Blue Light in Ocular Health:
WHAT OPTOMETRISTS NEED TO KNOW

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A. Paul Chous, OD, FAAO

Disclosures
Drs. Smick & Chous are or have been consultants for, been on advisory boards of, or spoken on behalf of:
  Bausch & Lomb, Freedom Meditech, Genentech, GlaxoSmithKline, Kestrel, Kowa, LifeMed Media, Optos, Prodigy Diabetes Care, Regeneron, Risk Medical Solutions, Vision Service Plan, ZeaVision

None of these affiliations have affected the content of this presentation

NEW INSIGHTS INTO UV OCULAR DAMAGE

Kirk L. Smick, OD, FAAO
UV radiation: UV-Visible

Small part of electromagnetic spectrum.

<table>
<thead>
<tr>
<th>UV</th>
<th>X-ray</th>
<th>Ultraviolet</th>
<th>Infrared</th>
<th>microwave</th>
<th>Radio</th>
</tr>
</thead>
<tbody>
<tr>
<td>nm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 nm</td>
<td>10 nm</td>
<td>380 - 780 nm</td>
<td>10 μm</td>
<td>10 nm</td>
<td>1 km</td>
</tr>
</tbody>
</table>

Shorter wavelengths cause greater damage

Biological damage
### Consequences of UV skin radiation

<table>
<thead>
<tr>
<th>Type of UV</th>
<th>Consequences of exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>UVA 315-380 nm</td>
<td>Less photobiologically active. Responsible for Vitamin D production</td>
</tr>
<tr>
<td>UV B 280-315 nm</td>
<td>More photobiologically active. Responsible for sunburn. Damages Collagen (resulting in aging/thickening/wrinkling) and destroys Vitamin A.</td>
</tr>
<tr>
<td>UV C 100-280 nm</td>
<td>The most photobiologically active. Responsible for cancer due to DNA mutation and creation of &quot;free radicals.&quot;</td>
</tr>
</tbody>
</table>

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**After absorption by the Earth’s ozone, the cornea and lens, what percentage of UVA radiation reaches the retina?**

- A. 0%
- B. 1.5%
- C. 10%
- D. 15%
- E. 25%

**Answer:** B. 1.5%

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**UV LIGHT TRANSMISSION THROUGH THE EYE**

- UV C
- UV B
- UV A

Light transmission through the various structures of the eye.
Age-Related Macular Degeneration (ARMD)

• In ARMD, the macula (central retina) develops degenerative lesions.

Light is both beneficial and harmful to vision and health

Harmful Role
- Cumulative damage to eye tissues
  • UV damage to cornea and lens
  • Implicated in cataracts and pterygium
- Cumulative damage to the retina
  • Blue light, at certain wavelengths, causes damage to the retina
    - Implicated in age-related macular degeneration (AMD)

Essential Role
- Visual functions
  • Visual acuity
  • Color perception
  • Contrast sensitivity
- Non-visual functions
  • Sleep/wake cycle
  • Memory and mood
  • Hormonal balance

High Energy Visible (HEV) Light or Blue Light spectrum: 380 – 500 nanometers

Dangers of Blue light
- Very energetic light that can induce and accelerate retinal cell damage
- Cumulative exposure to certain wavelengths of Blue Light can cause damage to the retina
- Risk factor for the development of age-related macular degeneration (AMD)

Benefits of Blue light
- Blue Light, however is also beneficial for our vision and overall health
- Visual acuity & color perception
- Sleep/wake cycle, mood and memory
- Pupil size
**Dangers of light to the eye**

<table>
<thead>
<tr>
<th>Ultraviolet (UV) Light</th>
<th>Blue Light</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cataract</td>
<td>Retina</td>
</tr>
<tr>
<td>Crystalline lens</td>
<td>Macula</td>
</tr>
</tbody>
</table>

**Normal Vision**

**AMD Vision**

**Increasing AMD and cataract population in the US alone**

**AMD & Cataract cases expected to DOUBLE in the next 20 years**

**CATARACT POPULATION**

- 2012: 24
- 2030: 60
- 2050: 50

**AMD POPULATION**

- 2012: 2
- 2030: 3
- 2050: 5

**CATARACT POPULATION AMD POPULATION**


**AMD & Cataract cases expected to DOUBLE in the next 20 years**

**SOURCES OF UV AND HEV/BLUE LIGHT**
SUNLIGHT

- Widely modified by the atmosphere
  • Season
  • Time of day
  • Geographic location
  • Also, gaze direction
- Blue Light proportion of daylight: Varies between 25% and 30%
- On a cloudy day, up to 80 percent of the sun’s UV rays can pass through the clouds

ARTIFICIAL LIGHT SOURCES

- Compact fluorescent lamps
  • Contain 26% harmful Blue Light
- LEDs
  • Contain 35% harmful Blue Light
  • The cooler the white LED, the higher the blue proportion is
- By 2020, 90% of all light sources will be LED

What wavelength of ‘blue light’ is most directly photo-toxic to retinal cells?

A. 250-350 nm
B. 300-380 nm
C. 415-455 nm
D. 480-520 nm

Answer: C. 415-455 nm
Discovery of specific band of harmful Blue-Violet light

In partnership with the Paris Vision Institute, ESSILOR aims to offer the most complete eye protection against dangerous light including HEV.

Result: 400nm (415-455nm) of the HEV spectrum—known as Blue-Violet light—are most harmful.

First in-vitro tests in the ophthalmic industry
Blue-Violet Light

- Blue-Violet light ranges from 415 to 455 nanometers (nm) – the band of visible light most harmful to retinal cells
- Cumulative exposure to Blue-Violet light can lead to retinal cell death
- Blue-Violet light is one of the risk factors for the development of age-related macular degeneration (AMD)
  - AMD is the leading cause of severe vision loss and legal blindness in adults over 60
  - There is no cure for AMD today

Blue-Violet Light Emission from LED

INTRODUCTION TO BLUE-TURQUOISE LIGHT
Blue-Turquoise Light

- Blue-Turquoise light ranges from 465 to 495 nanometers (nm)
- Blue-Turquoise light is essential for:
  - Pupillary Constriction Reflex
    - Retina's natural protection against light overexposure
  - "Human biological clock" synchronization
    - Allows the right functioning of the sleep/wake cycle, memory, mood, etc.
  - Visual acuity & color perception

Blue Light: Impact on Sleep, Melatonin, and Systemic Health

A. Paul Chous, MA, OD, FAAO
Tacoma, WA
Which of the following is \textbf{FALSE} regarding intrinsically photosensitive retinal ganglion cells?

A. ipRGCs are a small minority of all RGCs  
B. They contain the photopigment, rhodopsin  
C. They control circadian rhythms  
D. They regulate pupil size

\begin{itemize}
  \item ipRGCs
    \begin{itemize}
      \item Intrinsically photosensitive retinal ganglion cells (1-3\% of RGCs)
      \item The 3rd photoreceptor
      \item Synchronize circadian rhythms to the 24-hour dark/light cycle
      \item Regulate pupil size in ambient light
    \end{itemize}
\end{itemize}
The suprachiasmatic nucleus (SCN) exerts primary control over circadian rhythm via input from ipRGCs, exercise & feeding.

SCN controls production of melatonin via the pineal gland, exerting control over wakefulness and sleep.

Heart, Kidney and Liver are ‘peripheral circadian oscillators’ that are under direct influence of SCN.

Short sleep and/or low melatonin have been implicated in which diseases?

A. Diabetes, cancer, glaucoma
B. AMD, hypertension, obesity
C. Dyslipidemia, cardiovascular risk, dementia
D. All of the above

Importance of Melatonin

- “chronobiotic” substance that normalizes biological rhythms and adjusts the timing of other critical processes and biomolecules (hormones, neurotransmitters, etc) that, in turn, exert numerous peripheral actions
- Serum and CSF Melatonin levels are typically 4X higher at night
- Higher evening exposures to high energy, SWL dysregulates normal biological rhythms


ipRGCs Respond to Blue Light

- Contain the photopigment, melanopsin with peak spectral sensitivity of 460-520 nm
- Blue light absorption by ipRGC melanopsin down-regulates production of melatonin by the pineal gland
- Melatonin suppression results in increased wakefulness and alertness
So What??

- Poor sleep & shortened sleep cycle is associated with significantly increased risk of
  - Diabetes
  - Obesity
  - Dyslipidemia
  - Hypertension

Sleep and Diabetes Risk

Both long and short sleep duration, as well as napping, are associated with increased risk of Metabolic Syndrome and type 2 diabetes

Evening Light & Diabetes Risk

- Evening light exposure is independently associated with both decreased melatonin and increased diabetes risk in elderly subjects
  - 51% increased risk of DM comparing 25th to 75th percentiles of exposure
More Bad News with Light At Night (LAN)

- Increased blue light exposure during the evening meal increases hunger & decreases insulin sensitivity x 2 hours

- Increased light at night exposure significantly elevated BP 4/3 mm Hg in Japanese subjects — 6% increased mortality -10K additional deaths

- Increased LAN also significantly associated with increased rates of obesity and dyslipidemia independently of melatonin levels

J Clin Endocrinol Metab. 2013 Jan;98(1):337-44

Independently of poor sleep, low levels of melatonin also increase risk of multiple disease processes

Got Risk?

IN THE EYE

- Low night time melatonin implicated in glaucoma

- Lower night time & Higher daytime melatonin increases retinal light toxicity (esp blue light) and is implicated in AMD

Melatonin: An Underappreciated Player in Retinal Physiology and Pathophysiology
MELATONIN SUPPRESSION IMPLICATED IN:

- inflammation with excess cortisol production (diabetes/CV risk)
- dementia
- endocrine disruption
- suppression of nitric oxide resulting in elevated blood pressure
- potential activation of oncogenes


<table>
<thead>
<tr>
<th>Pathophysiology</th>
<th>Role of melatonin</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anoxia</td>
<td>Antidepressant</td>
<td>Kennedy, 1995(^{\text{F1}})</td>
</tr>
<tr>
<td>Alzheimer's syndrome</td>
<td>Synchronizes circadian rhythm, antioxidant, Poppala et al. 1998(^{\text{F2}})</td>
<td></td>
</tr>
<tr>
<td>Parkinson's disease</td>
<td>Antioxidant, neuroprotective</td>
<td>Mayo et al. 2009(^{\text{P1}})</td>
</tr>
<tr>
<td>Coronary heart disease</td>
<td>Immunosuppressor</td>
<td>Lunedi et al. 2001(^{\text{P1}})</td>
</tr>
<tr>
<td>Venereal wпeпulmonary virus</td>
<td>IL-10, TNF-α modulator, antioxidant</td>
<td>Bordini et al. 2008(^{\text{F2}})</td>
</tr>
<tr>
<td>Rheumatoid arthritis; spondylosis</td>
<td>Anti-inflammatory</td>
<td>West and Cordina, 1992(^{\text{F2}})</td>
</tr>
<tr>
<td>Cholesterosis</td>
<td>Calcium homeostasis</td>
<td>Sandik et al. 1994(^{\text{F2}})</td>
</tr>
<tr>
<td>Age-related muscular degeneration</td>
<td>Antioxidant</td>
<td>Chang et al. 2002(^{\text{F1}})</td>
</tr>
<tr>
<td>sudden infant death syndrome</td>
<td>Circadian and orthogonal modulator</td>
<td>Westphall and Westphall, 1961(^{\text{F2}})</td>
</tr>
<tr>
<td>Hypothalamic obesity disorders;</td>
<td>Circadian rhythm modulator</td>
<td>Sozinsky et al. 1998(^{\text{F2}})</td>
</tr>
<tr>
<td>Reproductive disorders</td>
<td>Downregulation of melatonin receptors</td>
<td>Costa et al. 1994(^{\text{F1}})</td>
</tr>
<tr>
<td>Diabetic neuropathy</td>
<td>Sympathetic rhythms stimulator</td>
<td>O'Callan et al. 1989(^{\text{F1}})</td>
</tr>
<tr>
<td>Psychiatric diseases schizophrenia</td>
<td>Anxiolytic</td>
<td>Mamo et al. 1988(^{\text{P1}})</td>
</tr>
<tr>
<td>Autism</td>
<td>Circadian rhythm modulator, antioxidant</td>
<td>MacKnee-Hayes, 1988(^{\text{F1}})</td>
</tr>
</tbody>
</table>

From www.hopkinsmedicine.org
Blue Light & RGC Health:

Is there a Direct Link to Inner retinal disease?

BLUE LIGHT DAMAGES RGC MITOCHONDRIA

- Chromophores in RGC mitochondria maximally absorb the energy from short wavelength visible light
- SWL may contribute to RGC death in conditions where RGC health is already compromised, such as glaucoma and diabetes
  

- Neuroglobin (NGB) is a neuro-protective protein up-regulated to protect retinal neurons from hypoxic and ischemic insult
  
  - SWL (453 nm) preferentially damages RGCs
  - 1-hour exposure doubles RGC NGB without structural damage
  - 2-hour exposure increases NGB 7-fold and causes permanent cellular damage
  
Practical Strategies For Reducing Harmful Endocrine Effects of Blue Light

- Turn off devices > 1 hour before bed time
- Reduce screen blue light emission at night
  – www.f.lux.com
- Wear spectacle lenses that filter both blue-violet and blue-turquoise light at night (415-520 nm)
- Wear spectacle lenses that filter blue-violet light at day (415-455 nm)

Illuminance Is Important

- Illuminance is the intensity of light spread over given area (1 lux = 1 lumen/m²)
- 100-300 Lux from a computer screen
- 1000 Lux on an overcast day
- 10,000-25,000 Lux on a sunlit day
A 65 yo obese pt with a Hx of pre-diabetes (image below) asks about ‘UV rays’ damaging his eyes. What advice makes biological sense?

Summary

• Blue light has both harmful and beneficial biological effects
• Shorter wavelength blue light is toxic to the retina
• Longer wavelengths have beneficial and harmful effects on endocrine function depending on diurnal timing of exposure
• Dose – both duration and intensity of illuminance (lux) matters

Thank You!

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