Prevention of scattered light-induced asthenopia and fatigue by a polarized filter

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None declared.

Summary

Background: It has been well documented that a long-time irradiation of the eye by a strong light elicits eyestrain and fatigue. To elucidate the mechanism for the induction of light-induced fatigue and asthenopia, changes in the mouse were analyzed after white light-irradiation to the eye.

Methods: C57BL/6j male mice were irradiated with white light in a specially designed room equipped with four mirrors covering all areas of its four walls to elicit diffused reflected light, and changes in their plasma levels of cortisol, INF-γ, interleukin-10 (IL-10) and transforming growth factor-β (TGF-β) were analyzed.

Results: Irradiation of mice with scattered white light significantly decreased the motional activity of animals, suggesting the occurrence of fatigue. Biochemical analysis and enzyme-immunoassay revealed that the irradiation of mice significantly elevated the plasma levels of cortisol, IFN-γ, IL-10 and TGF-β. All these changes were not observed with mice irradiated with the light in a similar room not equipped with mirrors. These changes were successfully inhibited by a polarized glass filter but not by a non-polarized filter with a similar absorbance.

Coclusions: These observations suggest that irradiation of the eye by scattered reflected light stimulated a stress response via hypothalamo-pituitary-adrenal axis to enhance the secretion of cortisol from the adrenal grand and increase the plasma levels of cytokines.

Exposure of the skin and eye to strong sunlight has been known to elicit fatigue and immunosuppression either by activating the proopiomelanocortin (POMC) pathway in dermal keratinocytes and/or by stimulating the POMC-dependent hypothalamo-pituitary-adrenal (HPA) axis, a major pathway for stress response (1–3). Ultraviolet lights (UV-A and B) have been shown to suppress various functions of antigen-presenting Langerhans cells in the skin and inhibit the sequence of immunological reactions at the site of irradiation (4–6). As UV irradiation causes fatigue and immunosuppression, use of a sunscreen and/or a sunglass that eliminates UV has been recommended for the protection of the skin and the prevention of fatigue, particularly in an area exposed to strong sunlight. Although exposure of the eye to a strong visible light has been known also to elicit eyestrain, its mechanism and an effective way to suppress fatigue and asthenopia remain unknown. The present work describes that irradiation of the eye with scattered reflection of white light elevated the plasma levels of cortisol, interferon-γ (IFN-γ), interleukin-10 (IL-10) and transforming growth factor-β (TGF-β) and suppressed the motional activity of mice by a mechanism that could be inhibited specifically by a polarized glass filter.

Materials and methods

Animal experiments

Specific pathogen-free and 8-week-old C57BL/6j male mice (SLC, Hamamatsu, Japan) were subjected to experiments according to the animal care regulations of the Osaka City University Medical School. The mice were placed in a scattered reflection room (Hiramoto model, USO-800, Hiramoto, Osaka, Japan) equipped with a white light at its ceiling (Fig. 1). The upper half of the side walls were covered with mirrors to reflect lights effectively and the lower half of the walls were painted with black color to absorb and eliminate light. The upper and lower compartments of the room could be separated either by an ordinary glass (TM-1) or by a specially polarized TOPCON TM-1 glass filter (TALEX, Osaka, Japan); the two glasses show similar

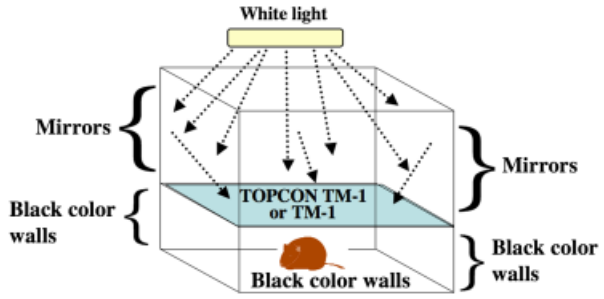

Fig. 1. Special device (Hiramoto model USO-800) to irradiate animals with scattered reflection light.

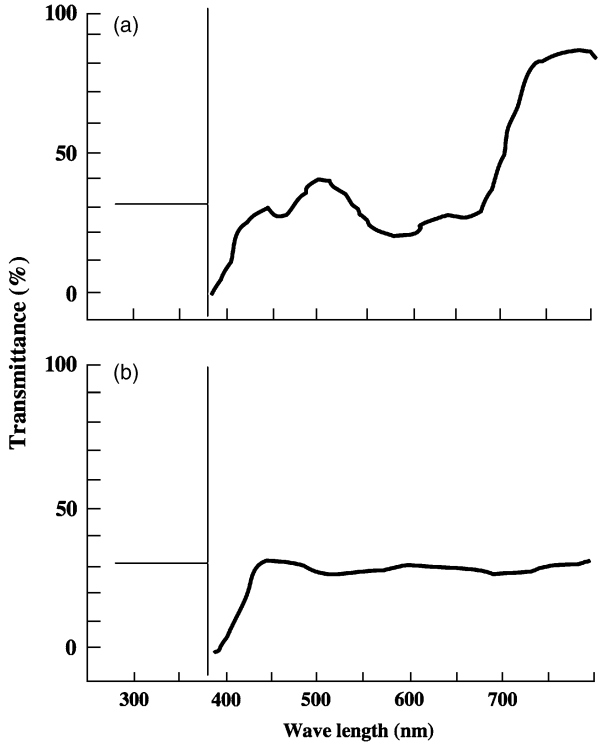

Fig. 2. Transmission spectrum of TM-1 (a) and TOPCON TM-1 (b) filters.

permeability (30%) to white light and intercepts all UV of < 390 nm (Fig. 2). In addition, the two glasses adopt the middle point of the three primary colors. The mice were exposed to white light (400–700 nm; FL20SN-SDL.NU, NU lamps, Toshiba Co., Tokyo, Japan) for 2 h. The irradiation was 15 W/cm^2 and the height of the light source was 30 cm from the mice.

As a result of having performed a similar examination in the mouse in which the scattered reflection light was exposed to the whole body except eyes, the motional activity and the plasma cytokine levels did not change compared with the control group (non-irradiation). Therefore, it suggested that the influence provided in our examination depends on the scattered reflection light that invaded from the eyes.

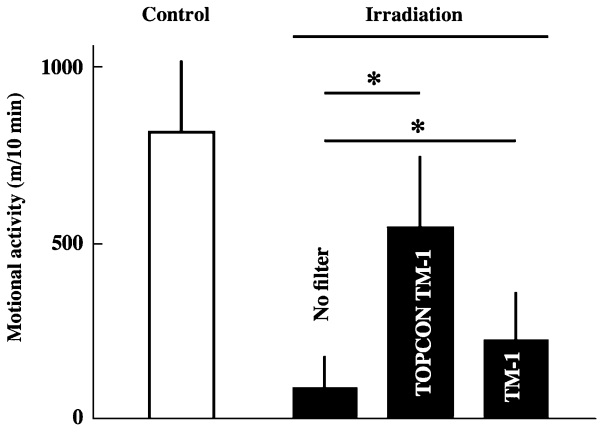

Fig. 3. Effects of irradiation by scattered reflection light and a polarized filter on the behavior and plasma components relating to stress and fatigue of animals. Before and 20 min after irradiation of the eye with white light in a specially designed room, the motional activity of animals was determined as described in the text. Irradiation was carried out in the presence or absence of either TM-1 or TOPCON TM-1 filter. Values are mean ± SD derived from six animals. *$P < 0.05$ compared with no-filter irradiation mice.

Analysis of animal behavior and plasma hormones

Before and after irradiation of the mice, their behavior was monitored for 20 min using a video-camera (DCR-TRV50, Sony, Tokyo, Japan) and analyzed using a software Smart (Panlab, Barcelona, Spain); the total distance of their movement during 10 min was assumed to be their voluntary action. Blood samples were obtained from the heart 6 h after irradiation, centrifuged at $1000 \times g$ for 10 min to obtain plasma samples. Plasma levels of cortisol, IFN-γ, IL-10 and TGF-β were analyzed by enzyme-linked immunoassay (ELISA) using commercially available ELISA kits (cortisol, Oxford Biochemical Research, MI, USA; IL-10 and IFN-γ, Pierce Biotechnology, IL, USA; TGF-β, Promega, WI, USA) according to the manufacturer's instructions.

Statistical analysis

All data were expressed as the mean ± SD derived from six animals and analyzed by either Student's *t*-test or ANOVA using a computer software program. Differences were considered significant when $P < 0.05$.

Results and discussion

Effect of scattered reflection light on animal behavior

To know the effect of irradiation of scattered reflection light on the motional activity of mice, their behaviors were analyzed before and after the irradiation. Irradiation of the eye significantly decreased the motional activity of animals (Fig. 3). The same dose of irradiation in a similar room without mirrors on the walls did not affect the behavior of animals. Thus, irradiation of the eye with scattered reflection light induced

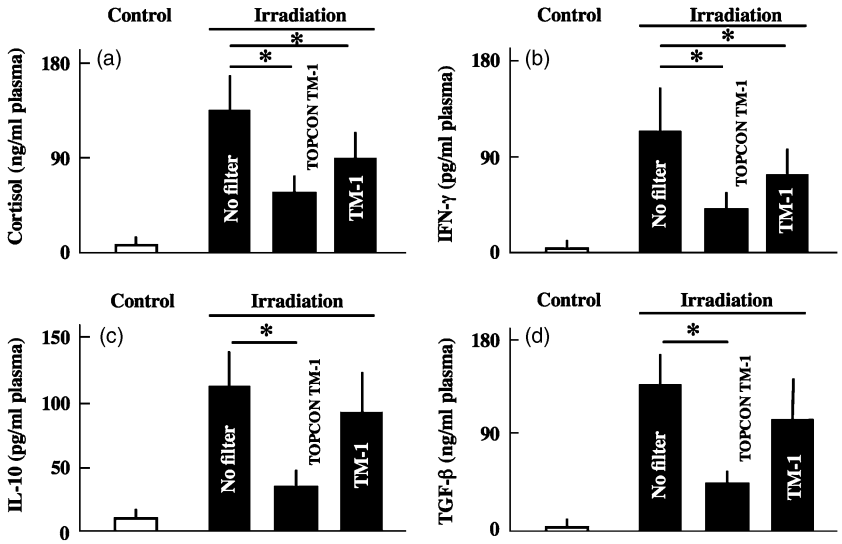

Fig. 4. Effects of irradiation of scattered reflection light and filters on the plasma concentrations of cortisol (a), IFN-γ (b), IL-10 (c) and TGF-β (d). Before and 6 h after irradiation of the eye with scattered reflection light, plasma concentrations of cortisol, IFN-γ, IL-10 and TGF-β were determined. Values are mean ± SD derived from six animals. $^{*}P < 0.05$ compared with experiments without filters.

significant fatigue in animals. The decrease in the motional activity was strongly suppressed by inserting a specially polarized TOPCON TM-1 glass filter between the two compartments in the room (see Fig. 1). In contrast, the inhibitory effect of an ordinary glass filter TM-1 was fairly low.

Effect of the two filters on plasma levels of cortisol

Irradiation of the eye by the scattered reflection light significantly increased the plasma levels of cortisol (Fig. 4a). The increase in plasma cortisol was inhibited strongly by a TOPCON TM-1 filter and only slightly by a TM-1 filter.

Effect of irradiation and the two filters on plasma levels of cytokines

Plasma levels of cytokines were also determined by using ELISA kits before and after irradiation by scattered reflection light. Irradiation of the eye markedly increased the plasma levels of IFN-γ, IL-10 and TGF-β (Fig. 4b and d). The increase in the plasma levels of all cytokines was suppressed strongly by a TOPCON TM-1 filter but not by an ordinary TM-1 filter.

A mechanism that could be inhibited specifically by a polarized glass filter

The present work clearly shows that irradiation of the eye by scattered reflection light increased the plasma levels of cortisol, IFN-γ, IL-10 and TGF-β and suppressed the motional activity of animals. As a result of our observation, the plasma levels of cytokine and hormone after the scattered reflection light irradiation on 0.5, 1, 3, 6, 9, 12 and 24 h showed the highest levels at 6 h (Fig. 5). In addition, the plasma levels of cytokine and cortisol rapidly increased after irradiation. Therefore, it is

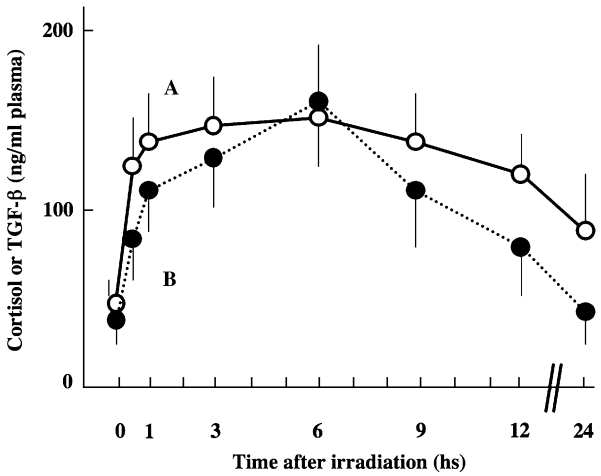

Fig. 5. Effects of irradiation of scattered reflection light on the plasma concentrations of cortisol (A) and TGF-β (B). At the indicated times after scattered reflection light irradiation, plasma samples were collected. Values are mean ± SD derived from six animals.

suggested that changes in cytokine and cortisol and the motional activity are related closely. These observations indicate that irradiation of the eye by scattered reflection light induced a stress response of animals by activating POMC-dependent HPA axis to increase the secretion of cortisol by the adrenal gland. As TGF-β is one of the key molecules that elicit fatigue in animals (7–9), the decrease in the motional activity of the irradiated animals seems to reflect the occurrence of eyestrain and/or related fatigue.

Previous studies in this laboratory (10) reported that irradiation of the eye with UVB activated a nitric oxide-dependent hypothalamo-pituitary POMC pathway, increased the plasma levels of melanocyte-stimulating hormone (MSH) and

systemically activated functions of MSH-responsive cells. This stress response also increased the plasma levels of TGF-β and elicited strong fatigue in the irradiated animals.

The present work also showed that irradiation of the eye by diffused reflection of visible light also evoked stress response as judged from the increase in plasma cortisol. Thus, the signaling pathway that stimulates HPA axis might also be activated by irradiation with the diffused reflection light. As cortisol has been know to increase the secretion of TGF-β that suppresses the immunological activity and elicits fatigue in rodents (11), a similar mechanism seems to underlie the pathogenesis of eyestrain. Thus, the special device to elicit scattered reflection light used in the present work permits studies for the mechanism of eyestrain and related fatigue and to establish efficient methods to suppress them.

As a specially polarized TOPCON TM-1 glass filter effectively inhibited the elevation of plasma levels of cortisol, IFN-γ, IL-10 and TGF-β, this filter might be useful for the prevention of fatigue and/or immunosuppression elicited by exposure to a scattered reflection light during the summer season and/or areas exposed to strong sunlight and reflection light from a screen elicited by the personal computer and television.

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