DECEMBER 2014

GE LIGHTING
LIGHTING AND SLEEP

INTRODUCTION

The National Institute of Health defines "circadian rhythms" as "physical, mental and behavioral changes that follow a roughly 24-hour cycle, responding primarily to light and darkness in an organism's environment."[1] Although, in the strictest sense, circadian rhythms refer to cyclical changes in hormones, body temperature, and other biological processes over the course of a 24 hour period, the term commonly is used to refer to the body's natural sleep-wake cycle. Indeed, a disruption of a person's circadian rhythms typically results in a disruption of the individual's sleep-wake cycle.

The Department of Health and Human Services has reported that "sleep deficiency and circadian disruption resulting from lifestyle factors are increasingly common societal problems that increase disease risk through complex pathways."[2] An estimated 50–70 million adults in the United States suffer from chronic sleep or wakefulness issues, and the percentage of adults who report averaging less than seven hours of sleep per night has increased by about one third since the 1980s.[3] According to the National Institute of Health, sleep disorders have been linked to a growing list of long-term health problems, including a greater risk of heart disease, stroke, diabetes, obesity, and other diseases."[4]

Lifestyle factors and stress levels certainly influence sleeping patterns, but more and more attention is being paid to the impact of light on sleep cycles. The invention of electric light in the nineteenth century and, more recently, the explosive rise of "screen time" associated with smart phones and tablets, places us in a world where we can have as much light as we want whenever we want it. Light, and human activity, is no longer tied to the rising and setting sun. But our biology is still linked to that astronomical cycle.

Recent scientific studies provide empirical and epidemiological evidence of positive and negative effects of lighting on sleep patterns. Light has the potential to strengthen our natural internal clocks but, more frequently, acts to disrupt it. Lighting solutions that more closely simulate the daily rhythms we receive from natural light may help improve our ability to enjoy sound sleep and awaken efficiently.

1 National Institute of Health, *Circadian Rhythms Fact Sheet*, *http://www.nigms.nih.gov/Education/Pages/Factsheet_CircadianRhythms.aspx.*

2 National Institute of Health (2011) National Institutes of Health Sleep Disorders Research Plan Publication No. 11–7820, U.S. Department of Health and Human Services, NIH

3 National Institutes of Health (2011, November 9) National Institutes of Health. Retrieved June 2, 2014, from Updated NIH Sleep Disorders Research Plan seeks to promote and protect sleep health, *http://www.nih.gov/news/health/nov2011/nhlbi-09.htm*

EXECUTIVE SUMMARY

At the AMA House of Delegates 2012 Annual Meeting, the American Medical Association (AMA), the largest physician organization in the U.S., voted to adopt policy that recognizes "that exposure to excessive light at night, including extended use of various electronic media, can disrupt sleep or exacerbate sleep disorders, especially in children and adolescents."[5]

At the center of this discussion is the impact of electric lighting, as well as the impact of modern electronics such as computer screens, phones, and tablets. These lighting and communication devices produce high levels of blue light, and this bluish light tends to suppress the body's production of melatonin — the "sleep hormone." Melatonin levels follow a daily rhythm, tending to drop sharply in the morning as we wake and then rising again in the evening, leading to end of the day drowsiness that fosters sleep.[6]

The link between light and melatonin production is well accepted in the scientific community. Many people would benefit from a more regular daily rhythm of light that mimics the intensity and spectrum that humans had received from natural lighting in the past. As discussed in more detail below, recent developments support this conclusion:

1. Studies going back several decades have established the link between melatonin and circadian/sleep rhythms. Recent scientific and medical studies are providing empirical and epidemiological evidence of the potential positive and negative effects of lighting on sleep.

2. Better scientific understanding of human circadian physiology has increasingly revealed the quantity, quality, and timing of light that is best for maintaining natural sleep-awake cycles.

3. Advancements in lighting technology now allow for precise spectral tailoring with LED technology.

4 Updated NIH Sleep Disorders Research Plan Seeks to Promote and Protect Sleep Health." U.S National Library of Medicine. U.S. National Library of Medicine, 9 Nov. 2011. Web. 2 June 2014. <http://www.nih.gov/news/health/nov2011/nhlbi-09.htm>.

5 Council on Science and Public Health (A-12), American Medical Association, 2012.

6 Brown, G. M. "Light, Melatonin and the Sleep-wake Cycle." J Psychiatry Neurosci 19.5 (1994): 345-53. Print.

THE ROLE OF SLEEP ON WELLNESS

There is ample evidence supporting the benefits of regular and adequate sleep. Getting between 7 and 9 hours of sleep per night is the recommended daily amount. Sleep deprivation can increase stress, increase the chance of chronic disease (specifically cardiovascular disease), and reduce brain function–including inattention, hallucinations and blurred vision.[7] Chronic sleep loss can result in a handful of health issues, including weakened memory, slowed metabolism, increased irritability and moodiness, hypertension, a weakened immune system.[8, 9] It has also been linked to obesity, diabetes, depression, bipolar disorder, and seasonal affective disorder.[10] Employing strategies and tactics to regulate sleep, and foster a regular sleep-wake cycle, should be a priority.

CIRCADIAN RHYTHM AND MELATONIN

Increased use of light-emitting technological devices in recent decades further challenges our ability to maintain a regular sleep-wake cycle. Several studies have demonstrated, with conclusive statistical strength, that nighttime light exposure can suppress the production of melatonin, which is secreted by the pineal gland.[11] This suppression, in turn, hinders our ability to fall to sleep, and wake, on a regular schedule.

Several studies have demonstrated, with conclusive statistical strength, that nightime light exposure can suppress the production of melatonin

The effect is particularly strong with bluish light, which has been researched heavily. In a telling study by Dr. George Brainard, eight subjects were exposed to different wavelengths of light. Researchers collected blood samples both before and after light exposures to measure melatonin levels. The results demonstrate that bluish light is particularly effective in suppressing melatonin.[12] Other, subsequent studies support these findings.[13]

7 MMWR Morb Mortal Wkly Rep. 2011 Mar 4;60(8):233–8., *http://www.cdc.gov/mmwr/pdf/wk/mm6008.pdf*

8 Meerlo, P., Sgoifo, A., Suchecki, D., 2008. Restricted and disrupted sleep: effects on autonomic function, neuroendocrine stress, systems and stress responsivity. Sleep Med. Rev. 12, 197-210, *http://cbn.eldoc.ub.rug.nl/FILES/root/2008/SleepMedRevMeerlo/2008SleepMedRevMeerlo.pdf*

9 Weinhouse GL, Schwab RJ. Sleep in the critically ill patient. Sleep 2006;29(5):707–16., *http://www.journalsleep.org/Articles/290519.pdf*

10 National Institute of Health, *Circadian Rhythms Fact Sheet*, *http://www.nigms.nih.gov/Education/Pages/Factsheet_CircadianRhythms.aspx.*

11 Thapan, Kavita, Josephine Arendt, and Debra J. Skene. "An Action Spectrum for Melatonin Suppression: Evidence for a Novel Non-rod, Non-cone Photoreceptor System in Humans." *The Journal of Physiology* 535 (2001): 261-67. Print.

Brainard, G. C., J. P. Hanifin, J. M. Greeson, B. Byrne, G. Glickman, E. Gerner, and M. D. Rollag. "Action Spectrum for Melatonin Regulation in Humans: Evidence for a Novel Circadian Photoreceptor." *J Neurosci.* 21.16 (2001): 6405-12. Print.

In a natural state, melatonin production by the pineal gland drops significantly in the morning, remains low during the day, and then rises considerably in the evening.[14] This daily hormonal cycle is strongly influenced by light. Certain photoreceptor cells in the human eye, melanopsin retinal ganglion cells, are especially sensitive to blue light with short wavelengths of approximately 460 nanometers.[15] When exposed to high doses of bluish light — whether generated by the sun, electric light, or smart devices — these cells send a message to brain to "shut down" the production of melatonin, and the brain retransmits this message to the pineal gland.[16] In this way light, especially bluish light, reduces the body's production of melatonin.

Melatonin suppression in the evening hinders sleep and disrupts the sleep cycle

This suppressive effect is naturally caused by sunlight during the day. It can also result from artificial light sources in the evening. This is important, because melatonin suppression in the evening (a relatively new phenomenon in human history brought about by electric light) hinders sleep and disrupts the sleep cycle.

Melatonin production may be suppressed by a variety of light sources but, as discussed above, the more bluish light produced by newer energy-efficient light bulbs, and electronics such as computer screens, smart phones, and tablets, is compounding the problem. Dr. Brainard explained that a large LED screen, for example, "could be giving you an alert stimulus at a time that will frustrate your body's ability to go to sleep later." And even when you turn it off, he says, "it doesn't mean that instantly the alerting effects go away. There's an underlying biology that's stimulated."[17]

12 Thapan, Kavita, Josephine Arendt, and Debra J. Skene. "An Action Spectrum for Melatonin Suppression: Evidence for a Novel Non-rod, Non-cone Photoreceptor System in Humans." *The Journal of Physiology* 535 (2001): 261-67. Print.

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13 Ibid

14 Brown, G. M. "Light, Melatonin and the Sleep-wake Cycle." J Psychiatry Neurosci 19.5 (1994): 345-53. Print.

15 Thapan, Kavita, Josephine Arendt, and Debra J. Skene. "An Action Spectrum for Melatonin Suppression: Evidence for a Novel Non-rod, Non-cone Photoreceptor System in Humans." *The Journal of Physiology* 535 (2001): 261-67. Print.

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16 Macchi M, Bruce J (2004). "Human pineal physiology and functional significance of melatonin". Front Neuroendocrinol 25 (3–4): 177–95. doi: 10.1016/j.yfrne.2004.08.001. PMID 15589268.

17 *http://www.nytimes.com/2011/07/05/health/05light.html?pagewanted=all&_r=0*

While the bluish light from new light sources has the strongest effect on melatonin levels, even bright standard room lighting has a noticeable impact.[18] Conversely, light with longer wavelengths above 550 to 560 nanometers (more towards the orange or red end of the spectrum) has a much lower suppressive effect.[19] Exposure to such light in the evening and at night, in lieu of bluish or regular lighting, has a less disruptive effect on the sleep-wake cycle.[20]

The effects of melatonin suppression can be long lasting, just as jet lag may persist several days after a trip.[21] Accordingly, maintaining a consistent schedule of the right kind of light exposure helps your body maintain a consistent sleep-wake schedule.

USING LIGHTING TO OUR ADVANTAGE

While certain types of lighting may negatively affect our sleeping schedules, there are ways to create lighting that can help our bodies maintain their natural rhythms. For example, research shows that illumination of less than 30 lux for 30 minutes should not significantly suppress melatonin production.[22] In addition, using a light source that is skewed towards the orange and red end of the spectrum (in place of a more whitish or bluish light) will also reduce melatonin suppression that would otherwise be caused by a bluish, or even a traditional white, light source.[23] Engineering LED bulbs in this way can provide individuals with the illumination (quality and quantity of light) they need in the evenings and at night, but without significantly suppressing melatonin. This can help them maintain their natural sleep cycles.

18 Figueiro et al. found that even low levels (30 to 300 lux at the eye) of incandescent light in the home, for ½ hour have a significant effect (8 to 35% reduction) on melatonin level in humans (Mariana G Figueiro, Mark S Rea, John D Bullough, J Carcinog 2006, 5:20).

McIntyre et al. found that maximum suppression of melatonin following 1 hr of light at midnight was 71%, 67%, 44%, 38%, and 16% with intensities of 3000, 1000, 500, 350, and 200 lux, respectively (McIntyre IM, J Pineal Res. 1989, 6(2):149-56).

Gooley, et al. found that compared with dim light (< 3 lux), exposure to room light (< 200 lux) before bedtime suppressed melatonin, resulting in a later melatonin onset in 99.0% of individuals and shortening melatonin duration by about 90 min. Also, exposure to room light during the usual hours of sleep suppressed melatonin by greater than 50% in most (85%) trials (Joshua J Gooley et al., J Clin Endocrinol Metab. Mar 2011; 96(3): E463–E472).

19 Thapan, Kavita, Josephine Arendt, and Debra J. Skene. "An Action Spectrum for Melatonin Suppression: Evidence for a Novel Non-rod, Non-cone Photoreceptor System in Humans." *The Journal of Physiology* 535 (2001): 261-67. Print.

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20 Ibid

21 National Institute of Health, Circadian Rhythms Fact Sheet, http://www.nigms.nih.gov/Education/Pages/Factsheet_CircadianRhythms.aspx.

22 Thapan, Kavita, Josephine Arendt, and Debra J. Skene. "An Action Spectrum for Melatonin Suppression: Evidence for a Novel Non-rod, Non-cone Photoreceptor System in Humans." *The Journal of Physiology* 535 (2001): 261-67. Print.

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23 Ibid

While bright, bluish light in the evening works to disrupt our circadian rhythm, such light in the early day actually assists our body to maintain its natural rhythms.[24] The light works to suppress melatonin at the same time the pineal gland is ramping down melatonin production in the morning. Engineering an LED light source in this way for use in the morning also can help an individual maintain a natural sleep cycle.

There are ways to create lighting that can help our bodies maintain their natural rhythms

In addition to color (bluish versus orange/reddish) and intensity (brightness), distance from the light source to a person is an important practical factor, since how much light actually reaches the eyes is critical. Having higher light levels reach the eyes in the morning, coupled with lower levels reaching the eyes in the evening, generally is better to support our body's natural melatonin production and maintain sleep-wake cycles.

Finally, pairing the use of a relatively high volume of bright, bluish light in the morning with the use of non-bluish light in the evening would seem to be most effective at helping an individual maintain the natural sleep-wake cycle. Light bulbs or fixtures designed to provide this "recipe" of lighting — in place of traditional light sources — can benefit an individual seeking to get, achieve and maintain, a more consistent, natural sleep cycle.

CONCLUSION

Thanks to advances in technology, we are living in a "new age of illumination." While these advancements come with many benefits, we should also be aware of unintended effects they can cause to our natural rhythms around day and night, such as their ability to interfere with wakefulness and sleep. New innovations in the field of lighting, and solutions that help mimic natural light patterns, will be important, since they may help to the body back into, and maintain, its natural circadian rhythm.

24 Thapan, Kavita, Josephine Arendt, and Debra J. Skene. "An Action Spectrum for Melatonin Suppression: Evidence for a Novel Non-rod, Non-cone Photoreceptor System in Humans." *The Journal of Physiology* 535 (2001): 261-67. Print.

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