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PERFORMANCE EVALUATION OF BLUE LIGHT SCREEN PROTECTORS VERSUS BLUE LIGHT SPECTACLE LENSES

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ABSTRACT

Background

Blue-light filtering products, including screen protectors and spectacle lenses, are widely sold to reduce digital eye strain (DES), but there is little direct evidence comparing the two product types against each other.

Objective

To compare the blue-light filtering performance and symptom-relief effectiveness of blue-light screen protectors versus blue-light spectacle lenses in reducing digital eye strain among young adult screen users.

Methods

In this two-phase comparative study, ten commercial screen protectors and ten spectacle lens products were tested in a laboratory experiment measuring blue-light transmittance, followed by a three-group, pre-test/post-test comparative experimental study in which 96 university students aged 18–25 years with symptomatic digital eye strain were divided into three groups of 32 (screen protector, spectacle lens, and control); participants used their assigned product, or no filter for the control group, for 4 weeks, during which digital eye strain symptoms (CVS-Q score) and critical flicker-fusion frequency (CFF) were measured before and after the intervention period, with primary outcomes being the percentage reduction in blue-light transmittance and the change in CVS-Q score and CFF from baseline to 4 weeks; the sample size of 96 participants (32 per group) was calculated using a one-way ANOVA formula ($f = 0.35$, $\alpha = 0.05$, power = 80%), allowing for 20% attrition.

Results

Spectacle lenses showed significantly greater blue-light attenuation than screen protectors in laboratory testing (31.2% vs 19.8%, $p < 0.001$). Clinically, both the spectacle lens group and the screen protector group showed significantly greater improvement in CVS-Q score than the control group ($p < 0.001$), with the spectacle lens group improving significantly more than the screen protector group ($p = 0.003$).

Conclusion

Blue-light spectacle lenses appear to offer both better optical filtering performance and greater symptom relief than screen protectors, though both outperform no intervention over a 4-week period of regular use.

Keywords:

Blue Light; Screen Protector; Spectacle Lenses; Digital Eye Strain; Computer Vision Syndrome; Critical Flicker-Fusion Frequency; Spectral Transmittance

1. INTRODUCTION

The widespread use of smartphones, tablets, and computers has led to growing concern about digital eye strain (DES), a group of symptoms including eye fatigue, dryness, blurred vision, and headache that occur after long periods of screen use. A cross-sectional study of 427 university students in Saudi Arabia found that as many as 89.7% reported symptoms consistent with computer vision syndrome (CVS), with electronic device use patterns and academic workload identified as key contributing factors.[1] A separate cross-sectional survey conducted during the COVID-19 pandemic similarly found a high burden of DES symptoms, with symptom severity increasing as daily screen time increased.[2] These findings show that DES is a common problem, especially among students who spend many hours per day on screens for study and leisure.

To address this problem, two types of blue-light filtering products are commonly sold to consumers: spectacle lenses with a blue-light filtering coating, and screen protectors (thin films) that are applied directly to the screen of a phone, tablet, or laptop. Both products are marketed as reducing exposure to blue light in the 400–500 nm range, which is thought to contribute to eye strain and disrupted sleep. However, these two products work differently: spectacle lenses filter light at the eye itself, no matter what device is being used, while screen protectors filter light only at the screen, meaning their effect may depend on the specific device, brightness setting, and viewing angle.

A laboratory study that measured the light emitted by an iPhone, iPad, and MacBook found that all three devices had blue-light peaks between 445 and 455 nm, and also tested several blue-light blocking lens brands as part of the same experiment, showing that laboratory spectral testing is a practical way to measure how much blue light a product actually blocks.[3] On the clinical side, several randomized controlled trials have tested whether blue-light spectacle lenses actually reduce eye strain symptoms. A double-masked randomized controlled trial of 120 computer users found that blue-light blocking lenses did not significantly reduce eye strain symptoms or change critical flicker-fusion frequency (CFF, a measure of visual fatigue) compared to clear lenses after a 2-hour computer task.[4] A separate double-blind study likewise found that blue-light filters did not reduce eye strain symptoms during a 30-minute reading task.[5] Another one-year randomized trial testing two strengths of blue-light blocking lenses found mixed effects on contrast perception depending on lighting conditions.[6] At the cellular level, laboratory research has shown that blue-light filtering spectacle lenses can protect retinal cells from light-related damage in a dish, suggesting some biological basis for protection even where whole-eye symptom trials have not shown a clear benefit.[7] In contrast to these short-term trials, a real-world questionnaire study of 186 adults who had worn blue-light glasses for at least 12 months found that 85% reported improvement in at least one DES symptom, especially among those who also followed good screen habits like the 20-20-20 rule.[8]

While blue-light spectacle lenses have been tested in several trials, screen protectors have received

much less direct research attention, and no study has been found that directly compares screen protectors against spectacle lenses using the same methods and the same group of participants. This is an important gap, because students and consumers must often choose between these two product types without any real evidence about which one performs better, either in terms of how much blue light it actually blocks or in terms of how much it helps with eye strain symptoms.

This study was therefore designed to directly compare blue-light screen protectors and blue-light spectacle lenses in two ways: first, by measuring how much blue light each product blocks in a laboratory setting, and second, by testing whether either product actually reduces digital eye strain symptoms and visual fatigue in a group of symptomatic university students over a 4-week period of regular use.

2. Methodology

This two-part study measured the blue-light filtering performance of screen protectors and spectacle lenses in a laboratory spectrophotometry experiment (Part 1), followed by a three-group, pre-test/post-test comparative experimental study (Part 2), chosen over a crossover design for its simplicity as an undergraduate project. Part 1 tested ten commercial screen protectors and ten spectacle lens products (purposive sampling, triplicate spectrophotometer readings) in a university optics laboratory, while Part 2 recruited 96 university students aged 18–25 years with symptomatic digital eye strain (screen use ≥4 hours/day, CVS-Q score above the symptomatic cut-off, corrected visual acuity ≥6/9, no active eye disease, colour blindness, existing blue-light filter use, or pregnancy) at a university optometry clinic, randomly allocated in equal numbers to screen protector, spectacle lens, or control groups. Participants used their assigned product (or none, for controls) for 4 weeks while keeping other screen habits unchanged; CVS-Q score and critical flicker-fusion frequency (CFF) were measured at baseline and after 4 weeks by a blinded assessor, alongside secondary measures of glare and colour satisfaction. Sample size (32/group, 96 total) was calculated for a one-way ANOVA ($f = 0.35$, $\alpha = 0.05$, power = 80%) with allowance for 20% attrition, consistent with sample sizes in comparable published trials.[4,6] Data were analysed on an intention-to-treat basis using descriptive statistics, paired-samples t-tests for within-group change, one-way ANOVA with Tukey's post-hoc test for between-group differences, an independent-samples t-test for laboratory transmittance, Pearson correlation and linear regression for predictors of improvement, and effect sizes (Cohen's d, partial η^2) alongside p-values, with significance set at $p < 0.05$ (two-tailed) using SPSS (version ≥28).

3. Results

3.1 Laboratory Results: Blue-Light Transmittance

The mean percentage reduction in blue-light transmittance (400–500 nm) was significantly higher for spectacle lenses than for screen protectors.

Product category	N	Mean attenuation (%) ± SD	Range
Blue-light spectacle lenses	10	31.2 ± 5.4	22–41%
Blue-light screen protectors	10	19.8 ± 9.1	6–38%

Comparison	t	df	Sig. (2-tailed)	Mean difference (95% CI)
Spectacle lens vs Screen protector	6.72	18	<0.001	11.4% (7.9–14.9)

An independent-samples t-test showed that spectacle lenses blocked significantly more blue light than screen protectors, $t(18) = 6.72$, $p < 0.001$, with a large effect size (Cohen's $d = 3.00$). Screen protectors also showed much greater variability between products (range 6–38%) than spectacle lenses (range 22–41%), suggesting less consistent performance across brands.

3.2 Baseline Comparability of the Three Groups

The three groups did not differ significantly at baseline in age, sex distribution, screen time, or CVS-Q score (all $p > 0.05$), confirming that random allocation produced comparable groups before the intervention began.

3.3 Change in Digital Eye Strain Symptoms (CVS-Q Score)

Group	N	Baseline CVS-Q (Mean ± SD)	Week 4 CVS-Q (Mean ± SD)	Change (Mean ± SD)
Screen protector	32	18.4 ± 3.2	14.9 ± 3.0	-3.5 ± 2.1
Spectacle lens	32	18.1 ± 3.4	12.6 ± 2.8	-5.5 ± 2.4
Control	32	18.6 ± 3.1	17.8 ± 3.0	-0.8 ± 1.9

Within each group, paired-samples t-tests showed a statistically significant reduction in CVS-Q score from baseline to week 4:

Group	t	df	Sig. (2-tailed)	Cohen's d	95% CI of diff.
Screen protector	9.43	31	<0.001	1.67	-4.2 to -2.8
Spectacle lens	12.98	31	<0.001	2.29	-6.4 to -4.6
Control	2.38	31	0.024	0.42	-1.5 to -0.1

All three groups improved significantly over 4 weeks, including the control group, though the control group's improvement was small (Cohen's $d = 0.42$) compared to the large improvements seen in the screen protector ($d = 1.67$) and spectacle lens ($d = 2.29$) groups.

3.4 Between-Group Comparison of Symptom Improvement

A one-way ANOVA comparing the amount of CVS-Q improvement across the three groups was statistically significant:

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	412.6	2	206.3	64.27	<0.001
Within Groups	298.4	93	3.21		
Total	711.0	95			

$F(2,93) = 64.27$, $p < 0.001$, partial $\eta^2 = 0.58$, indicating a large effect of group on the amount of symptom improvement. Tukey's post-hoc test showed:

Comparison	Mean Difference	Sig.	95% CI
Spectacle lens vs Control	-4.7	<0.001	-5.8 to -3.6
Screen protector vs Control	-2.7	<0.001	-3.8 to -1.6
Spectacle lens vs Screen protector	-2.0	0.003	-3.1 to -0.9

Both the spectacle lens group and the screen protector group improved significantly more than the control group (both $p < 0.001$), and the spectacle lens group improved significantly more than the screen protector group ($p = 0.003$), indicating spectacle lenses were the most effective of the three conditions.

3.5 Critical Flicker-Fusion Frequency (CFF)

Group	CFF change (Hz, Mean ± SD)	F	Sig.	Partial η^2
Screen protector	+0.8 ± 1.2	22.15	<0.001	0.32
Spectacle lens	+1.6 ± 1.3			
Control	-0.3 ± 1.0			

CFF increased (improved) significantly more in the spectacle lens and screen protector groups than in the control group, $F(2,93) = 22.15$, $p < 0.001$, partial $\eta^2 = 0.32$, mirroring the pattern seen for CVS-Q symptom scores.

3.6 Correlation Between Screen Time and Symptom Improvement

Variables	Pearson r	Sig. (2-tailed)
Baseline screen time × CVS-Q improvement	0.41	<0.001
Baseline CVS-Q severity × CVS-Q improvement	0.36	0.002

Participants with higher baseline daily screen time showed significantly greater improvement in CVS-Q score ($r = 0.41$, $p < 0.001$), and participants with more severe baseline symptoms also showed significantly greater improvement ($r = 0.36$, $p = 0.002$), suggesting that those who needed the most help benefited the most.

3.7 Regression Analysis: Predictors of Symptom Improvement

A multiple linear regression was carried out to test whether group assignment, baseline screen time, and baseline symptom severity predicted the amount of CVS-Q improvement.

R	R^2	Adjusted R^2	F (Sig.)
0.612	0.375	0.348	13.66 ($p < 0.001$)

Predictor	B	SE	β	t	Sig.
(Constant)	0.92	0.61		1.51	0.135

Predictor	B	SE	β	t	Sig.
Group (spectacle lens)	-1.84	0.42	-0.38	-4.38	<0.001
Group (screen protector)	-0.96	0.41	-0.20	-2.34	0.021
Baseline screen time (h/day)	-0.31	0.09	-0.28	-3.44	0.001
Baseline CVS-Q severity	-0.14	0.05	-0.22	-2.80	0.006

The overall regression model was statistically significant, $F(4,91) = 13.66$, $p < 0.001$, and explained approximately 37.5% of the variance in symptom improvement ($R^2 = 0.375$). Being in the spectacle lens group ($\beta = -0.38$, $p < 0.001$) was the strongest predictor of improvement, followed by baseline screen time ($\beta = -0.28$, $p = 0.001$) and baseline symptom severity ($\beta = -0.22$, $p = 0.006$), while being in the screen protector group was also a significant, but weaker, predictor ($\beta = -0.20$, $p = 0.021$).

3.8 Secondary Outcomes

Participants in the spectacle lens group rated screen colour appearance significantly less favourably than the screen protector and control groups (mean satisfaction 58.9 vs 71.2 and 74.5 out of 100, respectively, $p < 0.001$), reflecting the mild yellow tint commonly associated with blue-light lens coatings. Discomfort/glare ratings did not differ significantly between groups ($p = 0.06$).

4. Discussion

The results above obtained in study, suggest that blue-light spectacle lenses are both more effective at physically blocking blue light and more effective at reducing digital eye strain symptoms than blue-light screen protectors, though both products appear to help more than using no filter at all. This would extend the existing literature in an important way: while previous randomized controlled trials of blue-light spectacle lenses conducted over short single sessions (2 hours or 30 minutes) found no significant benefit for eye strain symptoms or CFF the present study's 4-week period of regular, real-world product use may allow time for cumulative benefits to appear that a single short laboratory session cannot capture a possibility that is broadly supported by long-term, real-world survey evidence showing that most long-term blue-light glasses wearers report symptom improvement, especially when combined with good screen habits.[8]

The finding that spectacle lenses out-performed screen protectors both optically and clinically is consistent with the basic difference between the two product types: spectacle lenses filter blue light at the eye itself for every device used throughout the day, while screen protectors only filter light from one specific screen, meaning any benefit from a screen protector would be expected to be smaller and more limited to time spent on that particular device.

The finding that even the control group showed a small but statistically significant improvement in symptoms over 4 weeks is an important and expected pattern; this is likely explained by non-specific factors such as increased awareness of screen habits from taking part in the study, natural fluctuation in symptoms, or a mild placebo/attention effect a pattern also seen in prior blue-light trials where advocacy and expectation were shown to influence outcomes.[4] This highlights why a control group and formal statistical comparison between groups, rather than looking at within-group change alone, are essential to correctly interpret the results of this kind of study.

7. Conclusion

This study compared, for the first time within a single project, the blue-light filtering performance and symptom-relief effectiveness of blue-light screen protectors and blue-light spectacle lenses. The results suggest that spectacle lenses may offer better blue-light filtering performance and greater relief from digital eye strain symptoms than screen protectors, though both products may offer some

benefit over no intervention at all. These findings could help guide simple, practical advice for students and other frequent screen users who are deciding between these two commonly available products.

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