

LIGHT AT NIGHT EFFECTS ON CARDIOVASCULAR DISEASE

SUMMARY

There is now increasing evidence that exposure to blue-rich light in the evening and at night increases the risk of cardiovascular disease. Because most energy efficient LEDs in the market today are rich in these blue wavelengths, the use of these LED lights at night can trigger the disease processes involved in hypertension, atherosclerosis and cardiovascular disease through:

- 1) Disruption of the circadian system (phase shifting and circadian misalignment),
- 2) Melatonin-suppression and phase shifting,
- 3) Activation of chronic inflammatory processes causing atherosclerosis in blood vessels.

Blue-rich light (including natural daylight) during the day is protective, but exposure to the same blue rich LED or florescent light during the night is harmful. To avoid this risk, light fixtures need to provide blue-rich light during the day, and blue-depleted light at night.

This paper presents the scientific evidence and the lighting solutions now available.

Authors	Date	Population	Odds Ratio	Increased Risk
Boggild	1999	Meta-analysis of 17 studies on cardiovascular disease & shift work	1.4	+ 40%
Vyas	2012	Meta-analysis of 34 studies of heart attacks in night shift workers	1.41	+ 41%
Gu	2015	Cardiovascular disease deaths in nurses working rotating night shifts	1.23	+ 23%
Kim	2017	Coronary artery disease in 34 meta-analysis	1.23	+ 23%

Figure 1: The increased risk of cardiovascular disease in people exposed to light at night

OVERVIEW OF SCIENTIFIC EVIDENCE

Based on over 15 years of published peer-reviewed scientific research the evidence indicates an association between artificial light exposure at night and cardiovascular disease:

- 1) Cardiovascular disease is increased by 40% in people regularly exposed to light at night while working night shifts based on 17 independent published peer-reviewed studies.
- 2) Deaths from coronary artery disease ("heart attacks") are increased by 23% in women regularly exposed to light at night while working night shifts.
- 3) Increased bedroom light levels in non-shiftworkers are associated with an increased risk of atherosclerosis, and elevated blood pressure.
- 4) Multiple research studies in humans and animals show that melatonin has blood pressure lowering properties, and the normal rise in melatonin at night is a protective mechanism that slows or prevents atherosclerosis and cardiovascular disease.

This scientific research is summarized on the following pages with references to key articles in the peer-reviewed scientific literature.

SCIENTIFIC LITERATURE REVIEW

Night Shift Work and Cardiovascular Disease

Numerous research studies have illustrated a strong association between night/ shift work and increased risk of cardiovascular diseases:

- A meta-analysis of seventeen independent studies [1] concluded that there was a strong association between shift work and CVD, with shift workers having on average 40% excess risk for ischemic heart disease as compared to day workers (RR about 1.4).
- A large prospective study of 74,862 registered U.S. nurses [2] found that working rotating night shifts for >5 years was associated with a 23% increase in deaths from cardiovascular disease.
- A recent meta-analysis [3] of 34 studies examining the association between shift work and coronary heart disease, including a combined population of more than two million people, concluded that shift work was associated with a 23% higher risk of heart attacks (myocardial infarction (pooled relative risk 1.23, 95% confidence interval 1.15 to 1.31) and ischaemic stroke (1.05, 1.01 to 1.09). The analysis found that the highest risks related to working night shifts where the relative risk was increased by 41%.
- A large systematic review and meta-analysis [4] based on 38 meta-analyses and 24 systematic reviews found a link between shift work and coronary heart disease (relative risk 1.23), and stroke (relative risk 1.05).

Evening-shift/night-shift workers were also shown to have higher systolic and diastolic blood pressure during the nighttime than day-shift workers [5].

Bedroom Light at Night and Cardiovascular Disease

In non-shiftworkers who regularly sleep at night, there is also an association between exposure to artificial light at night (ALAN) and an increased risk of cardiovascular diseases:

- ALAN exposure in home settings was associated with subclinical carotid atherosclerosis in the general elderly population [6].

- Increased light exposure in home settings at night is associated with a 3.3–4.7 mm Hg increase in nocturnal systolic blood pressure [7]. This increase in systolic blood pressure is sufficient to increase the risks of cardiovascular events by 4.5%–6.4% and death rates by 4.7%–6.7% [8].

Mechanism of Action

Exposure to artificial light at night and, most potently blue-rich light, causes melatonin suppression and circadian disruption (Figure 2) These in turn lead to increased release of catecholamines (epinephrine, norepinephrine), activation of chronic inflammatory processes in blood vessels, altered lipid and glucose metabolism, and related changes in the risk for atherosclerosis, metabolic syndrome, and type II diabetes [9].

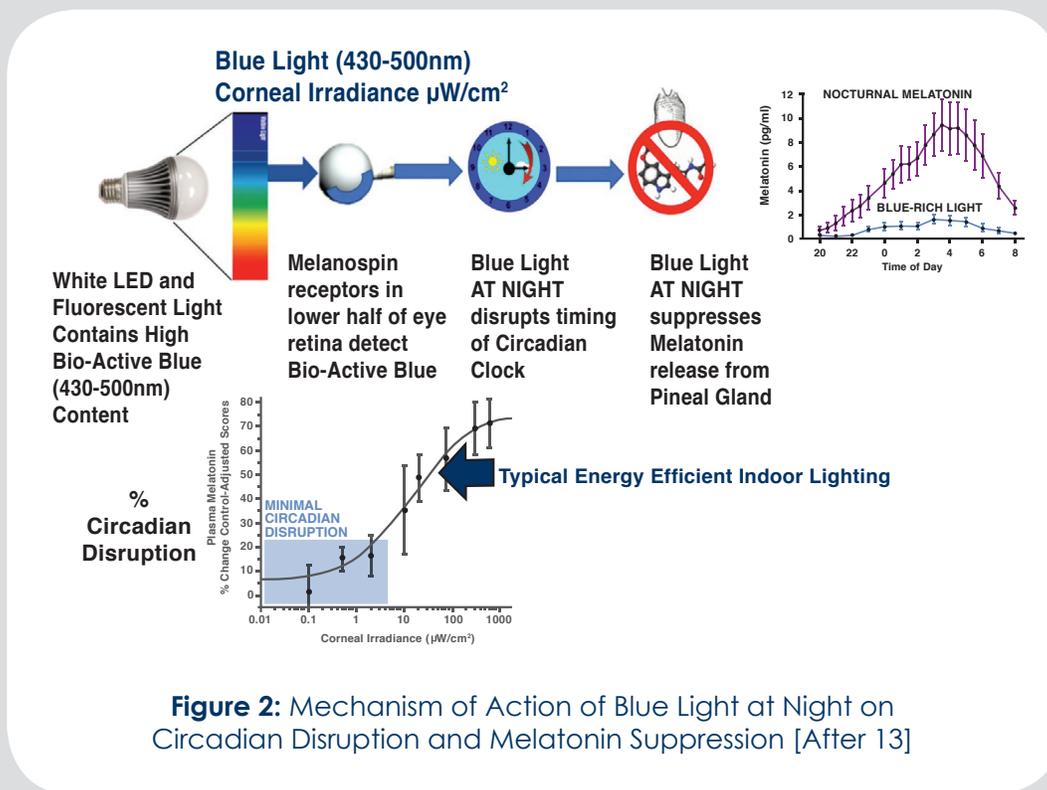


Figure 2: Mechanism of Action of Blue Light at Night on Circadian Disruption and Melatonin Suppression [After 13]

We will briefly summarize some of the extensive work exploring the pathways.

Circadian Disruption

Blood pressure normally follows a distinct circadian profile with a characteristic decline during sleep, followed by a surge in the early morning hours.

Circadian misalignment of sleep/wake cycles is associated with increased blood pressure during the nighttime, and increased endogenous catecholamine levels [10] and changes in sympathovagal cardiac modulation [11]. In addition, night/shift work diminishes a normal decrease in urinary norepinephrine and epinephrine levels during the non-work period, causing higher urinary catecholamine levels during the non-work period in night-shift workers than in day-shift workers [5].

Melatonin Effect

Normally in the hours of darkness, the elevation in nocturnal melatonin provides important protective effects on the cardiovascular system that is mediated through several pathways. It has been shown that melatonin decreases blood pressure and protects against atherosclerosis.

Suppression of nocturnal melatonin production by the light exposure at night causes increases in blood pressure and elevated atherosclerosis risk. Research studies have found an inverse association between melatonin and nighttime blood pressure, even at physiological levels. Moreover, clinical trials have suggested that oral melatonin administration decreases nighttime blood pressure, and that repeated melatonin intake reduced systolic and diastolic blood pressure during sleep [12].

The atherosclerotic process is primarily attributed to chronic inflammation related to oxidative stress in the vasculature. Low nocturnal melatonin levels are significantly associated with increased arterial stiffness (a bio-marker of atherosclerosis) in the general elderly population.

Melatonin activates NO (nitrous oxide) synthesis, and increased NO levels in endothelial cells may have protective effects against atherosclerosis. Furthermore, melatonin acts as a highly effective antioxidant by direct free radical-scavenging actions and indirect antioxidative functions mediated through receptors. Melatonin has a remarkable direct scavenging effect on a variety of reactive oxygen and reactive nitrogen species both at extracellular and intracellular levels. Melatonin signaling through receptors stimulates the antioxidant defense systems and activates anti-oxidant enzymes synthesis [7].

New CIRCADIAN® Zirc™ Lighting Solutions

To manage the risk of cardiovascular disease, light fixtures should provide blue-rich light during the day and blue-depleted light at night. The key is not just to lower blue content but to make sure the lights remove enough blue at night to reduce the risk (i.e., fall within the range of minimal circadian disruption in Figure 3).

For example, CCT color tuning products that transition from 6500K during the day to 2700 K at night do not remove enough blue out of the light spectrum at night to prevent circadian disruption, melatonin suppression, and the cardiovascular disease (Figure 3). While these CCT color tuning products may be marketed as “circadian” they still often rely on a blue pump that can cause circadian disruption.

To address the risk of blue light, CIRCADIAN® ZircLight™ has introduced fixtures that contain a light engine with both a blue-pump LEDs for daytime use as well as a patented violet-pump LED for evening and nighttime use. The “night” LED removes over 90% of the bio-active blue content to minimize circadian disruption, and provides white light with a CCT of 3200K, and CRI of 80+. To control blue light exposure 24/7, the CIRCADIAN® ZircLight™ fixtures automatically switch between day and night LEDs based on location, time and season.

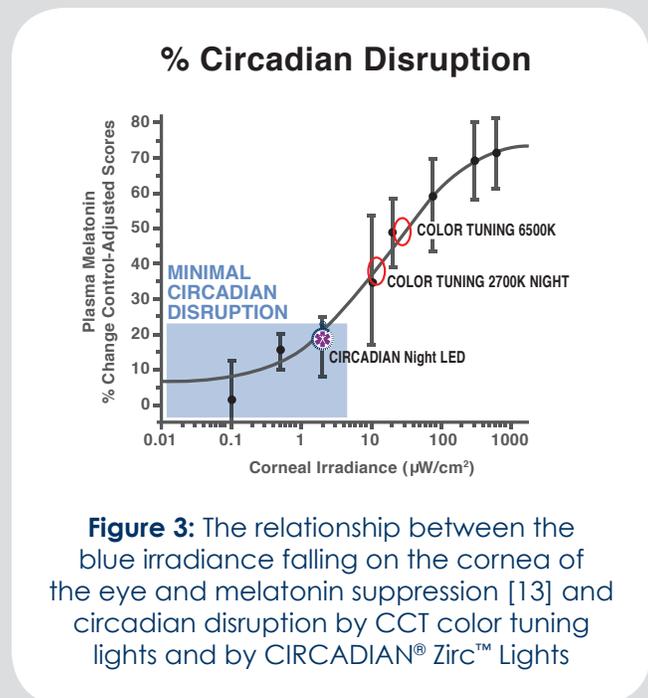


Figure 3: The relationship between the blue irradiance falling on the cornea of the eye and melatonin suppression [13] and circadian disruption by CCT color tuning lights and by CIRCADIAN® Zirc™ Lights

Normally in the hours of darkness, the elevation in nocturnal melatonin provides important protective effects on the cardiovascular system that is mediated through several pathways

1. Bøggild H and Knutsson A (1999). Shift work, risk factors and cardiovascular disease. *Scand J Work Environ Health* 25 :85-99.
2. Gu F, Han J, Francine Laden F, Caporaso NE, Stampfer MJ, Kawachi I, Rexrode KM, Walter C, Willett WC, Hankinson, SE, Speizer F and Schernhammer ES (2015). Total and Cause-Specific Mortality of U.S. Nurses Working Rotating Night Shifts. *Am J Prev Med.* 48(3): 241–252
3. Vyas MV, Garg AX, Iansavichus AV, Costella J, Donner A, Laugsand LE, Janszky I, Mrkobrada M, Parraga G and Hackam DG (2012). Shift work and vascular events: systematic review and meta-analysis. *BMJ* 345
4. Kecklund G and Axelsson J (2016). Health consequences of shift work and insufficient sleep. *BMJ* 355: i5210
5. Yamasaki F, Schwartz JE, Gerber LM, Warren K and Pickering TG (1998). Impact of shift work and race/ethnicity on the diurnal rhythm of blood pressure and catecholamines. *Hypertension* 32: 417–423
6. Obayashi K, Saeki K and Kurumatani N (2015). Light exposure at night is associated with subclinical carotid atherosclerosis in the general elderly population: The HEIJO-KYO cohort. *Chronobiol Int* 32(3): 310-317
7. Obayashi K, Saeki K and Kurumatani N (2014). Association Between Urinary 6-Sulfatoxymelatonin Excretion and Arterial Stiffness in the General Elderly Population: The HEIJO-KYO Cohort. *J Clin Endocrinol Metab* 99: 3233–3239
8. Boggia J, Li Y, Thijs L, Hansen TW, Kikuya M, Björklund-Bodegård K, Richart T, Ohkubo T, Kuznetsova T, Torp-Pedersen C, Lind L, Ibsen H, Imai Y, Wang J, Sandoya E, O'Brien E and Staessen JA (2007). Prognostic accuracy of day versus night ambulatory blood pressure: A cohort study. *Lancet.* 370: 1219–1229
9. Puttonen S, Harma M and Hublin C (2010). Shift work and cardiovascular disease – pathways from circadian stress to morbidity. *Scand J Work Environ Health* 36(2): 96-108
10. Scheer FA, Hilton MF, Mantzoros CS and Shea SA (2009). Adverse metabolic and cardiovascular consequences of circadian misalignment. *Proc Natl Acad Sci USA* 106: 4453–4458
11. Chung MH, Kuo TB, Hsu N, Chu H, Chou KR and Yang CC (2009). Sleep and autonomic nervous system changes – Enhanced cardiac sympathetic modulations during sleep in permanent night shift nurses. *Scand J Work Environ Health* 35: 180–187
12. Scheer FAJL (2002). Cardiovascular control by the biological clock. Neural and neuroendocrine mechanisms in human and rat. PH.D. Dissertation. University of Amsterdam
13. West KE, Jablonski MR, Warfield B, Cecil KS, James M, Ayers MA, Maida J, Bowen C, Sliney DH, Rollag MD, Hanifin JP, and Brainard GC (2011). Blue light from light-emitting diodes elicits a dose-dependent suppression of melatonin in humans. *J Appl Physiol* 110(3): 619-626

Blue Light InSight

LIGHT AT NIGHT

Volume 1 - Effects on Obesity and Diabetes

Volume 2 - Effects on Breast Cancer, Prostate and Other Cancers

Volume 3 - Effects on Cardiovascular Disease



CIRCADIAN[®]

ZircLight[™]

DynamicBlu[™] Spectrum Control
with Zirc[™] NightSafe[™] Technology

LIGHT AT NIGHT EFFECTS ON CARDIOVASCULAR DISEASE

ABOUT THE AUTHOR

MARTIN MOORE-EDE, M.D., Ph.D.

For over 30 years, Dr. Moore-Ede has been a leading expert on circadian clocks, and the health and safety risks faced by businesses that operate 24/7. After experiencing the challenges of fatigue as a surgeon-in-training required to work 36-hour shifts, Dr. Moore-Ede was one of the first to define the challenges of living, working, and sleeping in a 24-hours-a-day, 7-days-a-week world. As a professor at Harvard Medical School (1975–1998), he led the team that located the suprachiasmatic nucleus, the circadian biological clock in the human brain that controls the timing of sleep and wake, and pioneered research on how the human body can safely adapt to working around the clock and sustain optimum physical and mental performance.

In 1983, to implement circadian science in the workplace, Dr. Moore-Ede founded CIRCADIAN[®] which now helps over half of the Fortune 500 companies optimize 24/7 workforce productivity, health, and safety. In 2012, in response to the emerging evidence of the harmful effects of blue-rich LED light at night, Dr. Moore-Ede led the team that developed the first blue-depleted white LED lights for safe use at night, and established CIRCADIAN[®] ZircLight[™], to market LED lighting systems which provide the correct blue dosage for optimal human health and safety according to the time of day, based on a comprehensive proprietary IP portfolio.

Dr. Moore-Ede graduated with a First Class Honors degree in physiology from the University of London, received his medical degrees from Guy's Hospital Medical School, and his Ph.D. in physiology from Harvard University. He has published 10 books and more than 150 scientific papers on the physiology of sleep deprivation and circadian rhythms. Dr. Moore-Ede holds multiple patents on the spectral composition of light sources, and tools for assessing and mitigating fatigue risk including the Circadian Alertness Simulator (CAS), a scientifically validated fatigue risk model. He has served on multiple national and international committees and has received numerous awards including the Bowditch Lectureship of the American Physiological Society. He is a frequent guest on television (CNN, Today Show, Good Morning America, 20:20, Dateline, Oprah Winfrey, Nova, BBC), radio (NPR Fresh Air, Connection), and print media (Wall Street Journal, New York Times, Washington Post, Time and Newsweek). He has testified before Congressional committees on multiple occasions and advised government agencies on the health and safety of the 24/7 workforce in the US, Canada, and Europe.

2 Main St. Suite 310, Stoneham, MA 02180 / (781) 439-6333

info@circadianlight.com / www.circadianlight.com / © 2019 CIRCADIAN[®] ZircLight[™]