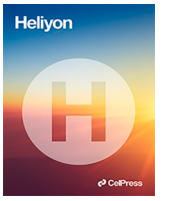
Heliyon 10 (2024) e38853

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



Research article

High correlated color temperature white light-emitting diodes disrupt refractive development in guinea pigs

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ARTICLE INFO

Keywords:
Light–emitting diodes
Correlated color temperature
Myopia
Sclera
Choroid
Guinea pig

ABSTRACT

Ubiquitous white light-emitting diodes (LEDs) possess optical properties that differ from those of natural light. This difference can impact visual perception and biological functions, thus potentially affecting eye health. Myopia, which leads to visual impairments and potentially irreversible vision loss or blindness, is the most prevalent refractive error worldwide. Ambient light has been found to be a significant factor in refractive development. The overlap between the commonly utilized of white LEDs and the rapid increase in the prevalence of myopia raises suspicions that white LEDs may represent hidden visual cues. To clarify the potential effects of white LEDs on refractive development, we exposed guinea pigs to different forms of artificial lighting over a period of eight weeks. We found that exposure to white LEDs with a high correlated color temperature (CCT) of approximately 5000 K can induce significant myopic shifts in guinea pigs, along with a decrease in collagen accumulation in the sclera. Additionally, this exposure was found to significantly reduce choroidal tissue thickness in guinea pigs. Our study findings indicate that high CCT white LEDs disrupt refractive development in guinea pigs. These results suggest that high CCT white LEDs might similarly affect refractive development in humans, highlighting the need for further clinical investigation.

1. Introduction

Humans are surrounded by light from light-emitting diodes (LEDs) in daily life, including sources ranging from LED lamps illuminating our homes and workplaces to LED screens on our televisions, computers, and smartphones. White LEDs are a common type of LED in the current lighting and display market [1]. However, it is worth noting that the spectral composition of white LEDs differs from that of natural light [1]. This difference can impact visual perception and biological functions, thus potentially affecting eye health [2,3].

Myopia is the predominant form of refractive error and is characterized by thinning of the choroid and sclera and excessive axial elongation. Myopia has numerous complications that can even lead to blindness [4]. Ambient light can participate in the regulation of refractive development [5]. Although the rise in myopia started before LEDs became widely used [6], numerous epidemiological

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https://doi.org/10.1016/j.heliyon.2024.e38853
Received 28 January 2024; Received in revised form 10 September 2024; Accepted 1 October 2024
Available online 1 October 2024

Abbreviations

LED	Light-emitting diode
IL:	Incandescent lamps
AL:	Axial length
ACD	Anterior chamber depth
VCD	Vitreous chamber depth
ECM	Extracellular matrix
ChBP	Choroidal blood flow perfusion
ChT	Choroidal thickness
ARVO	Association of research in vision and ophthalmology
OCT	Optical coherence tomography
COL1A1	Collagen type I alpha 1
RPE	Retinal pigment epithelium
CCT	Correlated color temperature
PMSF	Phenylmethylsulfonyl fluoride
RLRL:	Repeated low-level red-light
LCA	Longitudinal chromatic aberration

studies over the past decade have suggested a potential link between LED light exposure and the progression of myopia [7–12]. Children who used LEDs for homework after school had longer axial length (AL) than did those who used incandescent lamps (ILs) [8]. High correlated color temperature (CCT) white LEDs emit cool white light and contain a significant blue-light component, particularly compared to more traditional artificial light sources such as ILs and halogen lamps. One longitudinal study involving young monkeys demonstrated that, compared to ILs (CCT: 2709 ± 74 K) and low CCT LEDs (CCT: 2883 ± 30 K), high CCT white LEDs (CCT: 4740 ± 13 K) can accelerate axial elongation of eyeballs [13]. However, the study is solely limited to the relationship between high CCT white LEDs and changes in ocular AL; thus, more in-depth investigations into changes in ocular tissues related to the development of myopia, such as the choroid and sclera, are still lacking.

In this study, we exposed guinea pigs to indoor lighting conditions composed of white LEDs with a high CCT of approximately 5000 K or ILs for a period of eight weeks and assessed the effects of these different forms of artificial lighting on the refractive development of guinea pigs. Furthermore, we conducted a series of investigations to determine whether exposure to white LED light with a high CCT of approximately 5000 K could trigger a range of structural changes, including choroidal thinning and scleral remodeling, which could lead to the development of myopia. Our results elucidated the extent to which white LED lighting with a high CCT of approximately 5000 K interferes with refractive development in guinea pigs and raised awareness about the potential risks associated with high CCT white LEDs exposure. The insights gained from this research might help researchers improve vision healthcare practices and guide lighting choices in daily life. Further clinical investigations are warranted in future research.

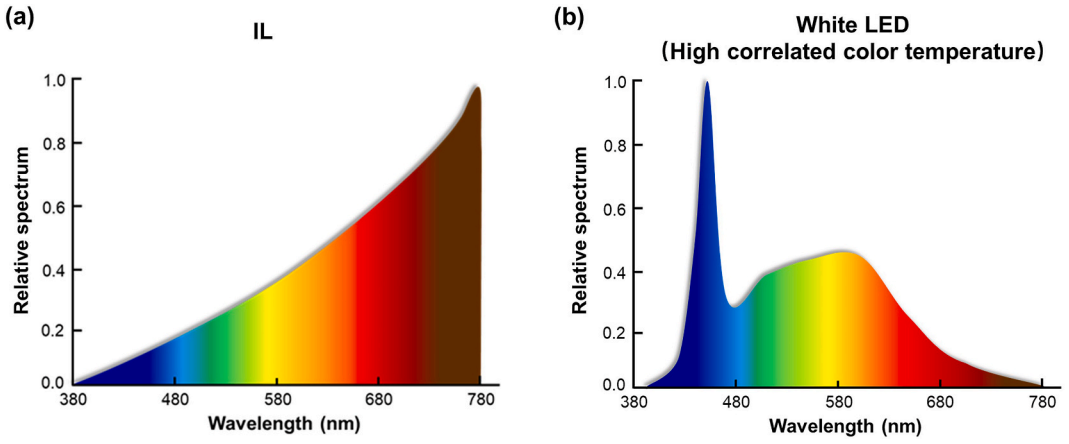

Fig. 1. Spectral composition of (a) the IL and (b) the white LED with a high CCT of approximately 5000 K. IL, incandescent lamp; LED, light-emitting diode.

2. Materials and methods

2.1. Chemicals and Reagents

Protein lysis buffer, phenylmethylsulfonyl fluoride (PMSF), an enhanced BCA protein assay kit and protein loading buffer (5X) were sourced from Beyotime (Shanghai, China). The β-tubulin antibody (Cat# 48375), goat anti-rabbit IgG secondary antibody (Cat# L3012) and goat anti-mouse IgG secondary antibody (Cat# L3032) that were used in this study were sourced from Signalway Technology (Maryland, USA). The COL1A1 antibody (Cat# 72026) was obtained from Cell Signaling Technology (St. Louis, MO, USA). The DyLight 488-conjugated goat anti-rabbit IgG antibody (Cat# A23220) that was used in this study was sourced from Abbkine (Wuhan, China). DAPI (Cat# C0060) was purchased from Solarbio (Beijing, China). One percent cyclopentolate hydrochloride eye drops and 0.5 % proparacaine hydrochloride eye drops were purchased from s.a.Alcon-Couvreur n.v. (Belgium).

2.2. Light Treatment

For a more precise replication of artificial lighting that is commonly encountered in daily environments, we chose IL and white LED light with a high CCT of approximately 5000 K as the experimental light conditions used in this study. These two types of artificial light sources are highly common on the market and are widely used in both home and office environments. The ILs and white LEDs were produced by CAS Applied Chemistry Science & Technology Co., Ltd (Changchun, China). The CCT of the experimental light sources was 2579 ± 2 K (ILs) and 4884 ± 6 K (white LEDs). The color rendering index of each experimental light was 92 (ILs) and 86 (white LEDs). A SPIC-200 spectral irradiance colorimeter (Everfine Corporation, Hangzhou, China) was used to measure the spectrum, CCT and color rendering index of each experimental light source (Fig. 1). When considering that the typical light intensity for indoor settings is approximately 300 lux, both the IL lamps and white LED lamps were strategically placed at the top of each breeding cage. This setup ensured that the light intensity reaching the floor of the cage was approximately 300 lux. A LX101 digital illuminance meter (LABFACILITY, London, UK) was used to measure the light intensity of each experimental light source.

2.3. Animal experiments

Three-week-old guinea pigs (*Cavia porcellus*, English short-hair stock, tricolor strain) were purchased from Danyang Changyi Experimental Animal Breeding Co., Ltd. (Jiangsu, China). Twenty guinea pigs were randomly allocated into two groups: (1) the IL group (n = 10) and (2) the white LED group (n = 10). The guinea pigs were kept under a 12/12-h light/dark cycle. The experimental lights were turned on at 7:00 and turned off at 19:00 at 25 °C. All of the guinea pigs were provided with ad libitum access to fresh vegetables and standard food. AL and refraction were examined at baseline and at weeks 2, 4, 6 and 8. Choroidal thickness (ChT) was assessed at the end of the study period, at week 8. After 8 weeks of light exposure and immediately after the animals were euthanized, both eyes were enucleated for Western blot analysis and immunofluorescence staining. All of the animal experiments were approved by the Ethics Committee of Changchun Wish Testing Technology Service Co., Ltd (Changchun, China) and conformed to the statement of the Association of Research in Vision and Ophthalmology (ARVO).

2.4. Biometric measurements

Prior to the refraction examination, the eyes were treated with 1 % cyclopentolate hydrochloride eye drops three times. Subsequently, the horizontal and vertical diameter of the retinoscopy was measured in a dark environment using a streak retinoscope to determine the refraction. After applying a drop of 0.5 % proparacaine hydrochloride to anesthetize the cornea, A-scan ultrasonography (MEDA Co., Ltd, Tianjin, China) was employed to examine the AL, which ranged from the anterior corneal surface to the retinal nerve fiber layer.

2.5. Western blot analysis

The guinea pigs were humanely euthanized. After the animals died, the eyeballs were removed and immersed in a culture dish filled with phosphate-buffered saline (PBS). The cornea, iris, lens, and vitreous humor were delicately excised. The integrity of the retina was preserved during removal. Microscissors were used to meticulously excise the choroid, thus ensuring the preservation of the scleral tissue in its entirety. Subsequently, the scleral tissue was transferred to a mortar and immersed in liquid nitrogen for rapid cooling. The scleral tissue was quickly ground into a fine powder by using a pestle. The scleral tissue samples were sonicated in protein lysis buffer containing 1 % PMSF. The samples were then centrifuged at 10,000 rpm for 5 min at 4 °C for collection of the supernatants, which were then subjected to the enhanced BCA protein assay kit to measure the protein concentrations. The protein samples were mixed with protein loading buffer (5X) at a ratio of 4 μl of protein sample to 1 μl of loading buffer. Afterward, the sample was boiled for another 10 min. Protein samples were separated via SDS–PAGE by using Bio-Rad equipment (USA) and subsequently transferred to PVDF membranes obtained from Merck Millipore (Burlington, MA, USA). After being blocked, the membranes were subjected to an overnight incubation at 4 °C with different primary antibodies (β-tubulin: 1:1000; COL1A1: 1:1000). Subsequently, the membranes were incubated with the corresponding secondary antibodies (goat anti-rabbit IgG: 1:10000; goat anti-mouse IgG: 1:10000). Protein bands were visualized by using electrochemiluminescence from Merck Millipore (Burlington, MA, USA) and analyzed by using the ImageJ program.

2.6. Immunofluorescence staining

After the fixation, permeabilization and blocking steps, the frozen eye ball slices were incubated with a COL1A1 antibody (1:100) overnight at 4 °C. Afterward, the sections were labeled with DyLight 488-conjugated anti-rabbit IgG secondary antibody (1:500). For nuclear staining, DAPI was used. A fluorescence microscope (Olympus, Tokyo, Japan) was used to capture representative images.

2.7. Optical coherence tomography (OCT) image acquisition

At the end of the study, the ChT of both eyes was measured for three randomly selected guinea pigs from each group following methods described in previous studies [14,15]. Briefly, these guinea pigs underwent bilateral swept-source OCT (SVision, Henan, China), which operates at a central wavelength of 1050 nm. The ChT measurements were taken at 2000 μm and 3000 μm from the optic disc, thus ensuring consistency in the data collection and providing comparable ChT readings across the study samples.

2.8. Statistical analysis

For statistical analysis, the same eye from each guinea pig was used. The results are reported as the means ± SD and were based on a minimum of three independent experiments. Statistical analysis was performed by using GraphPad Prism 9.4.1 software and SPSS 22.0 software. Differences between two groups were assessed by using Student's t tests or nonparametric U tests. Repeated-measures ANOVA (RM-ANOVA) was applied to the measurement data at different time points. Furthermore, $p < 0.05$ was considered to indicate statistical significance.

3. Results

3.1. High CCT white LED light exposure caused significant myopic shifts in Guinea pigs

Prior to light exposure, there were no significant differences in refractive diopters observed between the two groups. Both guinea pigs exposed to ILs and those exposed to white LEDs with a high CCT of approximately 5000 K exhibited a decrease in refraction over time. After 6 weeks of light exposure, a significant decrease in refraction was observed in the high CCT white LED group compared to the IL group. This difference was sustained throughout the next 2 weeks of light exposure (Fig. 2). This finding suggested that the guinea pigs exposed to high CCT white LED light experienced more pronounced myopic shifts.

Prior to light exposure, there were no statistically significant differences in AL, anterior chamber depth (ACD), lens thickness, and vitreous chamber depth (VCD) between the two groups of guinea pigs. As the duration of light exposure increased, all parameters (AL, ACD, lens thickness, and VCD) showed a growing trend in both groups. At each time point, there were no statistically significant differences in ACD and lens thickness between the two groups (Fig. 3b and c). However, after 6 and 8 weeks of light exposure, the AL and VCD in the white LED with a high CCT of approximately 5000 K group were significantly longer than those in the IL group (Fig. 3a and d), suggesting that the change in AL in guinea pigs is mainly related to the increase in VCD.

3.2. High CCT white LED light exposure significantly downregulated the expression of COL1A1 in the sclera of Guinea pigs

The sclera provides structural support and helps to maintain the shape of the eyeball. Collagen type I alpha 1 (COL1A1) is one of the main components constituting the extracellular matrix (ECM) of the sclera. The synthesis and degradation of COL1A1 are directly related to the biomechanical properties of the sclera, as well as any resulting refractive anomalies [16]. To determine whether high CCT white LED light exposure exerted detrimental effects on the sclera, we used Western blot analysis to evaluate potential changes in the expression of COL1A1 in the sclera of guinea pigs. As shown in Fig. 4a and b, COL1A1 expression in the sclera decreased in the white LED with a high CCT of approximately 5000 K group after 8 weeks of light exposure. Moreover, the fluorescence intensity of

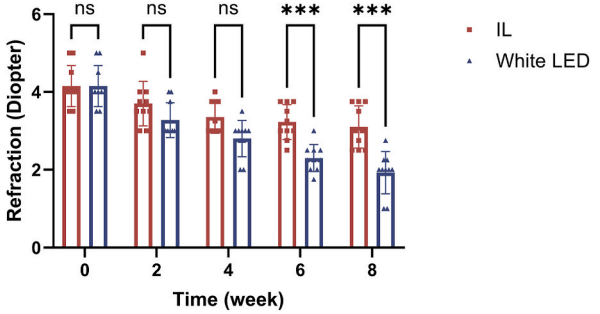

Fig. 2. Refraction of guinea pigs during the light exposure period.
Comparison of refraction between the two groups at 0, 2, 4, 6 and 8 weeks of light exposure (n = 10 for each group). The results are presented as the means ± SD. ***$p < 0.001$, ns $p > 0.05$. IL, incandescent lamp; white LED, white light-emitting diode with a high CCT of approximately 5000 K.

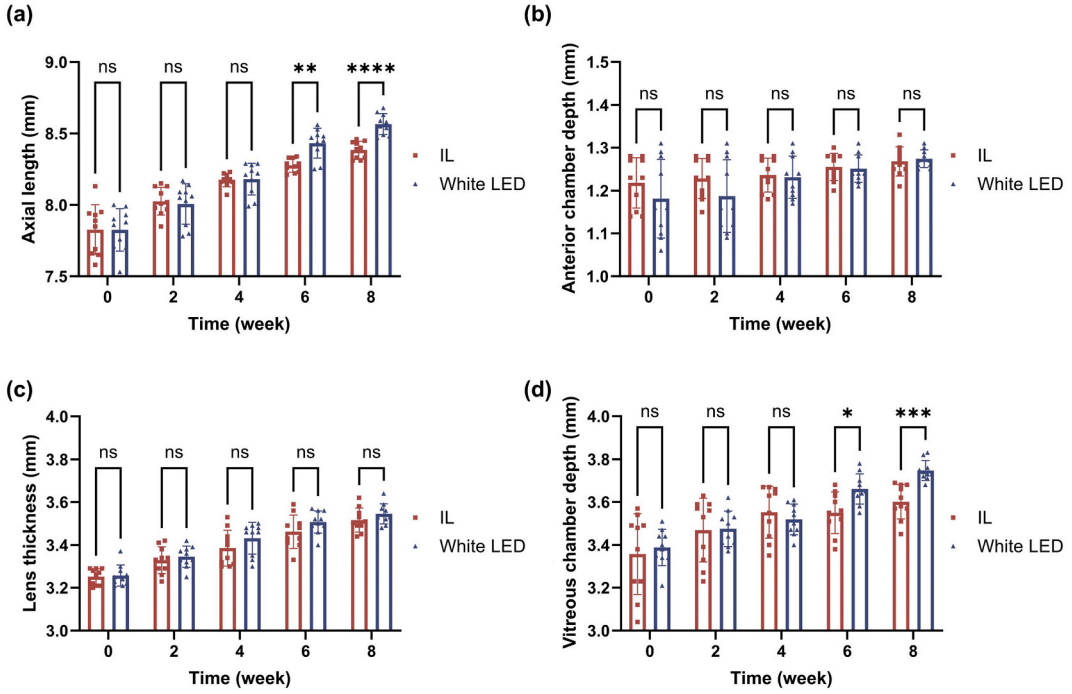

Fig. 3. Ocular biological parameters of guinea pigs during the light exposure period.
(a). Comparison of AL between the two groups at 0, 2, 4, 6 and 8 weeks of light exposure (n = 10 for each group). (b). Comparison of ACD between the two groups at 0, 2, 4, 6 and 8 weeks of light exposure (n = 10 for each group). (c). Comparison of lens thickness between the two groups at 0, 2, 4, 6 and 8 weeks of light exposure (n = 10 for each group). (d). Comparison of VCD between the two groups at 0, 2, 4, 6 and 8 weeks of light exposure (n = 10 for each group). The results are presented as the means ± SD. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$, $^{****}p < 0.0001$, ns $p > 0.05$. AL, axial length; ACD, anterior chamber depth; VCD, vitreous chamber depth; IL, incandescent lamp; white LED, white light-emitting diode with a high CCT of approximately 5000 K.

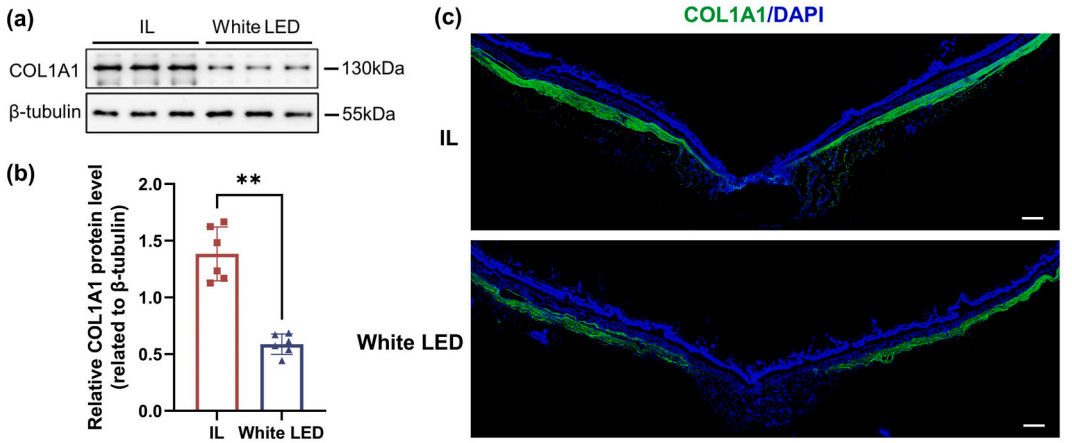

Fig. 4. High CCT white LED light exposure significantly downregulated the expression of COL1A1 in the sclera of guinea pigs.
(a), (b). Western blot analysis of COL1A1 in the sclera of guinea pigs after 8 weeks of light exposure. (c). The expression of COL1A1 in the sclera was qualitatively determined via immunocytochemistry. Scale bar = 200 μm. The data in this study were derived from a minimum of three independent experiments and are presented as the means ± SD. $^{**}p < 0.01$. IL, incandescent lamp; white LED, white light-emitting diode with a high CCT of approximately 5000 K.

COL1A1 in the sclera in the high CCT white LED group was lower than that in the sclera in the IL group (Fig. 4c). When considering our biometric data, we propose that high CCT white LED light exposure may induce myopic shifts in guinea pigs through COL1A1-mediated scleral remodeling.

3.3. High CCT white LED light exposure caused a significant decrease in the ChT in Guinea pigs

We evaluated the ChT at 2000 μm and 3000 μm from the optic disc in two groups of guinea pigs. At both 2000 μm and 3000 μm from the temporal side of the optic disc, the ChT in the group of guinea pigs exposed to white LED light with a high CCT of approximately 5000 K was significantly lower than that in the IL group (Fig. 5a and b).

4. Discussion

In this study, both guinea pigs exposed to ILs and those exposed to white LEDs with a high CCT of approximately 5000 K exhibited elongation of the AL and a decrease in refraction over time. The change in AL in guinea pigs is mainly related to the increase in VCD. This finding is consistent with previous reports, suggesting that guinea pigs undergo a process of emmetropization similar to that of humans [17,18]. Initially hyperopic at birth, their refraction gradually decreases over time, accompanied by an increase in AL. Additionally, our observations demonstrated that guinea pigs exposed to white LEDs with a high CCT of approximately 5000 K exhibited longer AL and lower refractive powers than those exposed to ILs, thus suggesting a relative myopic shift in the high CCT white LED group. These findings align with those of earlier experiments showing that, in juvenile monkeys, the ocular AL is longer under exposure to white LEDs (CCT: 4740 ± 13 K) than under exposure to ILs (CCT: 2709 ± 74 K) [13], and children who used LEDs for homework exhibited greater myopic refractive errors and longer AL than those who used ILs [8].

Previous studies have indicated that the spectral composition of light can influence refractive development [19,20]. Experiments with animals have demonstrated that exposure to red light has a more hyperopic effect and inhibits axial growth in species such as rhesus monkeys [21,22], tree shrews [23,24], and mice [25]. In contrast, exposure to blue light has been associated with a tendency toward myopia in tree shrews [24,26]. In addition to animal experiments, evidence from human clinical trials indicates that repeated low-level red-light (RLRL) therapy can promote choroidal thickening and slow axial elongation, thus effectively controlling the progression of myopia [27–31]. These findings suggest that long-wavelength red light can delay axial growth and inhibit myopic shifts. In this study, ILs contained a greater proportion of long-wavelength red light in their spectrum, whereas the specific white LEDs used in this study contained less long-wavelength red light. This difference may partially explain why the high CCT white LEDs used in this study promote myopic shifts compared to ILs. Importantly, in studies in which chicks were used as subjects, red light exposure induced myopia, whereas blue light exposure induced hyperopia [32–34]. The results from chick studies led researchers to propose the

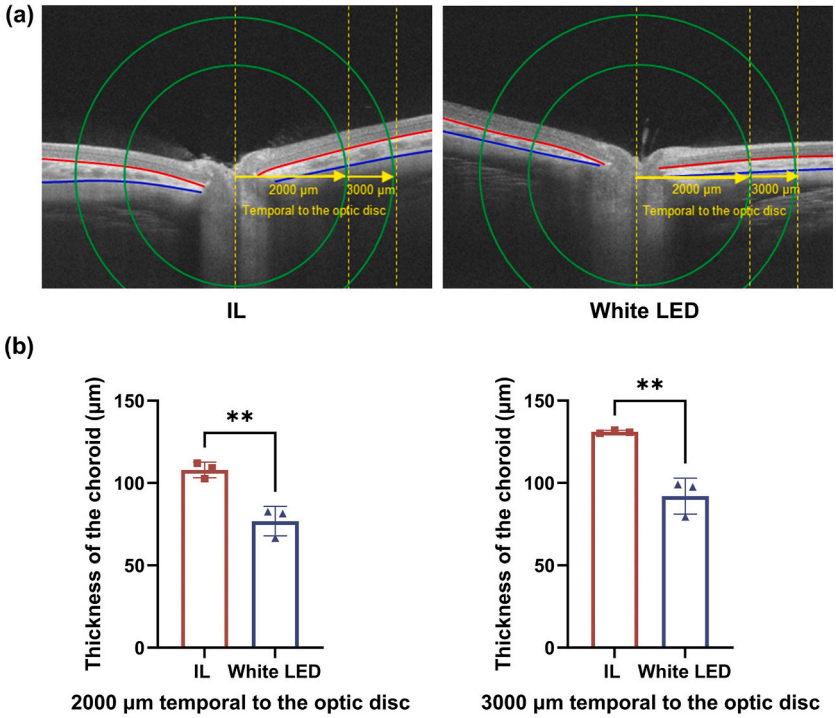

Fig. 5. *In vivo* measurement of the choroid in guinea pigs.
(a). Representative OCT images of the choroid in guinea pigs after 8 weeks of light exposure. Red lines, interior surface of the choroid; blue lines, exterior surface of the choroid; green lines, concentric circles with radii of 2000 μm and 3000 μm. (b). The thickness of the choroid was measured at 2000 μm and 3000 μm temporal to the optic disc. The data in this study were derived from a minimum of three independent experiments and are presented as the means ± SD. $^{**}p < 0.01$. OCT, optical coherence tomography; IL, incandescent lamp; white LED, white light-emitting diode with a high CCT of approximately 5000 K.

longitudinal chromatic aberration (LCA) theory. This theory posits that long-wavelength light, due to its longer wavelength and lower refractive index, focused behind the retina after passing through the eye's optical system, thus causing the focal plane to shift backward and promoting axial elongation [35]. However, the predictions of this theory are contrary to the findings of this study and previous studies on tree shrews, monkeys, and human clinical trials. Gawne [24] and Wildsoet [36] suggested that although the LCA can serve as a visual cue influencing refractive development, it may not be the only visual cue. Smith [21], Yang [25], and Rucker [37] proposed that the varying light intensities used in different illumination experiments could affect the sensitivity of retinal cone cells to different wavelengths, thus activating different color vision pathways and producing varying signals that influence refractive development. Additionally, in previous studies on the effects of monochromatic light on refractive development, the experimental light sources differed in power, peak wavelength, bandwidth, and duration of exposure. Therefore, there is still much to explore regarding the impact of spectral composition on refractive development.

Notably, shortwave blue light, which is a type of high-energy visible light, has been identified as being potentially harmful to the retina, particularly due to its capacity to cause dysfunction in the retinal pigment epithelium (RPE) [38,39]. Although natural daylight contains a high proportion of short-wavelength blue light, it is a composite light that also includes other components such as ultraviolet rays and infrared rays. The interactions between different wavelengths of light can have varying effects on the human eye, warranting further investigation. Moreover, natural light is a continuous spectrum, with different wavelengths of light transitioning smoothly from one to another. In contrast, the spectrum of LED light sources is not continuous and may have significant peaks or gaps at certain wavelengths. Therefore, natural light should be regarded as a composite light. A recent study reported that RPE dysfunction, which is promoted by blue light, may further dysregulate the activity of scleral fibroblasts and disrupt the balance between collagen synthesis and degradation in the sclera [40]. Our previous research showed that exposure to white LED light (CCT: 4884 $\pm$ 6 K) can impair the barrier function and ion transport function of the RPE, which may be a potential cause of choroidal thinning [41]. In the supplementary materials, we compared the effects of ILs and white LEDs with a high CCT of approximately 5000 K on the tight junctions of the guinea pig RPE. The results indicate that high CCT white LED light exposure damaged the tight junctions of the RPE, thus suggesting that high CCT white LED light is a possible threat to refractive development.

The sclera, as the outer and hardest layer of the eye, plays a vital role in maintaining the shape and integrity of the eyeball [16]. The sclera consists of ECM (mainly type I collagen) [16,42]. Previous research has indicated that the remodeling of the scleral ECM, particularly by decelerating synthesis and accelerating degradation of type I collagen, contributes to thinning of the sclera and irreversible elongation of the ocular AL [43,44]. Herein, white LED light with a high CCT of approximately 5000 K induced a marked decrease in the expression of COL1A1 in the sclera of guinea pigs, thus demonstrating that high CCT white LED light exposure is a myogenic visual cue that induces COL1A1-mediated scleral remodeling, thus ultimately resulting in excessive axial elongation of eyeballs and myopic shift.

In addition to scleral remodeling, significant thinning of the choroid was observed in guinea pigs after 8 weeks of exposure to white LED light with a high CCT of approximately 5000 K. The choroid is a highly vascularized tissue that provides oxygen to the sclera. The development of myopia is often accompanied by thinning of the choroid tissue [45] and a reduction in choroidal blood flow perfusion (ChBP) [46]. Studies have shown that changes in ChT may be responsible for changes in ChBP, and reductions in ChBP may result in a comparatively oxygen-deficient setting, thus potentially stimulating axial elongation and myopia development [14,47]. Importantly, the mechanical stress generated by axial elongation and the cascade of retinal signaling triggered by light stimulation can both contribute to the thinning of the choroid [45,46,48]. Although it is uncertain as to which specific factor causes the observed choroidal thinning in guinea pigs exposed to high CCT white LEDs, a thinning choroid indicates reduced blood flow perfusion [14]. This relatively hypoxic environment can lead to adjacent scleral hypoxia, thus further exacerbating scleral remodeling [47,49].

Overall, our research demonstrated that high CCT white LEDs can induce myopic shifts in guinea pigs. However, high CCT white LEDs can generate highly efficient light that meets the present demands for energy conservation and environmental preservation. Completely discarding high CCT white LEDs is impractical. If our results can be extended to human populations in future experiments, strategies such as the following might be appropriate for mitigating the negative impact of high CCT white LED light sources on refractive development and reducing the prevalence of myopia.

- Reducing exposure time to high CCT white LED lighting

Adolescents and children should be encouraged to engage in more outdoor activities. When indoors, it may be advisable to reduce the use of high-illuminance, high CCT white LED lighting. For children and adolescents, particularly those who engage in reading and writing tasks at night or before sleep, reducing the use of high CCT white LED lighting is recommended. Moreover, architects and engineers can incorporate daylighting into building designs by using windows, skylights, and other elements to optimize natural light, thereby minimizing reliance on high CCT white LED lighting [50].

- Optimization of the LED light source

Modifications to white LEDs, such as adjusting their spectral output to reduce the emission of high-energy blue light [51,52], are recommended. Although natural daylight contains a high proportion of short-wavelength blue light, it is a composite light that also includes other components, such as ultraviolet rays and infrared rays. The interactions between different wavelengths of light can have varying effects on the human eye, warranting further investigation. Moreover, natural light is a continuous spectrum, with different wavelengths of light transitioning smoothly from one to another. In contrast, the spectrum of LED light sources is not continuous and may have significant peaks or gaps at certain wavelengths. Therefore, natural light should be regarded as a composite and healthy form

of light, and we advocate for the design of more eye-friendly LED lighting systems that mimic the continuous spectrum of natural daylight or incorporate features such as adjustable CCT. This allows users to choose warmer, less blue-light-intensive illumination during evening hours to minimize circadian disruption and potentially reduce the risk of myopia development [53,54]. These systems could also incorporate options to reduce glare, which can contribute to eye strain and discomfort [55].

This study had certain limitations. First, we only measured the ChT of guinea pigs after 8 weeks of light exposure. In subsequent experiments, we will use OCT to measure changes in ChT throughout the entire light exposure period and increase the sample size of guinea pigs to obtain more robust data. Second, although guinea pigs are currently commonly used experimental animals for studying refractive development, the reliability of their experimental results is not as high as that of studies conducted on monkeys and human clinical trials. Therefore, we plan to conduct future clinical trials to study the effects of using high CCT white LEDs on the progression of myopia in adolescents.

5. Conclusion

Exposure to white LED light with a high CCT of close to 5000 K may trigger COL1A1-mediated scleral remodeling, which could lead to excessive axial elongation of the eyeballs in guinea pigs. Furthermore, such exposure has been linked to choroidal thinning, thus potentially diminishing the choroidal blood supply. This reduction in blood flow can result in scleral hypoxia, thus further exacerbating scleral remodeling in guinea pigs. We propose that high CCT white LEDs disrupt refractive development in guinea pigs and could be recognized as a myogenic visual stimulus, highlighting important directions for future research. If this hypothesis is validated in human populations through future experiments, a range of practical public health measures could be developed, aiming to promote healthier and more sustainable lighting practices.

Ethics approval

All animal experiments were approved by the Ethics Committee of Changchun Wish Testing Technology Service Co., Ltd (Changchun, China, 2024-0102-01).

Funding

This work was supported by the National Key R&D program of China (Grant no. 2019YFA0709101) and the Jilin Province Medical and Health Talent Program (Grant no. 2024WSZX-B12).

Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

CRediT authorship contribution statement

Chenchen Zhang: Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Qing Jiao:** Writing – review & editing, Methodology, Conceptualization. **Jing Zhao:** Writing – review & editing, Methodology. **Su Zhang:** Writing – review & editing, Investigation, Funding acquisition. **Da Li:** Writing – review & editing. **Wenbo Gao:** Writing – review & editing. **Hongjie Zhang:** Writing – review & editing. **Yajuan Zheng:** Writing – review & editing, Writing – original draft, Supervision, Resources, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e38853.

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