

An Added Benefit of Masks During the COVID-19 Pandemic: Ultraviolet Protection

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Abstract

The widespread use of masks during the COVID-19 pandemic presents a new avenue for protecting the lower half of the face from the harms of sun exposure. The increased social acceptability of masks, which may persist post-pandemic, has the potential to impact prevention of photosensitive disorders, photoaging, and skin cancer. The authors sought to review clinically relevant information on the ultraviolet (UV) shielding properties of masks. This synthesis of current research will help physicians counsel patients on optimal mask choices, from both dermatological and public health viewpoints. The variables impacting the UV protection of masks were reviewed, including fabric type, construction, porosity, and color. Other factors related to wear and use such as moisture, stretch, laundering, and sanitization are discussed in the context of the pandemic. Black, tightly woven, triple-layered polyester cloth masks were determined to be optimal for UV protection. The most protective choice against both SARS-CoV-2 and UV radiation is a medical mask worn underneath the aforementioned cloth mask. In order to preserve the filtration capacity of the fabric, masks should be changed once they have become moist. Washing cotton masks before first use in laundry detergents containing brightening agents increases their UV protection. Overall, cloth masks for the public that are safest against SARS-CoV-2 are generally also the most protective against UV damage. People should be encouraged to procure a high-quality mask to simultaneously help reduce the spread of SARS-CoV-2 and shield against sun exposure. Further investigation is needed on the UV-protective properties of medical masks.

Keywords

mask, ultraviolet, UPF, protection, SARS-CoV-2

Face masks are one of the main public health measures to prevent the spread of SARS-CoV-2 and have quickly become ubiquitous during the pandemic. This presents a new potential avenue for protecting the lower half of the face from the harms of sun exposure. The nose followed by the cheek/perioral region are common sites of both melanoma and keratinocyte carcinoma.¹⁻³ Secondary to their role in protection from SARS-CoV-2, masks may have the potential to help prevent skin cancer by shielding against further ultraviolet (UV) damage. In addition, masks could complement a photoprotection strategy for patients with pigmentary or photosensitive disorders. Mask-wearing as a public health measure has been widely adopted throughout the globe. Consequently, the effects of UV protection from masks on the lower face could be substantial. In order to maximize the potential benefits of masks, it is important to elucidate which factors make a mask more or less protective. This information can be used to counsel the general public regarding optimal mask choices, for both respiratory and dermatological protection.

Methods

A narrative literature review was conducted using articles from textile and dermatology journals published from 1994 through February 2021. PubMed and Google Scholar were searched with a combination of keywords and their MeSH terms: protection and (UV or ultraviolet or sun or UPF) and (mask or fabric or clothing or cotton or polypropylene or polyester). Publications relevant to the UV protection of masks were included. The reference lists of selected articles

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were screened for additional pertinent articles. Subsequent references were cross-referenced and additional references were obtained.

Measuring Fabric UV Protection

The level of UV transmission through a fabric can be standardized and represented by the ultraviolet protection factor (UPF). Similar to the sun protection factor (SPF) ratings of sunscreen, UPF has been adopted as the garment counterpart to SPF by most regulatory agencies. Though SPF and UPF are calculated differently, their values are thought to be comparable. UV radiation can be measured by its irradiance, which indicates the rate at which UV energy is delivered to a surface area (watts per square centimeter).⁴ Accordingly, UPF is the ratio of the effective UV irradiance for unprotected skin to skin protected by fabric. For instance, a garment rated UPF 15 allows 1/15th of the UV irradiance to pass through. Since the value is rounded down to increments of 5, garments labeled UPF 15 theoretically block 93.3% to 94.9% of effective UV radiation. Conventionally, the UPF rating of a fabric is determined with a spectrophotometer in the 290-400 nm range, as both in vitro and in vivo methods of UPF testing were shown to be comparable.² In laboratory setting, a spectrophotometer measures a collimated beam of UV radiation directed at the test fabric at a right angle. The fabric's transmission of both the UVA and UVB spectrum are measured; however, the UPF is weighed by the wavelengths that contribute to sunburn, which are overwhelmingly UVB. In practice, the clothing is worn outdoors where it is exposed to scattered UV radiation emitted from the sun. Therefore, the resulting UPF rating is considered a safe underestimate; the actual protection conferred by a garment in practice may be higher than the denoted UPF.^{5,6} Most studies use the normative Australian/New Zealand Standard (AS/NZS 4399) or the ASTM International to assign UPF values. In these classification systems, a rating of 15 to 24 is good, 25 to 39 is very good, and 40 to 50+ is excellent protection.⁷

From basic structure to fabric finish, there are a multitude of factors that interact to produce the UPF of garments. The spectrum of UPF in clothing in the literature is immense, ranging from 2.2 for wet white plain cotton to 3000+ in blue double-layered polyester.^{8,9} The UPF of a fabric cannot be readily estimated without using a spectrophotometer and attempts to model UPFs of fabrics is an ongoing area of research.⁹⁻¹¹ In a study of commercial summer fabrics, only 48% were UPF 30 or above.¹² To date, there has only been one small study published on the UPF of masks. The authors report UPF values over 100 in their 4 homemade cloth masks, but no details regarding fabric parameters are provided.¹² Homemade and retail cloth masks are unregulated and as a result have varying levels of protection from both pathogens and UV radiation. Since the UPF of masks is hardly ever provided, the following review can be used to help sun-aware

Table 1. Summary of Recommendations Regarding Cloth Masks for UV Protection.

Factor	Recommendations
Fiber Type	Polyester, Nylon, Wool or Exterior: Polyester Middle: Nylon, Polypropylene or Wool felt Inner: Cotton
Fabric Structure	Low porosity. Microfiber. Tightly woven. High density.
Layering	Triple-layered mask strongly recommended.
Fit and Stretch	Close seal on the face without stretching the fabric.
Color	Dark blue or black. Strong color depth. Avoid white fabrics.
Wetness	Moisture decreases UPF in cotton. Decreases breathability in all masks.
Fabric Treatments	TiO ₂ and ZnO finishes increase UPF.
Laundering	UPF increases for cotton after first wash. Do not bleach masks. Tinosorb FD laundry additive increases UPF of natural fibers
Recommendation for UV Protection:	
Best Mask: 3-layer mask labeled UPF 50+.	
Next Best Mask: Black, tightly woven, 3-layer mask composed of polyester or a fiber blend including polyester.	
Recommendations for Combined UV and Viral Protection:	
Add the following to a UV-protective mask:	
Best: Surgical mask worn underneath the cloth mask.	
Next Best: Nonwoven polypropylene filter as middle layer inside the cloth mask.	

The factors that affect the ultraviolet protection conferred by cloth face masks are presented.

Abbreviations: TiO₂, titanium dioxide; UPF, ultraviolet protection factor; ZnO, zinc oxide.

consumers make more informed choices when selecting masks. In order of importance, we will outline the parameters that influence a mask's ability to filter both pathogens such as SARS-CoV-2 and ultraviolet radiation.

Mask Material

Table 1 summarizes the factors that affect UV protection from masks, highlighting the best choices to optimize photoprotection. Generally, synthetic fibers have higher UPF values than natural fibers such as cotton.¹³ Plain undyed woven cotton samples were measured to have UPF values between

4 and 7.¹⁰ Newer studies have reported an average UPF of 11.4 for gray plain knit cotton¹⁴ and UPF ranges of 8 to 18 for single knit cotton.¹⁵ UPF 15 to 22 was determined to be the upper limit of UV protection for woven cotton fabrics designed with enough air permeability for summer wear.¹⁶ For comparison, the UPF of raw polyester has been reported in the range of 16 to 49, depending if the sample has been dyed or not.^{6,8,9} These values are from samples that were not subject to the common delustering treatment discussed further below, which further increases the UPF value of most polyester fibers.

Overall, masks composed of polyester, nylon, and wool are likely superior to those made of cotton, rayon, silk, and linen for UV protection.^{12,17–19} For filtration of pathogens, synthetic fibers are preferable and are used exclusively in medical masks. Specifically, polyester's large conjugated system in the polymer chains provide a high UVB protection and its acidic groups can efficiently trap and inactivate viruses.²⁰ Although polyester is considered to be a high-performing material for high UPF values,²¹ its UVA protection is lower than cotton and linen⁶ and the latter make more comfortable, light fabrics. Guidelines recommend a cotton inner layer that can absorb moisture, a middle filtration layer of nylon, polypropylene or wool felt, and a hydrophobic outer layer composed of polyester.^{22,23} Combining a variety of fabrics in this way can balance their unique properties and deliver respiratory protection as well as sun protection.

Fabric Structure and Porosity

Aside from the ultraviolet radiation being scattered at the surface or passing through the fibers, UV rays passing directly through the gaps between yarns can also significantly impact the UPF.^{18,24} Fabric tightness is the degree to which yarns are closely woven or knitted. The spaces between yarns are referred to as pores, and their void volume is represented by the fabric's porosity, defined as the percentage of fabric volume comprised of air space.^{24,25} Tightly woven fabric constructs have lower porosity and as a result yield greater sun protection.^{16,26} Unsurprisingly, double knit constructions, where two layers of fabric are knit simultaneously on one pair of needles, are better than single knit.²⁶ Additionally, the density, measured by weight per square area (g/cm^2), of a fabric has a higher correlation to its UPF than the thickness.¹⁵ Fabric made from microfibers is superior to normal fibers for the same density and construction.¹⁸ This is due to a greater number of fine fibers per yarn, producing less space between fibers. A small pore size is also optimal for virus filtration.^{23,27,28} For consumers, a quick way to approximate the tightness of a fabric is to hold up the mask to a light source and observe the amount of light coming through the pores.²⁹

Woven fabrics are made by interlacing 2 sets of yarns and have a checkered look. Knit fabrics are made of interlocking

loops of a single yarn to produce a braided pattern, using knitting needles or a machine.²⁴ Nonwoven fabrics are made by webs of fibers stuck together using glue, heat, or felting. Plain woven textiles typically have lower porosity than knits, resulting in better UV filtration.³⁰ The World Health Organization (WHO) recommends using nonwoven fabric for the middle filtration layer of masks, such as polypropylene.²² In regard to cloth masks, knitted constructs are argued to be better suited than woven structures due to their thicker cross-section and high air permeability.²⁷ The latter is an important consideration in the context of masks, since breathability decreases with increasing fabric tightness.¹⁶ Overall, tighter fabric constructions with low porosity offer better filtration of both viral particles and UV radiation, but have more resistance to air flow, decreasing breathability. Masks must strike a fine balance between these two variables. The mask's porosity should be optimized yet maintain enough permeability so that the wearer can breathe comfortably, and unfiltered air does not escape through the gaps between the mask and face.

Mask Stretch and Fit

Highly elastic fabric should be avoided, as stretching increases the garment's porosity and reduces its ability to filter particles as well as UV radiation.¹⁰ Indeed, the WHO guidance for masks recommends against stretchy materials.²² In 1 study of polyester and blended materials, 2D fabric extension 10% x 10% reduced UPF between 40% and 65%.³¹ Knit constructions allow more extensibility than woven fabrics.²⁴ However, knits are commonly found in nonfiltering mask layers as they tend to be breathable and comfortable. Ideally, masks should seal closely on the face without stretching the material.²⁰ Offering masks in multiple sizes could prevent mask overstretching thereby optimizing particle and UV radiation filtration efficacy.

Color and Dyes

Many dyes absorb both visible and UV radiation.¹⁸ The effect of color on UPF is variable and depends on the proportion of UV transmitting directly through yarns versus in between yarns. Except for white fabrics, which are notoriously permeable to UV,¹⁹ the structure of a fabric influences the UPF more than the color does.³¹ Hence, a tightly woven yellow fabric offers greater UV protection than a loosely woven black fabric.²⁶ The color of a fabric is only its reflection in the visible spectrum and unfortunately doesn't correlate well with its absorbance in the UV spectrum.²⁶ The chemical composition of dye molecules holds greater weight on the resulting UPF than the hue or darkness of the fabric.^{9,26}

Many studies demonstrate the large impact that colorants and chemical finishing compounds can have on UPF.^{11,32} Zinc oxide (ZnO) and titanium dioxide (TiO_2), the active ingredients in

mineral sunscreens, are primarily used for other purposes in the textiles industry. TiO_2 is the most common delustering agent, used to reduce shine from nylon and polyester, whereas ZnO is added for its antibacterial properties.¹⁹ Interestingly, they have the added benefit of significantly increasing the UV protection of these garments.³³ In 1 study, the addition of TiO_2 to polyester increased the UPF from 12 to 50+.³⁴

Optical brighteners found in many household laundry detergents absorb UV in the 340-370 nm range and re-emit energy as blue light.³⁵ Also known as fluorescent whitening agents, they have been shown to improve the UV protection of natural materials such as cotton and blended fabrics.³⁶ Tinosorb FD is another sunscreen ingredient that is available as an invisible laundry additive that can boost natural fibers to UPF 30, lasting up to 20 washes.³⁷ Laundry additives are an excellent option for consumers who wish to upgrade their existing cloth masks to a known UV protection level.

When a mask is available in multiple colors, black and blue make a better choice.^{26,31} The darkness of a shade also correlates, albeit weakly, with UPF.²⁶ Nevertheless, the bottom line is that the depth/strength of a color is the most important factor as it indicates a higher concentration of UV-absorbing dye molecules.²⁶

Masks and Moisture

Unfortunately, neither stretching nor wetness is taken into account in UPF measurements⁷; a garment's UPF in a wet state cannot be predicted, even when its UPF in a dry state is known. Analogous to a white t-shirt becoming transparent when wet, water in yarn interstices reduces light scattering at the air/fabric interface.³¹ Cotton's already low UV protection decreases in a linear fashion with water saturation.^{8,10} Dark fabrics are less affected by moisture because their dominant protection mechanism is through UV absorption rather than scattering.³⁸ This is another reason to choose dark colors, particularly for cotton masks.

Linen, viscose, polyester, and fabrics treated with UV absorbers such as TiO_2 were found to increase in UPF when wet.^{8,38} However, patients should follow public health guidelines and change their mask once it becomes damp, as wet masks are less effective against pathogens and less breathable.^{22,29} Polyester and polypropylene fibers are moisture-wicking and don't swell with water,³¹ making them good choices in situations when a mask must be worn for an extended period of time or during exercise.

Number of Mask Layers

Layering is an effective means of increasing protection against both UV radiation and pathogens. Combining two layers of uncolored fabric increased the UPF from 26 to 100, and the UPF values were even more impressive when one or both fabrics were dyed.⁹ In another study, double-layering different types of white polyester clothing decreased UV

transmission by 63% to 74% for the tightly woven fabrics, but only 31% for the eyelet, a loosely woven lace fabric with embroidered holes. Triple layering reduced transmittance by 84% to 87% in all fabric construction regardless of the porosity.³¹ This suggests that the lower UV protection of a more porous and breathable fabric can be compensated by wearing at least 3 layers. If different shades of a fabric are layered in a mask, better UV protection will be obtained when the dyed fabric is on the inner layer closest to the face.⁹ This provides flexibility for masks to sport any color or pattern on the outside, so long as there are dark layers beneath. Appropriately, triple-layered masks are the standard set by regulatory agencies for both surgical masks and cloth masks.^{22,23,29} The Center for Disease Control (CDC) recommends wearing a cloth mask over top of a surgical mask to push the edges of the surgical mask against the face and create a better seal.³⁹ Government agencies also recommend improving pathogen filtration by inserting a disposable nonwoven polypropylene filter inside a cloth mask's pocket.^{23,29} Overall, additional filtration layers prevent both UV damage and the spread of pathogens such as SARV-CoV-2.

Mask Laundering

Most cloth fabrics undergo shrinkage when washed, thereby reducing the gaps between the yarns and increasing UV protection. Indeed, in one experiment, new cotton t-shirts were put through 36 wash and dry cycles, a number which the textile industry considers to be the reasonable/typical life expectancy of garments. After the first wash, the UPF of all the t-shirts increased significantly from a mean of 20 to 38, and remained stable thereafter.⁴⁰ As such, new cloth masks should be washed before being first worn and they can safely be laundered between each use without impacting the ultraviolet protection. Masks should not be bleached as this has a deleterious effect on the UV protection of both cotton and polyester/cotton blends.¹⁹ The WHO and the CDC recommend washing masks daily with soap in at least 60 °C water. Similarly, the CDC recommends laundering using the warmest appropriate water setting for the cloth used to make the mask, so as to avoid damaging the fabric at the expense of sterilization.

Medical Masks

Surgical masks and respirators (ie, N95s) are tested for bacterial filtration efficiency, particle filtration, breathing resistance, and splash resistance. To our knowledge, the UPF of these products is largely unknown, likely because medical masks were not designed with the intention of being used outdoors or outside of healthcare settings. An analysis of medical masks in this context is difficult because the UV protection of these materials depends on the type and quantity of fiber additives, such as antioxidants or UV stabilizers.

Surgical masks are most commonly made of 3–4 layers of nonwoven polypropylene, which as a raw fiber is highly susceptible to oxidative degradation⁴¹ from both UV radiation and visible light.^{33,42,43} In recent studies, pristine polypropylene transmitted 40% to 70% of UV rays and only had a UPF of 5.^{32,33} The only data available thus far is a small *in vitro* study of 4 surgical masks, which found the UPF values to be between 6 and 11.⁴⁴ Since the polypropylene filter material can potentially deteriorate from extended UV exposure, some manufacturers recommend storage away from direct sunlight.⁴⁵

Respirators such as N95s are made of several nonwoven synthetic layers and offer better virus filtration due to electrostatic charges and a close seal to the face.⁴⁶ The ultrafine filtration layer is typically composed of meltblown polypropylene, that is then placed between multiple other polyester layers. Respirators are likely to be better than surgical masks for sun protection due to their polyester content. Nevertheless, given the shortage of respirators during the pandemic, they are not recommended to the public for UV protection. When outdoors, sun-conscious individuals should elect to wear a UV-protective cloth mask with a polypropylene filter or a surgical mask underneath.

Multiple at-home decontamination methods can reduce a mask's filtration efficiency for particles and UV radiation. In the case of extreme shortages where surgical masks must be reused, from a combined UV and pathogen protection standpoint, we recommend letting masks remain untouched in a paper bag for 5 days.⁴⁷ This storage minimizes cross-contamination while allowing the SARS-CoV-2 survival time to pass.⁴⁸

Discussion

Many variables with complex interactions come into play to produce a mask's UPF. Commercial and homemade cloth masks are unregulated, resulting in varying degrees of respiratory and skin protection. Consumers cannot readily predict to what level a mask will shield against UV radiation. Additional studies are needed on the UPF of masks, especially medical masks now that they are being worn outdoors by the public at large. Despite these limitations, optimizing the factors described above to make informed choices toward greater sun protection has the potential to result in adequate UV protection. For instance, the combination of a black colored, double-layered, polyester fabric reduced UV transmission to such an extent that its UPF could not be recorded by the spectrophotometer in 1 study.³¹ The variables most accessible for the public to select the most appropriate mask are the color, number of layers, and fabric type. Based on the literature, the best mask choice for sun-aware consumers is a black, densely woven, 3-layer mask composed of polyester or a combination of polyester and natural fibers. The ultimate method of ensuring excellent UV protection is to select a mask with a UPF 50 label and a seal from a reputable organization. There is a limited but increasing number of these masks available on the market. To increase viral protection to

even greater levels, consumers should wear a surgical mask under their cloth mask,³⁹ or insert a disposable nonwoven polypropylene filter as the middle layer inside a cloth mask.^{23,29} Therefore, the ultimate mask choice for both UV and viral protection is to wear a surgical mask underneath a UPF 50 cloth mask.

Our review highlighting the UV protection properties of masks raises the question: can adequate sun protection be achieved with a mask alone, or is sunscreen use under the mask also required?^{44,49} Since the UV filtration level conferred by individual masks is largely unknown, it may be wise to wear sunscreen under face masks. Special attention should be placed on protecting the ears from sun exposure, as tight masks tend to make the ears stick out more laterally. Given that polypropylene and polyester have low UVA protection, and healthcare workers can be exposed to UVA while indoors through windows, a broad-spectrum sunscreen should be worn under medical masks if tolerated. In the rare occasion that an N95 will be sterilized via UVC radiation for its reuse, the FDA warns that facial sunscreen left on the mask may interfere with this decontamination method.⁵⁰ Some individuals suffer from acne mechanica due to the increased occlusion and friction of frequent mask-wearing.⁴⁹ For those with "maskne" that is worsened by sunscreen, recommending a sunscreen that is noncomedogenic and nonirritating as well as avoiding makeup and cosmetics under the mask are reasonable first steps. If this is unsuccessful, they can opt to omit wearing sunscreen on the lower face and opt for masks with the aforementioned high-protection features outside of their workplace.

In order to reduce environmental waste and avoid a global shortage of medical masks, the general public is encouraged to opt for cloth masks in low-risk situations, such as outdoors and when physical distance is maintained. The WHO agrees that fabric masks should be worn for community use so that medical-grade masks and N95 respirators can be reserved for healthcare settings.²² Though not all masks provide a high enough UPF to meet photoprotection guidelines, given that the majority of the public does not regularly apply sunscreen on the face,^{51,52} the addition of a face covering during the pandemic likely has an overall positive effect in reducing exposure to UV radiation. This may manifest with reduction in severity of skin conditions exacerbated by sunlight (eg, melasma) during the pandemic.

Conclusion

Cloth masks for the public that are safest against pathogens such as SARS-CoV-2 are generally also the most protective against UV damage. People should be encouraged to procure a high-quality mask to simultaneously help reduce the spread of SARS-CoV-2 and shield against sun exposure. Based on the literature, the best mask choice for UV protection is a black, tightly woven, 3-layer mask composed of polyester or

a combination of polyester and natural fibers. For optimal protection against both pathogens and UV radiation, a surgical mask should be worn underneath a UV-protective cloth mask. Emerging evidence suggests that surgical masks confer UPF protection between 6 and 11, however further investigation is needed on the UV-protective properties of medical masks.

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