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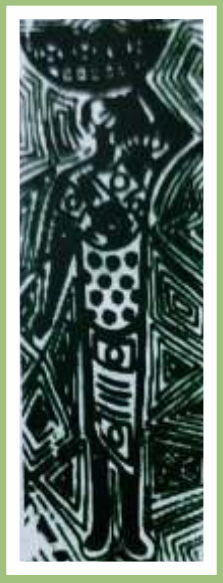

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Black Sock Tops: Effective Low-Cost Eye Shields for Phototherapy

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Abstract

Background: In low-resource settings, there is often a challenge with sourcing effective eye protection for newborns undergoing intensive phototherapy as treatment for neonatal jaundice.

Objective: To evaluate the efficacy of sock tops as an eye-shielding alternative for use in intensive phototherapy.

Methods: This study evaluated the efficacy of black, gray, and white thick, elastic, sock tops in various materials as eye-shielding alternatives for use in intensive phototherapy.

Results: Wool, cotton, and polyester black sock tops provided acceptable levels of shielding at all levels of irradiance when layered. However, white and gray sock tops in the same material did not provide adequate shielding, even when layered.

Conclusion: Black sock tops may provide an accessible, low-cost alternative to commercial eye patches in low-resource settings, especially when confirmatory testing with an irradiance meter is available.

Keywords: Global Health, Hyperbilirubinaemia, Low-resource settings, Neonatal jaundice, phototherapy.

Introduction

Neonatal jaundice remains a significant cause of hospitalization, lifelong sequelae, and mortality, especially affecting newborns in low and middle-income countries (LMICs) where access to standard-of-care intensive phototherapy is limited. [1] Effective methods of providing intensive phototherapy in low-resource settings have been developed, including fluorescent and LED lights and filtered sunlight. [2,3] However, commercially available phototherapy eye shields, such as *NeoShades®*, are often still largely inaccessible in LMICs due to both cost and availability, despite being a standard component of treatment in high-income countries.

While retinal damage has never been demonstrated in infants undergoing phototherapy, eye protection is still standard prophylaxis due to the potential damage from prolonged UV light exposure. [4] Additionally, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) has specified that exposure of the human retina to visible light (300 - 700 nm) should be limited to an effective irradiance of less than 1 W/m2 for longer exposures to protect the retina against acute photochemically-induced retinopathy. [5] Phototherapy delivery falls within the blue light range of the visible spectrum, typically between

450-470 nm, and thus has the potential to cause retinal damage. [2] To mitigate this risk for retinal damage in the absence of commercially available eye shield products, clinicians in LMICs have been led to improvise eye shields using gauze, tape, and other locally available materials.[6] Most of these alternative materials have not been tested for effectiveness. A literature review yielded one study which reports testing a newly invented eye shield designed for comfort.[7] This study reported achieving a level of protection akin to that "provided by the usual improvised means" but did not include concrete data. Data in the scientific literature regarding the properties of commercial eye patches is also largely unavailable, likely due to the lack of reported clinically relevant eye changes in neonates undergoing phototherapy. Despite limited research in this area, it is prudent to use material that has been shown to screen out blue light effectively. This led to a previous article by Slusher and Abdulkadir in which black cotton was evaluated and shown to be effective as an eye-shielding alternative.[8] White cotton and gauze were also tested and found to be less effective.[8]

Although black cotton has been shown to be effective as an eye shield, it can still be challenging to secure the cloth on a neonate without using adhesives, such as medical tape. Thus, there is a need to evaluate the efficacy of other commonly used, low-cost eye-shielding materials that can be secured straightforwardly. One possible low-cost alternative is "sock tops," the thick, elastic band which can be cut from the top of the sock. Sock tops have the advantages of not requiring anything else to secure them (no tape, ties, etc.), a record of safe use on human skin, and wide availability in LMICs at low cost. Accordingly, this study aimed to evaluate the efficacy of sock tops as an eye-shielding alternative for use in intensive phototherapy, using the ICNIRP visible light exposure limits as a marker of effectiveness.

Methods

Black, grey, and white socks were obtained in three different materials (98% cotton, 96% polyester, and 90% wool). The sock tops were removed from the body of the sock and used to shield the sensor of an irradiance meter from intensive phototherapy. The irradiance meter was mounted on a foam platform, and the sock top was stretched to a diameter of 35 cm to simulate the size of a newborn head (Figure 1).

Measurements were taken for each sock top in single and double layers under phototherapy at 30, 60, and 90 µW/cm2/nm irradiance levels. Measurements were compared to the suggested upper limit for light exposure (1 W/m2), established by the ICNIRP for exposures longer than 10000 seconds, equivalent to a little less than three hours. [5] For these longer exposures, natural eye movements spread the light over a larger area of the retina, allowing for higher safe limits than for very short exposures, such as those less than 100 seconds. [5] To calculate the safe exposure limit, a blue light hazard function of 1.00 was chosen to represent the "worst case scenario" of a phototherapy unit emitting blue light at 440 nm, the most harmful part of the spectrum.

In reality, most phototherapy units put out light peaking between 450 and 470 nm, which would allow for safe exposures in the corresponding range of 1.06 – 2.22 W/m2. [5] Because phototherapy units usually put out minimal light at < 440 nm wavelength, the aphakic hazard function was assumed to be equivalent to the blue light hazard function. [5]

Results

Table I includes the raw data collected when shielded with nine sock tops of varying colours, materials, and number of layers at all phototherapy levels. Figure 2 displays the level of irradiance measured at a phototherapy level of 90 µW/cm^2/nm, which is well above the

Minimum Table I includes the raw data collected when shielded with nine sock tops of varying colours, materials, and number of layers at all phototherapy levels. Figure 2 displays the level of irradiance measured at a phototherapy level of 90 µW/cm^2/nm, which is well above the minimum suggested level for intensive phototherapy of 30 µW/cm^2/nm. Single-layer black wool sock tops at the maximum phototherapy level recorded 0.84 µW/cm^2/nm. Double layers of black wool and polyester sock tops at the maximum phototherapy level recorded zero µW/cm^2/nm. Double layers of black cotton sock tops at the maximum phototherapy level recorded 0.24 µW/cm^2/nm.

Table 1: Irradiance measurement at different levels of phototherapy after shielding with sock tops of various materials and colours

Colour	Material	Single Layer			Double Layer		
		W/m^2 at 30 µW/cm^2/nm	W/m^2 at 60 µW/cm^2/nm	W/m^2 at 90 µW/cm^2/nm	W/m^2 at 30 µW/cm^2/nm	W/m^2 at 60 µW/cm^2/nm	W/m^2 at 90 µW/cm^2/nm
Black	Wool	0.24	0.36	0.84	0	0	0
Black	Polyester	0.6	0.96	1.8	0	0	0
Black	Cotton	0.84	1.44	4.44	0.12	0.12	0.24
Gray	Wool	17.4	33.12	45.12	8.76	16.68	25.68
Gray	Polyester	13.44	29.52	40.92	5.88	11.76	15.48
Gray	Cotton	8.04	11.64	19.8	3.12	4.56	8.64
White	Wool	18.72	36	53.28	11.28	21.84	35.52
White	Polyester	18.84	38.04	55.8	12.12	22.56	33.72
White	Cotton	16.68	34.2	50.04	13.08	25.8	36.48

Figure 1: An irradiance meter is mounted on a foam platform to simulate a newborn head. The Dräger Phototherapy 4000 lamp was used at varied distances to achieve different irradiance levels (left). The newborn head model is shown without phototherapy (top right) and with phototherapy and sock top shield (bottom right).

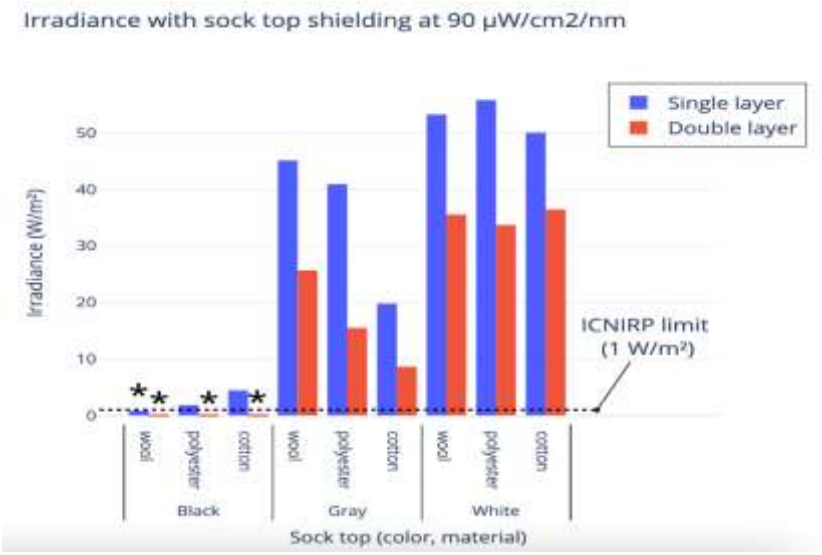

Figure 2: Irradiance with sock top shielding at 90 µW/cm^2/nm. Asterisks (*) represent irradiance measurements under the ICNIRP limit (dashed line).

Discussion

When tested in single layers, none of the sock tops provided absolute shielding. Black sock tops allowed for the least irradiance, followed by grey and white sock tops. However, when doubled, black wool and black polyester sock tops did provide absolute shielding. Double-layered black cotton sock tops also provided shielding within the ICNIRP limit, albeit not absolute.

This data suggests that some black sock tops screen out enough blue light for use as an alternative to commercial eye patches in neonatal phototherapy, especially when layered. On the other hand, the lighter colours allowed for exposure exceeding the ICNIRP limit at all levels of irradiance tested regardless of material, even when doubled. Thus, it may be best to use sock tops made from darker colours to achieve optimal shielding for infants undergoing intensive phototherapy. As always, neonates with eye patches should be monitored to ensure that the eye patches do not slip down over the nose and occlude the nostrils, regardless of the material from which the eye patches are made.

As previously stated, there is an unfortunate paucity of studies on this issue, most likely due to the lack of clinically relevant eye damage seen in neonates who have had phototherapy. However, these findings align with the previous article by Slusher and Abdulkadir, in which black cotton was evaluated and shown to be more effective as an eye-shielding alternative than white cotton and gauze.

Study limitations include using different brands and thickness of socks in this study. This limitation reflects the reality of using sock tops in low-resource settings, as brands and styles of socks vary greatly between regions and countries. The available sock tops in specific locations vary significantly from those we tested; therefore, we suggest testing sock tops made from socks available in a given locale using an irradiance meter to ensure they screen out most blue light. A theoretical limitation is that gaps in the weave of some sock tops could potentially allow light to penetrate, however, this can be prevented by using sock tops that are large enough to fit around the infant's head without excessive stretching.

Conclusion

Sock tops, especially when testing with an irradiance meter is possible, may provide an accessible, low-cost alternative to commercial eye patches in low-resource settings.

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Clinical Trial Registration (if any): N/A
Abbreviations: Low and middle-income countries (LMICs); UV (ultraviolet); International Commission on Non-Ionizing Radiation Protection (ICNIRP)
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