



NICOLAUS COPERNICUS  
UNIVERSITY  
IN TORUŃ

**Quality in Sport. 2026;52:68902. eISSN 2450-3118.**

<https://doi.org/10.12775/QS.2026.52.68902>



**Quality in Sport. eISSN 2450-3118**

**Journal Home Page**

<https://apcz.umk.pl/QS/index>

POPCZYK, Michał, ŚWIĄTECKA, Martyna, PRZYBYŁOWSKA, Agnieszka, BRYKSY, Sylwia, BUCZKOWSKA, Ewa, KAŹMIERCZYK, Jakub, TYMCHENKO, Hanna, PIECHOWICZ, Agnieszka, POPCZYK, Natalia and MARCISZEWSKA, Aleksandra. The Impact of Blue Light Exposure on Cortisol Secretion and Psychophysiological Readiness in Sport. *Quality in Sport*. 2026;52:68902. eISSN 2450-3118. <https://doi.org/10.12775/QS.2026.52.68902>

The journal has been awarded 20 points in the parametric evaluation by the Ministry of Higher Education and Science of Poland. This is according to the Annex to the announcement of the Minister of Higher Education and Science dated 05.01.2024, No. 32553. The journal has a Unique Identifier: 201398. Scientific disciplines assigned: Economics and Finance (Field of Social Sciences); Management and Quality Sciences (Field of Social Sciences).

Punkty Ministerialne z 2019 - aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398. Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych). © The Authors 2026.

This article is published with open access under the License Open Journal Systems of Nicolaus Copernicus University in Toruń, Poland. Open Access: This article is distributed under the terms of the Creative Commons Attribution Noncommercial License, which permits any noncommercial use, distribution, and reproduction in any medium, provided the original author(s) and source are credited. This is an open access article licensed under the terms of the Creative Commons Attribution Non-commercial Share Alike License (<http://creativecommons.org/licenses/by-nc-sa/4.0/>), which permits unrestricted, non-commercial use, distribution, and reproduction in any medium, provided the work is properly cited.

The authors declare that there is no conflict of interest regarding the publication of this paper.

Received: 11.02.2026. Revised: 15.02.2026. Accepted: 17.02.2026. Published: 28.02.2026.

## **The Impact of Blue Light Exposure on Cortisol Secretion and Psychophysiological Readiness in Sport**

POPCZYK Michał, ŚWIĄTECKA Martyna, PRZYBYŁOWSKA Agnieszka, BRYKSY Sylwia, BUCZKOWSKA Ewa, KAŹMIERCZYK Jakub, TYMCHENKO Hanna, PIECHOWICZ Agnieszka, POPCZYK Natalia, MARCISZEWSKA Aleksandra

1. Michał Popczyk (MP)

Wroclaw Medical University 1 Ludwik Pasteur., 50-367 Wrocław, Poland

<https://orcid.org/0009-0007-3882-2279>

[michu19041@gmail.com](mailto:michu19041@gmail.com)

2. Martyna Świątecka (MŚ)

Jagiellonian University Medical College in Cracow, Santa Anne 12 Street, 31-008 Cracow, Poland

<https://orcid.org/0009-0000-6061-2314>

[emswiatecka@gmail.com](mailto:emswiatecka@gmail.com)

3. Agnieszka Przybyłowska (AP)

Jagiellonian University Medical College in Cracow, Santa Anne 12 Street, 31-008 Cracow, Poland

<https://orcid.org/0009-0009-7840-499X>

[agnieszka.przybylowska@proton.me](mailto:agnieszka.przybylowska@proton.me)

4. Sylwia Bryksy (SB)

Jagiellonian University Medical College in Cracow, Santa Anne 12 Street, 31-008 Cracow, Poland

<https://orcid.org/0009-0007-7877-1541>

[bryksy.syl@gmail.com](mailto:bryksy.syl@gmail.com)

5. Ewa Buczkowska (EB)

Silesian Medical University in Katowice, Poniatowskiego 15 Street, 40-055 Katowice, Poland

<https://orcid.org/0009-0006-5516-3538>

[ewaabuczkowska@gmail.com](mailto:ewaabuczkowska@gmail.com)

6. Jakub Kaźmierczyk (JK)

Jagiellonian University Medical College in Cracow, Santa Anne 12 Street, 31-008 Cracow, Poland

<https://orcid.org/0009-0000-5552-0781>

[kuba.kazmierczyk@gmail.com](mailto:kuba.kazmierczyk@gmail.com)

7. Hanna Tymchenko (HT)

Jagiellonian University Medical College in Cracow, Santa Anne 12 Street, 31-008 Cracow, Poland

<https://orcid.org/0009-0009-9641-4286>

[hannatymchenko07@gmail.com](mailto:hannatymchenko07@gmail.com)

8. Agnieszka Piechowicz (AP)

Medical Centre in Otwock, Batorego 44 Street, 05-400 Otwock, Poland

<https://orcid.org/0009-0000-0479-0642>

[agnieszka.piechowicz4@gmail.com](mailto:agnieszka.piechowicz4@gmail.com)

9. Natalia Popczyk (NP)

Wroclaw Medical University 1 Ludwik Pasteur., 50-367 Wrocław, Poland

<https://orcid.org/0009-0007-0562-1171>

[npopczyk0811@gmail.com](mailto:npopczyk0811@gmail.com)

10. Aleksandra Marciszewska (AM)

Medical University of Lodz, Al. Kosciuszki 4, 90-419 Lodz, Poland

<https://orcid.org/0009-0009-1580-6916>

olamarci2002@gmail.com

## **Abstract**

### **Introduction:**

Cortisol is a crucial stress hormone regulated by the hypothalamic-pituitary-adrenal (HPA) axis. Its secretion is intricately linked to the central biological clock and the suprachiasmatic nucleus in hypothalamus (Figueiro & Rea, 2010). Although the interaction between light exposure and cortisol secretion is indicated in numerous studies, the effect of specific light on the cortisol secretion during stress response is not yet fully understood (Petrowski et.al, 2021a). Blue light is characterized by a short wavelength and high-energy and is present of natural sun light, and artificial light. It is a key for regulating circadian rhythms.

**Purpose of Work:** This review is a comprehensive summary of mechanisms through which different light spectra affect cortisol secretion in several contexts, such as stress reaction, sleep-restriction, and seasonal changes, taking into consideration health implications.

**Materials and methods:** A comprehensive literature search was conducted in the Google Scholar and PubMed databases from 1998 onward. The review included controlled laboratory, longitudinal, clinical and field studies that investigated the impact of various types of light on cortisol secretion.

**Summary:** The evidence indicates a stimulatory effect of exposure to blue and bright light on cortisol secretion primarily targeting the cortisol rising phase (post-awakening) or night time, and strengthening cortisol stress reaction. In context of sleep limitation, daytime light exposure mitigates morning decline in cortisol. However, prolonged exposure to extremely bright white light suppresses cortisol secretion, but only when its level is already elevated. Furthermore, the review identifies light manipulation as a non-invasive tool for optimizing athletic performance. Blue light exposure stimulates the anticipatory cortisol response required for activation and cognitive readiness, whereas red light facilitates recovery and reduces pre-competitive anxiety.

**AI:** AI was utilized for two specific purposes in this research. Text analysis of clinical reasoning narratives to identify linguistic patterns associated with specific logical fallacies. Assistance in refining the academic English language of the manuscript, ensuring clarity, consistency, and adherence to scientific writing standards. AI were used for additional linguistic refinement of the research manuscript, ensuring proper English grammar, style, and clarity in the presentation of results. It is important to emphasize that all AI tools were used strictly as assistive instruments under human supervision. The final interpretation of results, classification of errors, and conclusions were determined by human experts in clinical medicine and formal logic. The AI tools served primarily to enhance efficiency in data processing, pattern recognition, and linguistic refinement, rather than replacing human judgment in the analytical process.

**Keywords:** Blue light, Cortisol secretion, Short wavelength of light, Blue light Stress, Cortisol level, Sleep restriction, Circadian rhythm, Cortisol awakening response, Shift work, Performance in sport, Quality of work environment

## **INTRODUCTION**

### **Background on Cortisol and Circadian Rhythms**

Cortisol, commonly known as the stress hormone is closely linked with, and follows, circadian rhythms, which repeat every 24 hours and are a reflection of the self-regulating master clock in the SCN aligned with the natural 24-hour light-dark cycle (Jung et.al, 2010). Cortisol rhythms are not associated with day and night but with periods of transitions between light and dark (Figueiro & Rea, 2010). Cortisol levels are typically lowest near habitual bedtime and gradually increase during the night and reach peak level around wake time. (Jung et.al, 2010) Cortisol Awakening Response (CAR) is a rapid increase in cortisol secretion within 30 to 60 minutes after awakening time (Dickmeis, 2009) Elevated CAR is supposed to take part in anticipation of stress in available sources (Figueiro & Rea, 2010).

### **Blue Light**

The importance of blue light as a component of sunlight in the regulation of circadian rhythms is well documented and commonly known (M.A. St Hilaire et.al, 2022). Nowadays, increasing

screen time in society leads to greater artificial blue light exposure, particularly at night. That issue is often being accused of disrupting circadian rhythms and causing sleep problems (Chang et.al, 2015). Wavelengths of 400-500 nm have a strong impact on circadian cycles. Natural sunlight contains a wide spectrum of wavelengths, including blue light, and is known to stimulate cognitive functions, synchronizing circadian rhythms and increase alertness.

### **The Wavelength and the HPA Axis Response**

Experimental studies using narrow-spectrum light sources have clarified the spectral components responsible for modulating cortisol levels, which confirmed that the HPA axis pathway is controlled in different way than the pineal gland's melatonin secretion pathway (Figueiro & Rea, 2010). That specific research reported the following findings:

Melatonin levels decrease only in response to blue light, compared with dim and red light.

Cortisol levels respond to both blue and red light.

## **THE SHORT WAVELENGTH LIGHT EXPOSURE**

### **The Impact on Cortisol Awakening Response (CAR)**

Multiple studies focus on the impact of blue light on CAR. Results show that sleep limited adolescents (4.5 h) respond to a single one-hour exposure to short wavelength blue light (470 nm, 40 lx) applied after waking up (6:00), significantly strengthened the CAR and the total cortisol level (AUC) compared with exposure to dim light. (Figueiro & Rea, 2012)

20 minutes after waking up, salivary CAR was notably higher following exposure to blue and bright light compared with red light (235lx) and dim light. (Figueiro & Rea, 2012; Petrowski et.al, 2021b)

In conditions of sleep deprivation, in the morning, a significant decline of cortisol in saliva is observed. However, blue light exposure sessions, not only impeded morning cortisol downfall, but also increased its level in the afternoon. (Faraut et.al, 2020)

Increased CAR by short wavelength light may help in preparing sleep-restricted individuals for an active day and coping with stressors. (Figueiro & Rea, 2012)

### **The Impact of Blue and Bright Light on Cortisol Level in The Morning (no sleep-restricted):**

Research conducted by Petrowski and associates (2021) on healthy adult men, who had saliva cortisol level measured one hour after awakening, found that:

Exposure to bright white light (414 lx) resulted in the highest cortisol level in compared with dim light (<2 lx)

Exposure to blue light (201 lx) significantly increased cortisol level compared with both red (235 lx) and dim light (<2 lx)

Results confirm hypothesis that blue and bright light has stimulatory effect on the HPA axis during the cortisol rising phase. The stimulatory effect begins approximately 30 minutes after light onset and persists for about 15 minutes after exposure ends (Petrowski et.al, 2021b).

### **The Blue Light Exposure as a Compensating Mechanism for Sleep Deprivation**

Chronic sleep deprivation (less than 6 hours) leads to neurobehavioral deficits and physiological stress, which may result in increased cardiovascular risk and chronic diseases (Léger D et.al, 2011). Repetitive exposure to blue enriched light during the day is thought to counteract negative effects of sleep restriction (Faraut et.al, 2020).

Blue light exposure leads to stabilization and improved performance in Go/No/Go test, and prevents decline in efficiency during the day, observed in individuals who were not exposed to blue light (Faraut et.al, 2020).

Effect is not fully noticeable for memory tasks, which suggests that blue light exposure is specific for tasks taking place in present time (Faraut et.al, 2020).

Blue light exposure reduces subjective sleepiness and mental tension, especially at the end of the day, which results in improved mood (Faraut et.al, 2020).

### **The Silencing Effect of Extremely Bright Light on Cortisol Level**

Exposure to light intensity of 10 000 lx (instead of 1000 lx) for prolonged duration (6-7 hours) notably reduces cortisol levels, during both rising and declining phases of cortisol rhythm, but only if its level was already elevated (Jung et.al, 2010). Those results support conclusion that light intensity directly affects adrenal gland activity.

### **The Comparison of Different Light Spectra Influence on Cortisol Secretion**

The impact exposure to other light wavelengths, such as green light (520 nm, 806 lx), which is also included in short wavelength light, was part of the following reasearch, focused on effect of light on cortisol awakening response (CAR) (Petrowski et.al 2019).

Exposure to green light after awakening intensified cortisol awakening response (CAR) compared with red light, however the difference between impact of blue and green light was not statistically significant.

In this particular study, time of light exposure was shorter (60 minutes) than in the above mentioned (80 minutes), and that may be a reason why the elevated cortisol level was maintained for longer period of time, compared to other studies (Figueiro & Rea, 2012).

Those results confirm the hypothesis, that melanopsin retinal ganglion cells (mRGCs), which affect the HPA axis, are sensitive to short wavelength light (Petrowski et.al 2019).

## **CORTISOL STRESS REACTION**

### **The Correlation Between Light Wavelength and Intensity, and Cortison Stress Reaction**

Stress is a common experience that occurs when an organism is exposed to stressor, or to overstimulation by multiple stressors, followed by physiological adaptation (McEwen et.al, 1998). Most studies focus on baseline cortisol levels, however, what the impact of light wavelength and intensity on cortisol reactivity induced by stress is also important. In the

Maastricht Stress Test (MAST) physical and psychological stress is induced, followed by controlled light exposure (Petrowski et.al, 2021a).

Exposure to bright, white, high intensity light (1240 lx) produced the strongest stress-induced cortisol response effect compared with dim, red and blue light. These results indicate a key role of light intensity in hormonal stress reaction.

Blue light (420 nm) increased cortisol activity and elevated and prolonged elevated cortisol levels compared with red and white dim light.

Red light (635 nm) significantly reduced cortisol activity after stress induction compared with bright white light.

The authors of this experiment hypothesize that the intense cortisol stimulation induced by bright white light results from connection between melanopsin-expressing retinal ganglion cells (mRGCs) and visual receptors – cone photoreceptors (Petrowski et.al, 2021a). mRGCs are located in the retina and form part of light-detection system connected with SCN via retinohypothalamic tract, and influence the HPA axis (Dickmeis, 2009). Although they do not participate in vision, they are essential for accessory visual functions, including the circadian clock regulation (Petrowski et.al, 2021b).

### **The Impact of Seasonal Variability of Light Exposure on Cortisol Level**

People living above 56° N experience marked seasonal changes in light exposure, including higher intensity and a higher proportion of blue wavelengths in summer, as well as, seasonal variation of melatonin levels (with higher peaks in winter) (Adamsson et.al, 2016).

Cortisol levels, in contrast to melatonin, did not demonstrate significant seasonal variability in this research. However, other studies have reported elevated cortisol levels during winter. In conclusion, cortisol is supposedly more receptive to long term changes than melatonin (Adamsson et.al, 2016).

### **The Light Exposure as an Adaptaion to Night Shift Work**

In shift workers, who frequently experience insomnia (Hurst et.al, 2008), exposure to bright full-spectrum light (2000 lx) for six hours per shift, repeated over more than three weeks, significantly shifted the timing of the cortisol awakening response, supporting adaptation of the circadian rhythm to a night-oriented work schedule (James et.al, 2004).

## **The Blue Light Exposure and Immune System Disruption**

As the above-mentioned studies have shown, exposure to blue light increases cortisol levels, which deactivates the immune system response and leads to malfunction and long-term consequences (Pascu et. al, 2019).

Another research focuses on interleukin-6 (IL-6), a pro inflammatory cytokine (Mekschrat et. al, 2024). Exposure to blue light also resulted in an increase in IL-6 levels compared with red light. However, due to the pro-inflammatory effects of IL-6 that counteract cortisol's anti-inflammatory properties, changes in sensitivity of cortisol and IL-6 were observed under the blue light exposure. These results suggest that different wavelengths of light can shape the interaction between these mechanisms. The greater the cortisol rise was, the greater suppression of IL-6, which confirms that cortisol is a factor suppressing IL-6 secretion (Del Giudice & Gangestad, 2018). However, IL-6 can activate the HPA axis, resulting in increased cortisol levels (Cain & Cindlowski, 2017). In summary, exposure to blue light can influence general state of the immune system.

Another study reports that due to chronic stress increases not only cortisol levels, but also IL-6 levels, which can increase the HPA axis activity (Koutentaki et.al, 2023). The interaction between these inflammatory regulating factors can influence the hippocampal volume (Sudheimer et.al, 2014).

## **The Impact of The Light Exposure on Performance in Sport**

Analyzing the impact of light on cortisol secretion is particularly significant for optimizing athletic performance and managing competitive stress. Research indicates that athletes experience a significant anticipatory rise in cortisol levels while awaiting competition, which serves as a physiological preparation for rivalry (van Paridon et.al., 2017). It has been demonstrated that a moderate increase in cortisol is associated with reduced reaction times and better inhibition of irrelevant stimuli, thereby facilitating sports performance in accordance with the "inverted U" theory (van Paridon et.al., 2017).

In light of the evidence presented in this review, manipulating light spectra may serve as a non-invasive tool for regulating this arousal. Since exposure to blue light and bright white light effectively stimulates the cortisol awakening response (CAR) and cognitive functions (Petrowski et.al, 2021a), it can be applied to athletes requiring activation, especially in cases of early morning competitions or sleep deprivation, which dampens natural reactivity. Conversely, for athletes struggling with excessive pre-competitive anxiety or requiring post-exercise recovery, the application of red light (635 nm) may prove crucial, as it has been shown to significantly reduce cortisol activity following stress induction (Figueiro & Rea, 2012).

In the broader context of Quality of Life, proper light hygiene is becoming a key element of public health. Given that chronic sleep restriction and shift work disrupt circadian rhythms, leading to neurocognitive deficits, strategic exposure to blue light can serve a compensatory function, improving performance in attention-demanding tasks (Go/No-Go tests) (Faraut et.al, 2020). However, it must be emphasized that non-physiological exposure to blue light in the evening disrupts not only sleep but also immune balance through cortisol's interactions with Interleukin-6 (IL-6) (Léger D et. al., 2011) Therefore, conscious design of the light environment—both in sports facilities and domestic spaces—is essential for maintaining hormonal homeostasis and long-term well-being.

### **The Role of Environment and Technology on Activity of HPA Axis**

Studies on the effects of blue light on cortisol levels indicate that it has profound implications for public health and workplace environment (Léger D et.al, 2014).

Electronic readers emit predominantly short wavelength light and are commonly used before sleep, have negative effect on circadian cycle (Chang et.al, 2015). Although their primary impact is suppression of melatonin secretion, exposure to similar spectrum of light (452 nm) also plays crucial role in modulating the HPA axis activity (Faraut et.al, 2020).

Because people spend most of their time in indoor environments with artificial light, which intensity and spectrum is not controlled, understanding how blue light affects cortisol and stress process, is crucial for designing appropriate lighting systems (Adamsson et.al, 2016).

Exposure to blue light is a promising method for restoring the HPA axis activity and improving in alertness for sleep-restricted individuals, (Figueiro & Rea, 2012) such as adolescents and shift workers, 34% of whom, according to a Statistics Canada survey, report sleep onset and sleep maintenance difficulties (Hurst et.al, 2008).

### **How Blue Light Filters in Screens Affect The Impact of Blue Light on The Cortisol Levels**

People tend to spend a lot of time using screens in the evening, which is known to disrupt sleep and circadian rhythms (Komada et.al, 2015).

Exposure to a blue light deprived screen did not produced statistically significant differences compared with the regular screen in terms of cortisol levels, however, it did reduce the suppression of the melatonin secretion typically caused by regular screen and blue light.

These results confirm that cortisol and melatonin secretion pathways are controlled differently, and suggest that the stimulating effect of blue light exposure on cortisol secretion is primarily seen, when exposure occurs in the morning (Komada et.al, 2015).

### **Further Studies**

Further research is needed to determine the specific time window during which the HPA axis is most sensitive to light exposure. It is also essential to identify the optimal light intensity range for effective modulation of cortisol secretion (Petrowski et.al, 2021b).

### **Discussion**

Results reviewed in this study strongly confirm the hypothesis, that exposure to short wavelength – blue light and broad-spectrum, white, bright light produces a stimulatory effect on the HPA axis. This effect is the most evident in the cortisol awakening response (CAR) and in context of stress reaction. Studies on sleep restricted adolescents determined that morning exposure to blue light increased CAR (Figueiro & Rea, 2012). Similarly, in studies conducted on healthy, adult men showed that exposure to blue narrowlength light at 7:30 significantly

increased salivary cortisol compared with both red and dim light. Therefore, specific light exposure in the morning may be important in activating the organism, and preparing it for daily stressors (Petrowski et.al, 2021b).

Modulation of the cortisol stress response by bright white light exposure (1240 lx) has been demonstrated. It produced the strongest stimulation of cortisol secretion after MAST-induced stress, while blue light also increased cortisol levels. Therefore, inappropriate lighting in workplace environment may be disruptive (Petrowski et.al, 2021a).

A key and intriguing finding is that photosensitive pathways modulating melatonin and cortisol are different. Melatonin secretion is reduced only by blue light exposure, whereas cortisol levels are sensitive to both blue and red light exposure. This suggests that cortisol-activating mechanisms may be mediated by a broader pathway or by autonomic tracts, independent of SCN-driven circadian rhythms regulation, but involved in modulation of the adrenal glands through retinohypothalamic tract, which bypasses the HPA axis (Figueiro & Rea, 2010); (Jung et.al, 2010).

Exposure to blue light and the resulting increase in cortisol secretion may be used as a short-term remedy for reducing negative effects of sleep deprivation. Blue light exposure was found to stabilize cortisol stress reaction, by leveling the cortisol awakening response (CAR), weakened by sleep deprivation, and increasing afternoon cortisol levels, which can affect one's quality of sleep, regeneration and life (Faraut et.al, 2020).

Blue light exposure improved cognitive functions and performance in Go/No/Go test in sleep restricted individuals. However, this effect was not observed in long-term memory retention test (Faraut et.al, 2010).

Exposure to various light spectra modulates circadian rhythms by affecting cortisol secretion. Moderate white, bright light increased cortisol levels (40-414 lx), but extremely bright light (10 000 lx) strongly suppressed plasma cortisol levels (Jung, 2010). This finding suggests that designing appropriate artificial lighting is essential for coping with daily stressors.

Although laboratory exposures to blue light produce immediate changes in the HPA axis activity, long-term seasonal changes in natural environment did not affect cortisol levels. These findings suggest that cortisol levels are more resistant to seasonal adaptation than melatonin levels (Adamsson et.al, 2016).

Optimizing Arousal and Cognitive Function Research confirms that a moderate anticipatory rise in cortisol is beneficial for athletic performance, as it improves reaction time and the inhibition of irrelevant stimuli, supporting the "inverted-U" theory of arousal. Since short-

wavelength (blue) and bright white light are potent stimulators of the HPA axis, they serve as practical tools to induce this optimal psychophysiological state. This "light doping" is particularly valuable for athletes who typically exhibit blunted anticipatory cortisol responses, such as females, or international-level competitors. Furthermore, for sleep-restricted athletes, blue light exposure acts as a compensatory mechanism, stabilizing performance in executive tasks (e.g., Go/No-Go), ensuring that the cognitive demands of competition are met despite physiological fatigue. Conversely, the finding that red light (635 nm) significantly reduces cortisol activity after stress suggests it can prevent the debilitating effects of excessive anxiety (choking), keeping the athlete at the peak of the performance curve.

## **Conclusions**

In recent years, short wavelength light - blue light has received increasing attention, paralleling growing exposure to screens and artificial lightning. (Komada et.al, 2015) The findings summarized above provide a clear and comprehensive picture of the influence of short wavelength light – blue light on cortisol secretion via the HPA axis. Exposure to bright white light and blue light strongly stimulates cortisol secretion, particularly in the morning, resulting in a strengthened cortisol awakening response (CAR), regardless of sleep-deprivation status. This response plays a crucial role in preparing the organism for coping with daily stressors (Figueiro & Rea, 2012); (Petrowski et.al, 2021b). The management of light exposure constitutes a non-invasive ergogenic aid capable of modulating the psychophysiological readiness for sport. Strategic exposure to blue-enriched light is recommended to stimulate the Cortisol Awakening Response (CAR) and mimic the necessary anticipatory stress response, thereby sharpening focus and alertness. This is crucial when competition schedules (e.g., early morning) or individual physiology (e.g., lack of natural reactivity) do not provide sufficient activation. Simultaneously, the use of red light or controlled high-intensity light (10,000 lx) offers a novel pathway for rapid recovery and anxiety management by suppressing excessive cortisol levels. Therefore, sports facility lighting should be adaptive: stimulating blue light for warm-up zones to enhance performance, and warmer, red-spectrum lighting in recovery areas to facilitate homeostasis. Elevated cortisol may temporarily improve cognitive functions, under conditions of sleep restriction. However, chronic elevation of cortisol contributes to sleep disruption, which can reduce long-term quality of life. In summary, exposure to blue light can have both positive and negative consequences, depending on the time of exposure. It provides positive effects if the exposure aligns with the time when, physiologically, organisms should be exposed

to intense light enriched in short wavelengths. Such exposure can prepare an organism to cope with stressors and improve alertness. When exposure happens during evening or night it can cause sleep disruption, excessive stress, immune system and inflammation malfunctions, which can further increase risk brain and heart issues. The notable effect is that chronic elevated cortisol levels can lead to cerebral atrophy (Lara et.al, 2013). As a society, we should be more aware of the influence blue light has on our metabolism and take action in providing ourselves and work environment with proper lighting, adjusted to time of day.

**Authors' Contributions:** Conceptualization was done by Michał Popczyk; methodology by Michał Popczyk and Martyna Świątecka; software by Agnieszka Przybyłowska; checking by Sylwia Bryksy; formal analysis by Ewa Buczkowska; investigation by Jakub Kaźmierczyk; resources by Hanna Tymchenko; data curation by Agnieszka Piechowicz; writing-rough preparation by Natalia Popczyk; writing-review and editing by Aleksandra Marciszewska; visualization by Michał Popczyk and Sylwia Bryksy; supervision by Natalia Popczyk; project administration by Agnieszka Przybyłowska; All authors have read and agreed with the published version of the manuscript.

**Funding statement:** The study did not receive special funding.

**Informed Consent Statement:** Not applicable.

**Acknowledgements:** Not applicable.

**Conflict of Interest Statement:** The authors report that there are no conflict of interest.

## References:

1. Figueiro, M. G., & Rea, M. S. (2010). The effects of red and blue lights on circadian variations in cortisol, alpha amylase, and melatonin. *International journal of endocrinology*, 2010, 829351. <https://doi.org/10.1155/2010/829351>
2. Petrowski, K., Buehrer, S., Niedling, M., & Schmalbach, B. (2021a). The effects of light exposure on the cortisol stress response in human males. *Stress (Amsterdam, Netherlands)*, 24(1), 29–35. <https://doi.org/10.1080/10253890.2020.1741543>
3. Jung, C. M., Khalsa, S. B., Scheer, F. A., Cajochen, C., Lockley, S. W., Czeisler, C. A., & Wright, K. P., Jr (2010). Acute effects of bright light exposure on cortisol levels. *Journal of biological rhythms*, 25(3), 208–216. <https://doi.org/10.1177/0748730410368413>
4. Dickmeis T. (2009). Glucocorticoids and the circadian clock. *The Journal of endocrinology*, 200(1), 3–22. <https://doi.org/10.1677/JOE-08-0415>

5. St Hilaire, M. A., Ámundadóttir, M. L., Rahman, S. A., Rajaratnam, S. M. W., Rüger, M., Brainard, G. C., Czeisler, C. A., Andersen, M., Gooley, J. J., & Lockley, S. W. (2022). The spectral sensitivity of human circadian phase resetting and melatonin suppression to light changes dynamically with light duration. *Proceedings of the National Academy of Sciences of the United States of America*, 119(51), e2205301119. <https://doi.org/10.1073/pnas.2205301119>
6. Chang, A. M., Aeschbach, D., Duffy, J. F., & Czeisler, C. A. (2015). Evening use of light-emitting eReaders negatively affects sleep, circadian timing, and next-morning alertness. *Proceedings of the National Academy of Sciences of the United States of America*, 112(4), 1232–1237. <https://doi.org/10.1073/pnas.1418490112>
7. Figueiro, M. G., & Rea, M. S. (2012). Short-wavelength light enhances cortisol awakening response in sleep-restricted adolescents. *International journal of endocrinology*, 2012, 301935. <https://doi.org/10.1155/2012/301935>
8. Petrowski, K., Bührer, S., Albus, C., & Schmalbach, B. (2021b). Increase in cortisol concentration due to standardized bright and blue light exposure on saliva cortisol in the morning following sleep laboratory. *Stress (Amsterdam, Netherlands)*, 24(3), 331–337. <https://doi.org/10.1080/10253890.2020.1803265>
9. Faraut, B., Andrillon, T., Drogou, C., Gauriau, C., Dubois, A., Servonnet, A., Van Beers, P., Guillard, M., Gomez-Merino, D., Sauvet, F., Chennaoui, M., & Léger, D. (2020). Daytime Exposure to Blue-Enriched Light Counters the Effects of Sleep Restriction on Cortisol, Testosterone, Alpha-Amylase and Executive Processes. *Frontiers in neuroscience*, 13, 1366. <https://doi.org/10.3389/fnins.2019.01366>
10. McEwen B. S. (1998). Stress, adaptation, and disease. Allostasis and allostatic load. *Annals of the New York Academy of Sciences*, 840, 33–44. <https://doi.org/10.1111/j.1749-6632.1998.tb09546.x>
11. Adamsson, M., Laike, T., & Morita, T. (2016). Annual variation in daily light exposure and circadian change of melatonin and cortisol concentrations at a northern latitude with large seasonal differences in photoperiod length. *Journal of physiological anthropology*, 36(1), 6. <https://doi.org/10.1186/s40101-016-0103-9>
12. Hurst, M. (2008). Qui dort la nuit de nos jours? Les habitudes de sommeil des Canadiens. *Statistique Canada*, 11(008), 42-49.
13. Léger, D., Roscoat, E.d, Bayon, V., Guignard, R., Pâquereau, J., & Beck, F. (2011). Short sleep in young adults: Insomnia or sleep debt? Prevalence and clinical description of short sleep in a representative sample of 1004 young adults from France. *Sleep medicine*, 12(5), 454–462. <https://doi.org/10.1016/j.sleep.2010.12.012>
14. Petrowski, K., Schmalbach, B., Niedling, M., & Stalder, T. (2019). The effects of post-awakening light exposure on the cortisol awakening response in healthy male

individuals. *Psychoneuroendocrinology*, 108, 28–34.  
<https://doi.org/10.1016/j.psyneuen.2019.05.016>

15. Pascu, L. S., Perri, D., Bradeanu, A. V., Ciubara, A., Marin, M., & Virginia, M. (2019). The effects of blue light in modern society. *BRAIN. Broad Research in Artificial Intelligence and Neuroscience*, 10, 5-11., <http://dx.doi.org/10.70594/brain/v10.s1/1>
16. Komada, Y., Aoki, K., Gohshi, S. et al. Effects of television luminance and wavelength at habitual bedtime on melatonin and cortisol secretion in humans. *Sleep Biol. Rhythms* 13, 316–322 (2015). <https://doi.org/10.1111/sbr.12121>
17. Mekschat, L., Schmalbach, B., Rohleder, N., & Petrowski, K. (2024). IL-6 after wake-up in human males: Exposure to red versus blue light and the interplay with cortisol. *Brain, behavior, & immunity - health*, 40, 100833. <https://doi.org/10.1016/j.bbih.2024.100833>
18. Del Giudice, M., & Gangestad, S. W. (2018). Rethinking IL-6 and CRP: Why they are more than inflammatory biomarkers, and why it matters. *Brain, behavior, and immunity*, 70, 61–75. <https://doi.org/10.1016/j.bbi.2018.02.013>
19. Cain, D. W., & Cidlowski, J. A. (2017). Immune regulation by glucocorticoids. *Nature reviews. Immunology*, 17(4), 233–247. <https://doi.org/10.1038/nri.2017.1>
20. Koutentaki, E., Basta, M., Antypa, D., Zaganas, I., Panagiotakis, S., Simos, P., & Vgontzas, A. N. (2023). IL-6 Enhances the Negative Impact of Cortisol on Cognition among Community-Dwelling Older People without Dementia. *Healthcare (Basel, Switzerland)*, 11(7), 951. <https://doi.org/10.3390/healthcare11070951>
21. Sudheimer, K. D., O'Hara, R., Spiegel, D., Powers, B., Kraemer, H. C., Neri, E., Weiner, M., Hardan, A., Hallmayer, J., & Dhabhar, F. S. (2014). Cortisol, cytokines, and hippocampal volume interactions in the elderly. *Frontiers in aging neuroscience*, 6, 153. <https://doi.org/10.3389/fnagi.2014.00153>
22. Lara, V. P., Caramelli, P., Teixeira, A. L., Barbosa, M. T., Carmona, K. C., Carvalho, M. G., Fernandes, A. P., & Gomes, K. B. (2013). High cortisol levels are associated with cognitive impairment no-dementia (CIND) and dementia. *Clinica chimica acta; international journal of clinical chemistry*, 423, 18–22. <https://doi.org/10.1016/j.cca.2013.04.013>
23. van Paridon, K. N., Timmis, M. A., Nevison, C. M., & Bristow, M. (2017). The anticipatory stress response to sport competition; a systematic review with meta-analysis of cortisol reactivity. *BMJ open sport & exercise medicine*, 3(1), e000261. <https://doi.org/10.1136/bmjsem-2017-000261>