

The Ability of Periorbitally Applied Antiglare Products to Improve Contrast Sensitivity in Conditions of Sunlight Exposure

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Background: Sun glare decreases athletes' contrast sensitivity and impairs their ability to distinguish objects from background. Many commercial products claim to reduce glare but have not been proven effective in clinical studies.

Objective: To determine whether glare-reducing products such as eye black grease and antiglare stickers reduce glare and improve contrast sensitivity during sunlight exposure.

Design and Methods: We tested 46 subjects for contrast sensitivity using a Pelli-Robson contrast chart. Each subject served as an internal control and then was randomized to either application of eye black grease, antiglare stickers, or petroleum jelly at the infraorbital rim. All testing was performed in conditions of unobstructed sunlight.

Results: Analysis of variance revealed a significant difference between eye black grease (mean \pm SD, Pelli-

Robson value, 1.87 ± 0.09 logMAR units) and antiglare stickers (1.75 ± 0.14 logMAR units) in binocular testing ($P = .02$). No statistical difference was found between the groups in right eyes, left eyes, or in combined data from the right and left eyes. Paired *t* tests demonstrated a significant difference between control (mean \pm SD, 1.77 ± 0.14 logMAR units) and eye black grease (1.87 ± 0.09 logMAR units) in binocular testing ($P = .04$). There was also a significant difference between control (mean \pm SD, 1.65 ± 0.05 logMAR units) and eye black grease (1.67 ± 0.06 logMAR units) in combined data from the right and left eyes ($P = .02$).

Conclusion: Eye black grease reduces glare and improves contrast sensitivity in conditions of sunlight exposure compared with the control and antiglare stickers in binocular testing.

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LIGHT DAMAGES eye structures as a result of the physical phenomenon of energy transmission. Light also has a psychophysical component that affects the quality of vision. Scattering of light can produce glare, which in turn can lead to visual disability. Athletes are particularly challenged by the effects of light radiation and glare. Glare from sunlight or stadium lighting impairs an athlete's contrast sensitivity and impairs the ability to see detail if the light source is from elsewhere in the visual field.¹ Scattered light degrades contrast sensitivity by splashing extra, noninformation-containing light onto the retinal image and reducing the contrast of the image.² Studies have shown that the higher an athlete's contrast sensitivity, the more likely the athlete can discriminate an object as its velocity increases.³

Natural protection from glare is provided by facial anatomy, including the

brow and forehead, the bony orbital cavity, cheekbones, and the upper and lower eyelids. The ocular media has protective light absorbing and reflecting properties. In addition, now there are many commercial products that balance UV protection with glare reduction; many of these items, however, have not been proven effective in clinical studies and may provide a false sense of protection.

The first known glare-reducing devices were made by Eskimos from Alaska, Canada, and Siberia approximately 2000 years ago. Ivory or wooden goggles with horizontal slots effectively allowed peripheral vision while blocking out light reflected by snow and ice. The Chinese used colored transparent pebbles gathered from riverbeds for protection. The earliest recorded use of "sports sunglasses" is attributed to Nero, who viewed gladiators through an emerald. More recently, Tuberville, a 15th-century English ophthalmologist, prescribed silk veils for his post-

operative patients complaining of photophobia, and, in 1886, the mail order company Sears, Roebuck, and Company began to offer sunglasses.^{4,6}

Currently, available glare reducers include visors, sunglasses, and contact lenses. In addition there are various filters for glare reduction, including photochromic lenses, polarizing filters, and tinted filters. Also, antireflective coating can be placed on lenses to reduce glare. Sunglasses, however, can lower background illumination and diminish visual acuity, especially at dimmer levels of light.

Eye black, a form of face paint applied to the cheekbone, is a controversial product that has been used by athletes for decades to reduce sun glare. It is thought to reduce reflected glare into athletes' eyes from the cheekbone by absorbing incident light with its dark pigment. Eye black grease is made from a mixture of beeswax, paraffin, and carbon. Antiglare stickers are made from patented fabric. According to product advertisements, the correct positioning is one-half inch below the eyelid on the cheekbone, and the reported function is similar to that of the natural masks found on wolves, badgers, and even killer whales.^{7,8}

Professional baseball and football players have been using eye black for decades, and other sports are beginning to catch on. More recently, antiglare stickers have become available commercially. The history of eye black is unknown; there is no history of the product anywhere in the annals of baseball, and its obscure arrival has become part of the folklore of the game. The first photographic evidence of its use is found in a 1942 photograph of Washington Redskins' football player Andy Farkas in a game against the Philadelphia Eagles. At the time, evidence suggests that players used to burn cork and then smear the ashes on their cheeks.⁷

The actual effectiveness of eye black has been a constant source of debate, in part because no trials have ever been performed in its decades-long history. Curt Mueller, owner and president of Mueller Sports Medicine (Prairie du Sac, Wis), has been selling it for nearly 40 years but has never seen any studies proving its effectiveness.⁷ Eye black has become a sports accessory, with players donning it during night games and indoor games. Athletes use it for the competitive edge, an aggressive look, and an extra psychological advantage.

The purpose of this study is to determine if glare-reducing products such as eye black grease and antiglare stickers marketed to athletes for reduction of glare actually improve contrast sensitivity during sunlight exposure. To do this, we designed a randomized, controlled trial using natural sunlight as our source of glare. We used the Pelli-Robson contrast sensitivity chart to document changes in contrast sensitivity before and after randomization to 1 of 3 treatment groups: eye black grease, antiglare stickers, and petroleum jelly placebo.

METHODS

We recruited 46 students (92 eyes) for a 1-time measurement of contrast sensitivity using a Pelli-Robson contrast chart. Each student served as an internal control by initially being tested without a product and then tested again after being randomized to application of eye black grease (EyeBlack grease; Easton Sports Inc, Van Nuys, Calif), petroleum jelly, or an antiglare (No Glare; Mueller Sports Medicine, Inc) sticker. Each

product was applied by the same data collector on the participant's skin at the level of the infraorbital rim just prior to testing. A second Pelli-Robson contrast chart with a different order of optotypes was used to avoid familiarity upon retesting.

Participants were students drawn from the schools of Medicine, Nursing, and Epidemiology and Public Health of Yale University, New Haven, Conn. The Yale University School of Medicine institutional review board approved the project and informed consent forms, and informed consent was obtained for all participants. Students wearing eyeglasses were not included in the study because of the effect of the lenses on glare and contrast sensitivity.

Testing was conducted outdoors during a period of direct and unobstructed sunlight, with the nearest trees more than 50 yd away. All subjects faced into the sun during a 3-hour period from noon to 3 PM. A volunteer assigned each subject a number and collected demographic data, including age, sex, ethnicity, a brief ocular history, the level of sports participation, and previous use of eye black or antiglare stickers. Contrast sensitivity testing was performed by placing the subject approximately 1 m away from a Pelli-Robson chart. Subjects were asked to read as far as they could using each eye separately and then with both eyes together. No time limits were set, and subjects were asked to guess letters they felt they could not see. The Pelli-Robson contrast sensitivity value was determined by the last set of triplets with 2 or more letters correctly read and was recorded in logMAR (logarithm of the minimal angle of resolution) units. Data consistency was maintained by having a separate data collector for each Pelli-Robson chart who remained for the duration of the study.

Statistical analysis was performed using ANOVA (analysis of variance) and paired *t* tests. The ANOVA testing was done to compare results between the treatment groups, whereas paired *t* tests tested for a difference between the control and each treatment group. Raw data included data from the right eye, the left eye, both eyes, and the combined data from the right and left eyes. $P < .05$ was considered statistically significant. Data are given as mean \pm SD.

RESULTS

Subjects were aged from 18 to 30 years (mean, 23 years). Women composed 52.2% of the subject population; 62.8% were white, 32.6% were Asian, and 4.7% were Hispanic. Contact lenses were worn in the past by 54.4%, and 8.9% reported some type of ocular history, including corneal abrasions and dry eyes. A history of sports participation was elicited from 91% of subjects, and 8.7% reported having used eye black or antiglare stickers at least once.

From a total of 46 participants, 276 readings were recorded (testing each eye separately and then both eyes together for each of the 2 Pelli-Robson charts). Of the 46 students, each was tested as a control; 16 were assigned to the eye black grease treatment group, 16 to the petroleum jelly treatment group, and 14 to the antiglare sticker group.

An ANOVA was used to compare differences between the treatment groups of eye black grease, petroleum jelly, and antiglare stickers (**Table 1**). There was a significant difference between eye black grease (Pelli-Robson value, 1.87 ± 0.09 logMAR units), petroleum jelly (1.78 ± 0.11 logMAR units), and antiglare stickers (1.75 ± 0.14 logMAR units) in students tested binocularly ($P = .02$). A Bonferroni multiple comparison test was performed to test pairwise difference within this group and demonstrated that the statistically significant differ-

ence was between eye black grease and antiglare stickers. There was no significant difference found between the 3 groups in the right or left eye alone or in the combined data from right and left eyes ($P = .86$, $P = .59$, and $P = .55$, respectively).

A paired t test was used to compare the control with each treatment group (**Table 2**). We demonstrated a statistically significant difference between the control (Pelli-Robson value, 1.77 ± 0.14 logMAR units) and the eye black (1.87 ± 0.09 logMAR units) in binocular testing ($P = .04$). We also found a statistically significant difference between the control (1.65 ± 0.05 logMAR units) and the eye black group (1.67 ± 0.06 logMAR units) by combining the data from the right and left eyes ($P = .02$). There was no statistically significant difference between control and eye black grease in the right or left eye alone ($P = .16$ and $P = .08$, respectively). There was no statistically significant difference between control and petroleum jelly in the right eye, left eye, binocularly, or with combined data from the right and left eyes ($P = .50$, $P = .58$, $P = .27$, and $P = .37$, respectively). There was no statistically significant difference between control and antiglare stickers in the right eye, left eye, binocularly, or with combined data from the right and left eyes ($P = .19$, $P = .58$, $P = .58$, and $P = .16$, respectively).

COMMENT

In the between-groups analysis, we found a statistical difference between eye black grease and antiglare stickers in binocular testing. Although there were statistically significant differences in the contrast sensitivity, the actual differences on the Pelli-Robson chart testing varied. The actual mean Pelli-Robson contrast sensitivity value was 1.87 ± 0.09 logMAR units for eye black and 1.75 ± 0.14 logMAR units for antiglare stickers. This is about equivalent to 1 level of contrast sensitivity difference on the Pelli-Robson chart, which decreases in contrast in equal logarithmic steps of 0.15. Similarly, in analysis between control and treatment, we found a statistically significant difference in the eye black group in both binocular testing and the combined data from the right and left eye. For binocular testing, this translated into a control mean Pelli-Robson value of 1.77 ± 0.14 logMAR units and an eye black mean value of 1.87 ± 0.09 logMAR units. Again, this is about equivalent to 1 level of contrast sensitivity difference. However, the combined data from the right and left eyes had a control mean value of 1.65 ± 0.05 logMAR units and an eye black mean value of 1.67 ± 0.06 logMAR units, a much smaller difference in contrast sensitivity. The reason behind the values was apparent on the testing day. We observed a significant decrease in recognition at contrast levels of 1.65 logMAR units, particularly in monocular testing. We urged participants to continue guessing until we had recorded a value but certainly observed that subjects consistently had difficulty at a similar point on the chart. As a result, monocular testing revealed mean values clustered around 1.65 with very small SDs regardless of treatment group. Binocular testing fared better with most participants reading beyond the 1.65 level.

What is the significance of 1 level of improved contrast sensitivity? In a study of the test-retest reliability

Table 1. Pelli-Robson Values for Analysis of Variance

Data Source	Mean \pm SD, LogMAR Units			P Value
	Eye Black Grease (n = 16)	Petroleum Jelly (n = 16)	Antiglare Sticker (n = 14)	
Right eye	1.67 ± 0.05	1.66 ± 0.07	1.65 ± 0.14	.86
Left eye	1.67 ± 0.08	1.64 ± 0.09	1.64 ± 0.11	.59
Binocular	1.87 ± 0.09	1.78 ± 0.11	1.75 ± 0.14	.02
Combined right and left eye*	1.67 ± 0.06	1.64 ± 0.08	1.64 ± 0.13	.55

Abbreviation: logMAR, logarithm of the minimum angle of resolution.

*Sample sizes for combined data are eye black grease, $n = 32$; petroleum jelly, $n = 32$; antiglare sticker, $n = 28$.

of the Pelli-Robson chart, Elliot et al⁹ measured contrast sensitivity in the dominant eye of normal younger and older populations. Most of the younger population (mean age, 22.5 years) were found to have a Pelli-Robson mean value of 1.80 log units or better. Retesting 2 weeks later showed contrast sensitivity scores to be repeatable to within 0.15 log units (or the equivalent of 1 step in contrast sensitivity). Thus, they define a significant change as a difference of 0.30 log units, or 2 steps on the Pelli-Robson chart. According to this study, 1 level of improved contrast sensitivity in the same subject—that is, in those who tested in the control group and the eye black treatment group—is within the error margin of the test reliability and not necessarily a result of glare-reducing products. The study by Elliot et al differed from our own in 3 major respects: all testing was done monocularly and without a glare source and tests occurred 2 weeks apart. Possibly as a result of these differences, we did not see the same pattern in our data. Each participant in our study underwent a test-retest situation by testing as a control and in a treatment group, with a unique Pelli-Robson chart at each reading. There was a significantly smaller difference between the first and second readings in those who were randomized to the petroleum jelly and antiglare sticker groups, both of which had minimal antiglare effects. As a result, our data seem to show higher test-retest reliability, and the differences found between the control and eye black groups in the binocular testing becomes more significant in our study. However, both the study by Elliot et al and our study agree that testing for smaller gradations in contrast sensitivity would improve the results.

The Pelli-Robson contrast sensitivity chart was chosen because of its high test reliability and ease of function. There are 2 main approaches to testing contrast sensitivity. The first is a subjective method that uses pattern testing with printed or electronically generated charts. The second is the objective or electrophysiologic method, which measures pattern visual evoked potentials. However, this method is too time consuming for clinical purposes. Test-retest reliability is the highest with familiar optotypes such as the letters in the Pelli-Robson chart or Landolt C rings.¹⁰ Letters have the advantage of having innate orientation and minimizing the odds of guessing correctly. Letter charts are also relatively error tolerant because the subject is typically allowed to make 1

Table 2. Control Pelli-Robson Values for Paired *t* Tests

Data Source	Mean ± SD, LogMAR Units					
	Eye Black Grease Group (n = 16)	<i>P</i> Value†	Petroleum Jelly Group (n = 16)	<i>P</i> Value†	Antiglare Sticker Group (n = 14)	<i>P</i> Value†
Right eye	1.65 ± 0.00	.16	1.64 ± 0.10	.50	1.62 ± 0.09	.19
Left eye	1.64 ± 0.07	.08	1.63 ± 0.05	.58	1.63 ± 0.08	.58
Binocular	1.77 ± 0.14	.04	1.75 ± 0.12	.27	1.74 ± 0.13	.58
Combined right and left eye*	1.65 ± 0.05	.02	1.64 ± 0.08	.37	1.62 ± 0.08	.16

Abbreviation: logMAR, logarithm of the minimum angle of resolution.

*Sample sizes for combined data are eye black grease group, n = 32; petroleum jelly group, n = 32; antiglare sticker group, n = 28.

†*P* values are for control vs treatment. Treatment values are presented in Table 1.

mistake per line without affecting the results.¹⁰ As a result, there is a growing interest in using more familiar optotypes to measure contrast sensitivity. First-time subjects tend to be conservative in their answers; requiring them to guess improves measuring accuracy.¹¹ We standardized our testing protocol by having a single tester test all subjects for each chart. Each tester asked the subject to continue guessing until the test recorded 2 incorrect responses within a triplet.

Prior to testing, preliminary sample size calculations, based on an α of .5 and power of 80, indicated that we would need a sample size of 40 subjects in each treatment group to have significant results. Our sample size was much smaller, with a total of 46 participants. As a result, it was unclear whether our results would achieve the normal distribution necessary for parametric analysis. We analyzed the data with both parametric and nonparametric tests: parametric analysis was done with ANOVA and paired *t* tests; equivalent nonparametric tests were the Kruskal-Wallis 1-way ANOVA and the Wilcoxon matched-pairs signed-rank test. Our results were nearly identical in either case, indicating that our small sample size nevertheless reflected a normal distribution. Thus, we present the data here with parametric analysis.

It is impossible to avoid a certain level of bias associated with the application of the various products. Eye black is prevalent enough in our culture that participants could guess the intended effects. There was no way to mask the participants to their treatment groups. We also suspect a learning bias based on repeated readings of the chart. Subjects were asked to read both charts with each eye separately and then binocularly. In all, each subject gave 6 readings, 3 for each chart. We attempted to control for this possibility by providing charts with different letters. However, we found that binocular scores were consistently higher than monocular scores; whether this is the effect of longer exposure to the chart, which resulted in clarification of hard-to-see letters, or the superiority of binocular contrast sensitivity is difficult to assess.

Our study had a slight majority of women, which introduces the question as to whether it would be possible that eye black benefits male athletes. Brabyn and McGuinness¹² have shown there are sex differences in contrast sensitivity, with women being more sensitive to low spatial frequencies and men more sensitive to high spatial frequencies but no significant difference being seen in mi-

drange spatial frequencies. Our study itself was too small to give any reliable information on sex breakdown.

There is questionable validity in combining right and left eye data to double the sample size. It has been shown that left and right eye readings are not independent readings, which stems from the fact that they arise from the same single brain. In terms of contrast sensitivity testing, binocular contrast sensitivity has been shown to have higher sensitivity than monocular sensitivity across all spatial frequencies compared. The difference was shown to be approximately 42% higher than the predicted sum of the monocular responses.^{13,14} Gilchrist and McIver¹⁴ also showed that decreased luminance in one eye from any ocular condition decreases the binocular contrast sensitivity such that it is worse than the better eye.

Other limitations of the study include the inability to measure sunlight luminance and the position of the sun. Thus, it would be difficult to relate our results with future results achieved under similar conditions. Variability in ambient testing conditions could effect our results by exposing participants to varying levels of sun brightness. Perceptual brightness changes with the angle of the sun, with cloud conditions, and with time of year. We performed our testing within a 3-hour period on a single day to minimize variability in sun luminance; however, gradual changes could not be assessed.

In summary, we found eye black grease to be statistically superior to control and to antiglare stickers in 3 situations. There was a statistically significant difference between eye black grease and antiglare stickers in binocular testing. There was also a statistically significant difference between the control and eye black grease in binocular testing and in the combined data from the right and left eyes.

Based on this study, eye black grease appears to be more than psychological war paint. These results suggest that eye black grease does in fact have antiglare properties, whereas antiglare stickers and petroleum jelly do not. Perhaps the mixture of wax and carbon in eye black grease is superior for reducing reflected light than is the fabric material in antiglare stickers.

The cheekbone itself reduces glare by reflecting light away from the eye socket. Placing a pigment on top of the cheekbone could theoretically absorb more light. Future studies may help elucidate the best location and material for maximal improvement of contrast sensitivity. The greatest challenge facing contrast sensitivity mea-

surement and glare testing is the lack of standardization in procedures, both in stimulus parameters and testing style. Future studies may benefit from a controlled glare source, larger sample sizes, and more sensitive contrast sensitivity testing techniques.

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Drs DeBroff and Pahk had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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REFERENCES

1. Rubin GS. Clinical glare testing. In: Schachat AP, ed. *Current Practice in Ophthalmology*. St Louis, Mo: Mosby-YearBook Inc; 1992:153-163.
2. Miller D, Sanghvi S. Contrast sensitivity and glare testing in corneal disease. In:

- Nadler MP, Miller D, Nadler DJ, eds. *Glare and Contrast Sensitivity for Clinicians*. New York, NY: Springer-Verlag; 1990:45-52.
3. Kluka DA, Love PL, Kuhlman J, Hammach G, Wesson M. The effect of a visual skills training program on selected collegiate volleyball athletes. *Int J Sports Vision*. 1996;3:23-34.
4. Charman WN, MacEwen CJ. Light and lighting. In: Loran DFC, MacEwen CJ, eds. *Sports Vision*. Oxford, England: Butterworth-Heinemann Ltd; 1995:88-112.
5. Miller D. The effect of sunglasses on the visual mechanism. *Surv Ophthalmol*. 1974;19:38-44.
6. Miller D, Nadler MP. Light scattering: its relationship to glare and contrast in patients and normal subjects. In: Nadler MP, Miller D, Nadler DJ, eds. *Glare and Contrast Sensitivity for Clinicians*. New York, NY: Springer-Verlag; 1990:24-32.
7. Bryce R. Out of left field. *Austin Chronicle*. 2001. Available at: <http://www.austinchronicle.com/issues/vol18/issue44/xtra.leftfield.html>. Accessed February 5, 2002.
8. Glareblox stick-on strips product Web site. Available at: <http://www.glareblox.com>. Accessed February 5, 2002.
9. Elliot DB, Sanderson K, Conkey A. The reliability of the Pelli-Robson contrast sensitivity chart. *Ophthalmic Physiol Opt*. 1990;10:21-24.
10. Lempert P. Standards for contrast acuity/sensitivity and glare testing. In: Nadler MP, Miller D, Nadler DJ, eds. *Glare and Contrast Sensitivity for Clinicians*. New York, NY: Springer-Verlag; 1990:5-23.
11. Wolfe JM. An introduction to contrast sensitivity testing. In: Nadler MP, Miller D, Nadler DJ, eds. *Glare and Contrast Sensitivity for Clinicians*. New York, NY: Springer-Verlag; 1990:113-119.
12. Brabyn LB, McGuinness D. Gender differences in response to spatial frequency and stimulus orientation. *Percept Psychophys*. 1979;26:319-324.
13. Leege GE. Binocular contrast summation, I: detection and discrimination. *Vision Res*. 1984;24:373-383.
14. Gilchrist J, McIver C. Fechner's paradox in binocular contrast sensitivity. *Vision Res*. 1985;25:609-613.

Ophthalmological Numismatics

Ramon Castroviejo (1904-1987), born in Spain, became one of the most famous ophthalmologists of his era as a pioneer in corneal transplantation surgery. He invented many surgical instruments, some of which are still in use today. The Castroviejo Cornea Society struck a medal in his honor in 1975. It is a 51-mm bronze medal created by the firm Calico (Madrid, Spain).

The obverse, **Figure 1**, depicts the bust of Castroviejo facing right. It is inscribed "Ramon Castroviejo." The reverse, **Figure 2**, depicts an eye with a square keratoplasty incision. It is inscribed "The Castroviejo Society, MDMLXXV." (Note date is engraved in error; it should have read MCMLXXV.)

Courtesy of: Jay M. Galst, MD, 30 E 60th St, New York, NY 10022.



Figure 1.



Figure 2.