract surgery. A yellow-colored crystalline lens serves as an intra-ocular blue light filter to suppress circadian rhythm synchronization. Kessel et al.³⁹ and Kim et al.⁴⁰ both reported that severity of cataracts was significantly correlated with preoperative sleep quality. In the present study, statistical significance was found in sleep latency (before vs. 2 months after surgery) of the cases with severe

TABLE 5. STEPWISE MULTIPLE REGRESSION ANALYSIS OF CHANGES IN HEALTH INDICES AND VISION-RELATED PARAMETERS

	$\Delta VFQ-25$ score		$\Delta PSQI$		$\Delta Gait$ speed	
	β	p value	β	p value	β	p value
Model 1. Preoperative health index values						
VFQ-25 score	-0.66	<0.001*	0.10	0.45	-0.05	0.70
PSQI score	0.30	<0.05*	-0.53	<0.001*	0.01	0.72
Gait speed	0.02	0.89	0.20	0.21	-0.62	<0.001*
Model 2. Preoperative systemic parameters						
Age	0.22	0.08	0.07	0.56	-0.02	0.90
Sex	-0.05	0.72	-0.09	0.50	0.14	0.41
BMI	0.32	<0.05*	0.15	0.31	-0.20	0.26
Diabetes	0.03	0.71	-0.02	0.90	0.05	0.75
SBP	0.28	0.07	0.04	0.78	0.41	<0.05*
Serum triglycerides (mg/dL)	0.10	0.41	-0.10	0.45	-0.05	0.75
Model 3. Preoperative cataract opacity and vision						
Nuclear sclerosis	0.05	0.70	0.08	0.54	0.10	0.44
Posterior subcapsular	0.31	<0.05*	0.07	0.62	0.25	<0.05*
Central cortical	0.13	0.32	0.01	0.95	0.06	0.69
Model 4. Changes in health indices						
$\Delta VFQ-25$ score	—	—	-0.27	<0.05*	0.16	0.23
$\Delta PSQI$	-0.27	<0.05*	—	—	-0.30	<0.05*
$\Delta Gait$ speed	0.16	0.23	-0.30	<0.05*	—	—

Male = 1, female = 0, diabetic = 1, nondiabetic = 0.

Changes in the health indices and gait speed were calculated by subtracting preoperative values from values taken at 2 months after surgery. All values were adjusted for age and sex.

* $p < 0.05$

VFQ-25, Visual Function Questionnaire 25; PSQI, Pittsburgh Sleep Quality Index; BMI, body mass index; SBP, systolic blood pressure.

nuclear sclerosis cataract, and global score and many other sub-scales of PSQI remarkably improved, whereas the same improvements were not observed in those with mild nuclear sclerosis cataracts (Table 4). These findings were not reported in cases implanted with yellow-colored IOLs,⁴ and we speculate the distinct difference in light transmittance between yellow crystalline lens and clear IOLs might underlie such a surgical effect. We believe sleep disorders in older persons include “cataract-related sleep disorder” due to decreased intra-ocular light transmittance in old age leading to circadian rhythm dysfunction.

Recently two investigators^{41,42} reported that sleep quality significantly improved in cataract cases implanted with blue light-blocking IOLs, based on the survey with questionnaire, and their results supported our previous results with blue light-blocking IOLs.⁴ In terms of the IOL color, a clear lens has greater light transmittance than a yellow-colored IOL and thus the effect on circadian rhythm synchronization may be stronger.^{43–45} Sleep quality is affected by many physiological and mental factors, as is photo-entrainment calculated from the IOL spectral transmission.

The cases in this study with abnormal metabolic parameters achieved improvements in vision-related quality of life, sleep quality, and gait speed. Thus, we speculate that the prognosis of cataract surgery would not be influenced by metabolism unless retinopathy or neuropathy develops. It is anticipated that the improvements in gait speed and quality of life achieved after cataract surgery might facilitate physical activity and a better diet, which together could eventually advantage lipid metabolism because exercise at least contributes to increasing HDL-C.⁴⁶ There was no significant change 7 months after surgery, and a longer follow-up and the measurement of other indicators such as BMI, muscle volume and strength, and computerized motion analysis may provide further information.

The present study has some limitations. Precise evaluations of sleep quality should include polysomnography and endocrinological evaluations. The time frame of the surgery was more than a year and there may be a potential seasonal effect. It was a single-center study, and the sample size was not large.

In conclusion, our studies of cataract cases implanted with IOLs of two different spectral transmissions indicated that cataract surgery has potential rejuvenation effects on sleep quality and gait speed in addition to restoring vision and vision-related quality of life. Cataract is a very common geriatric disease, and any additional value of cataract treatment would contribute significantly to a healthy life in older adults. Further evaluations should be carried out to determine the long-term effects of IOL on systemic and ocular health.

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Author Disclosure Statement

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References

1. Fong CS, Mitchell P, Rochtchina E, de Loryn T, Tan AG, Wang JJ. Visual impairment corrected via cataract surgery and 5-year survival in a prospective cohort. *Am J Ophthalmol* 2014;157:163–170.
2. Ishii K, Kabata T, Oshika T. The impact of cataract surgery on cognitive impairment and depressive mental status in elderly patients. *Am J Ophthalmol* 2008;146:404–409.
3. Greenberg PB, Liu J, Wu WC, Jiang L, Tseng VL, Scott IU, Friedman PD. Predictors of mortality within 90 days of cataract surgery. *Ophthalmology* 2010;117:1894–1899.
4. Ayaki M, Muramatsu M, Neghisi K, Tsubota K. Improvements in sleep quality and gait speed after cataract surgery. *Rejuvenation Res* 2013;16:35–42.
5. Gray R, Perkins SA, Suryakumar R, Maxwell WA. Reduced effect of glare disability on driving performance in patients with blue light-filtering intra-ocular lenses. *J Cataract Refract Surg* 2011;37:38–44.
6. Schmack I, Schimpf M, Stolzenberg A, Conrad-Hengerer I, Hengerer FH, Dick HB. Visual quality assessment in patients with orange-tinted blue light-filtering and clear ultraviolet light-filtering intraocular lenses. *J Cataract Refract Surg* (United States), 2012;38:823–832.
7. Henderson BA, Grimes KJ. Blue-blocking IOLs: A complete review of the literature. *Surv Ophthalmol* 2010;55:284–289.
8. Zhu X-f, Zou H-d, Yu Y-f, Sun Q, Zhao NQ. Comparison of blue light-filtering IOLs and UV light-filtering IOLs for cataract surgery: A meta-analysis. *PLoS One* 2012;7:e33013.
9. Espindle D, Crawford B, Maxwell A, Rajegopalan K, Barnes R, Harris B, Hileman K. Quality-of-life improvements in cataract patients with bilateral blue light-filtering intraocular lenses: clinical trial. *J Cataract Refract Surg* 2005;31:1952–1959.
10. Mainster MA, Turner PL. Blue-blocking IOLs decrease photoreception without providing significant photoprotection. *Surv Ophthalmol* 2010;55:272–289.
11. Broendsted AE, Hansen MS, Lund-Andersen H, Sander B, Kessel L. Human lens transmission of blue light: A comparison of autofluorescence-based and direct spectral transmission determination. *Ophthalmic Res* 2011;46:118–124.
12. Provencio I, Jiang G, De Grip WJ, Hayes WP, Rollag MD. Melanopsin: An opsin in melanophores, brain, and eye. *Proc Natl Acad Sci USA* 1998;95:340–345.
13. Berson DM, Dunn FA, Takao M. Phototransduction by retinal ganglion cells that set the circadian clock. *Science* 2002;295:1070–1073.
14. Herbst K, Sander B, Lund-Andersen H, Kawasaki A. Intrinsically photosensitive retinal ganglion cell function in relation to age: A pupillometric study in humans with special reference to the age-related optic properties of the lens. *BMC Ophthalmol* 2012;12:4.
15. Ham WT Jr, Mueller HA, Sliney DH. Retinal sensitivity to damage from short wavelength light. *Nature* 1976;260:153–155.
16. Kurihara T, Omoto M, Noda K. Retinal phototoxicity in a novel murine model of intra-ocular lens implantation. *Mol Vis* 2009;15:2751–2761.
17. Carson D, Margrain TH, Patel A. New approach to evaluate retinal protection by intra-ocular lenses against age-related

- lipofuscin accumulation-mediated retinal phototoxicity. *J Cataract Refract Surg* 2008;34:1785–1792.
18. Mainster MA, Sparrow JR. How much blue light should an IOL transmit? *Br J Ophthalmol* 2003;87:1523–1529.
 19. Braunstein RE, Sparrow JR. A blue-blocking intraocular lens should be used in 296 cataract surgery. *Arch Ophthalmol* 2005;123:547–549.
 20. Margrain TH, Boulton M, Marshall J, Sliney DH. Do blue light filters confer protection against age-related macular degeneration? *Prog Retin Eye Res* 2004;23:523–531.
 21. Yuki K, Tanebe S, Kouyama K, Fukagawa K, Uchino M, Shimoyama M, Ozeki N, Shiba D, Ozawa Y, Abe T, Tsubota K. The association between visual field defect severity and fear of falling in primary open angle glaucoma. *Invest Ophthalmol Vis Sci* 2013;54:7739–7745.
 22. Yamada M, Mizuno Y, Miyake Y. Cataract Survey Group of the National Hospital Organization of Japan. A multicenter study on the health-related quality of life of cataract patients: Baseline data. *Jpn J Ophthalmol* 2009;53:470–476.
 23. Reed-Jones RJ, Solis GR, Lawson KA, Loya AM, Cude-Islas D, Berger CS. Vision and falls: A multidisciplinary review of the contributions of visual impairment to falls among older adults. *Maturitas* 2013;75:22–28.
 24. Karlsson MK, Magnusson H, von Schewelow T, Rosengren BE. Prevention of falls in the elderly—a review. *Osteoporos Int* 2013;24:747–776.
 25. Robertson MC, Campbell AJ, Herbison PJ. Statistical analysis of efficacy in falls prevention trials. *Gerontol A Biol Sci Med Sci* 2005;60:530–534.
 26. Balzer K, Bremer M, Schramm S, Lühmann D, Raspe H. Falls prevention for the elderly. *GMS Health Technol Assess* 2012;8:Doc01.
 27. Lee BS, Munoz BE, West SK, Gower EW. Functional improvement after one- and two-eye cataract surgery in the Salisbury Eye Evaluation. *Ophthalmology* 2013;120:949–955.
 28. Desapriya E, Subzwari S, Scime-Beltrano G, Samayawardhena LA, Pike I. Vision improvement and reduction in falls after expedited cataract surgery: Systematic review and metaanalysis. *J Cataract Refract Surg* 2010;36:13–19.
 29. Church J, Goodall S, Norman R, Haas M. An economic evaluation of community and residential aged care falls prevention strategies in NSW. *Public Health Bull* 2011;22:60–68.
 30. Meulenens LB, Ng JQ, Fraser M, Hendrie D, Morlet N. Impact of gender on first eye cataract surgery and motor vehicle crash risk for older drivers. *Clin Experiment Ophthalmol* 2012;40:591–596.
 31. Meulenens LB, Hendrie D, Lee AH, Ng JQ, Morlet N. The effectiveness of cataract surgery in reducing motor vehicle crashes: A whole population study using linked data. *Ophthalmic Epidemiol* 2012;19:23–28.
 32. Studenski S, Perera S, Patel K, Rosano C, Faulkner K, Inzitari M, Brach J, PhD; Chandler J, Cawthon P, Connor EB, Nevitt M, Visser M, Kritchevsky S, Badinelli S, Harris T, Newman AB, Cauley J, Ferrucci L, Guralnik J. Gait speed and survival in older adults. *JAMA* 2011;305:50–58.
 33. Ayaki M, Negishi K, Tsubota K. Increased gait speed after cataract surgery confers longer expected survival. *Asia Pacific J Ophthalmol* (accepted for publication).
 34. Mangione CM, Lee PP, Gutierrez PR. National Eye Institute Visual Function Questionnaire Field Test Investigators. Development of the 25-item National Eye Institute Visual Function Questionnaire. *Arch Ophthalmol* 2001;119:1050–1058.
 35. Buysse DJ, Reynolds CF 3rd, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. *Psychiatry Res* 1989;28:193–213.
 36. Auyeung TW, Lee SW, Leung J, Kwok T, Woo J. Age-associated decline of muscle mass, grip strength and gait speed: A 4-year longitudinal study of 3018 community-dwelling older Chinese. *Geriatr Gerontol Int*. 2014;14(Suppl 1):76–84.
 37. Helbostad JL, Oedegaard M, Lamb SE, Delbaere K, Lord SR, Sletvold O. Change in vision, visual disability, and health after cataract surgery. *Optom Vis Sci* 2013;90:392–399.
 38. Tempesta D, Curcio G, De Gennaro L. Long-term impact of earthquakes on sleep quality. *PLoS One* 2013; 8:e55936.
 39. Kessel L, Siganos G, Jørgensen T, Larsen L. Sleep disturbances are related to decreased transmission of blue light to the retina caused by lens yellowing. *Sleep* 2011;34:1215–1219.
 40. Kim YH, Jung KI, Song CH. The effect of cataract on sleep time and quality in late adulthood. *Aging Clin Exp Res* 2012;24:663–668.
 41. Wei X, She C, Chen D. Blue-light-blocking intra-ocular lens implantation improves the sleep quality of cataract patients. *J Clin Sleep Med* 2013;9:741–745.
 42. Schmoll C, Khan A, Aspinall P. New light for old eyes: Comparing melanopsin-mediated non-visual benefits of blue-light and UV-blocking intraocular lenses. *Br J Ophthalmol* 2014;98:124–128.
 43. Artigas JM, Felipe A, Navea A, Fandiño A, Artigas C. Spectral transmission of the human crystalline lens in adult and elderly persons: color and total transmission of visible light. *Invest Ophthalmol Vis Sci* 2012;53:4076–4084.
 44. Tanito M, Okuno T, Ishiba Y, Ohira A. Measurements of transmission spectrums and estimation of retinal blue-light irradiance values of currently available clear and yellow-tinted intra-ocular lenses. *Jpn J Ophthalmol* 2012;56:82–90.
 45. Tanito M, Okuno T, Ishiba Y, Ohira A. Transmission spectrums and retinal blue-light irradiance values of untinted and yellow-tinted intra-ocular lenses. *J Cataract Refract Surg* 2010;36:299–307.
 46. Kodama S, Tanaka S, Saito K. Effect of aerobic exercise training on serum levels of high-density lipoprotein cholesterol: A meta-analysis. *Arch Intern Med* 2007;167:999–1008.

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