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Comparison of Ultraviolet Protection Factor of Pure Cotton and Cotton Coated with Titanium Dioxide Nanoparticles using the Electrospinning Method with Two Ultraviolet-C Generators

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ABSTRACT

Introduction: Protection against harmful effects of ultraviolet radiation (UV) is measured under Ultraviolet Protection Factor (UPF) scale. The utilization of protective clothing is the best way to deal with the damage caused by ultraviolet radiation. The purpose of this study was to compare the ultraviolet ray protective factor of pure cotton and cotton coated with titanium dioxide (TiO2) nanoparticles using the electrospinning method with two natural and artificial generators.

Material and Methods: This is an analytical-descriptive study in which, a pure cotton fabric and a cotton fabric coated with nanoparticles of dioxiditenium were coated for 10, 20 and 40 minutes, as an example, with the titanium dioxide with two types of sunlight and artificial light (widespread and dotted) beams. UV radiation divided into three spectra A, B and C that we use UV-C to measurement. Finally, the comparison of the average UV-c radiation penetration from different fabrics were conducted. We use SPSS Ver.22 to analyze data and p-value<0.05.

Results: The highest and the lowest amount of penetration were for pure and coated cotton fibers for 40 min of UV-C radiation, respectively. As the beam decreases, the UPF rises. In nano-coated fabrics, the amount of beam penetration is lower and absorption is higher giving higher UPF.

Conclusion: Due to the very low UPF, cotton fabrics are not suitable for utilization in areas with UV radiation. Therefore, in order to protect against UV radiation, fabrics coated with TiO_2 nanoparticles can be used in the domain of health care.

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Introduction

Radiation is one of the factors which have been extensively studied regarding its pathogenic effects. So far, various neglected points have remained about radiation; however, the mechanism through which radiation damages cells, molecules, or primary organs of the body has been known more than other environmental damaging factors, and there is no hesitation about it [1]. With the reduction in the thickness of ozonosphere layer by Chlorofluorocarbons and increased production of greenhouse gases, it is estimated that every 1% reduction in the ozone of the stratosphere causes 0.8% increase in cataracts. This phenomenon is equivalent to an incidence of around 100-150 thousand additional cases of cataract around the world. Furthermore, different epidemiological and experimental studies on animals have clearly shown that extra ultraviolet radiation (UV) radiation causes skin cancer [2].

In addition to the generation of cancers, UV radiation results in the generation of herpes on lips and eye SEC in rare cases. This global investigation considers the risks resulting from UV radiation as a convincing reason for taking public health measures [3]. According to the wavelength, the UV radiation is divided into three strips, namely UV-A (320-390 nm), UV-B (280-320 nm), and UV-C (254-280 nm). Different wavelengths of UV radiation have different effects on vegetative, physiological, and biochemical properties [4]. The utilization of suitable textiles for different seasons of the year and in line with the

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geographical location of the place is of crucial importance for every single person in society.

Clothes have always been under study as one of the most important protective equipment against UV rays [5]. Cotton is one of the most important fibrous plants in the world as well as Iran [6], which is a cellulose compound and its polysaccharide chains are kept fixed in their place through hydrogen bonds [7]. In the past, cotton was valued based on its apparent characteristics, including the level of plant impurity, color, and quality of treatment.

Although the color and cleanness of fiber are favorable factors for cotton fiber, the real value of cotton depends on the properties of the fiber that influence the quality of the product (i.e., yarn) [8]. The investigations on Ultraviolet Protection Factor (UPF) of different types of a textile indicate that UPF of cotton textiles is in the worst level [9]. The UPF is a factor to determine the allowable time for being exposed to sunlight when clothes are worn, which is an equivalent to sun protection factor (SPF) for sunscreen creams or sunglasses. In recent years, different countries including Australia, New Zealand, European Union, United States of America, and Britain, as well as different organizations, including International Organization for Standardization have developed and presented standard methods for measuring UPF in clothing [10-12]. The Measurement of UPF in different textiles was calculated as follows [13]:

$$UPF = \frac{risk\ unprotected}{risk\ protected} = \frac{\sum s_\lambda A_\lambda \Delta_\lambda}{\sum s_\lambda A_\lambda \Delta_\lambda T_\lambda} \qquad (1)$$

Where, S_λ is the primary spectrum of the radiation source, T_λ shows the level of passed ray, A_λ represents the effective cross-section, and Δ_λ signifies the thickness of the object of interest [13]. This formula is used for the measurement of absorption and penetration of UV-C radiation in to textile.

Today, UPF is considered as an important characteristic in the textile industry. Recently, the utilization of nanotechnology in the production of textiles with a high UPF has attracted a great deal of attention. Nanoparticles, including titanium dioxide (TiO_2) and zinc oxide have been studied in this regard [14]. The employment of small-sized particles is a solution for the evolution of bionanotechnology. The surface properties are among the determinant parameters of characteristics of any product, which can be modified by nanometric coatings.

Nanoparticles are able to attach to surfaces using methods, including spray coating, electrostatics, and padding [15]. In the recent decade, TiO_2 has been known as one of the best options for photocatalytic applications [16]. To perform a photocatalytic activity in this nanoparticle, TiO_2 requires absorbing energy equal to or more than the difference of energy between two balances of its electron energy. This process results in electronic transmission from the capacity balance to the conductor balance, whereby a positively charged pore is generated [17].

The electron and pore react with air oxygen and water vapor, respectively, thereby producing superoxide anion and hydroxyl radical [18]. This results in the improvement of the UPF degree of the textile through enhancing absorption and reducing the passage of UV-C rays using the properties of TiO_2 particle and coating by electrospinning method. Accordingly, textile with suitable UPF are produced contributing to the reduction of biological effects of UV-C rays.

Materials and Methods

This study is of analytical-descriptive type conducted in Medical Physics and Pharmacy Department of Jondishapour University of Medical Sciences, Ahvaz, Iran. In this study, cotton textile was utilized with circular rib and purity of 100%. To investigate the textile's UPF scale, it was divided into four same-sized parts. One part was utilized as pure textile (control), while the other three pieces were coated with TiO_2 nanoparticles for 10, 20, and 40 min by electrospinning method using the electro-spinning device (Nano Azma Co., Iran) at a voltage of 30000 V.

Natural and artificial UV radiation generators were employed, one of which was a UV generator lamp with a power of 30 w (Phillips Co., Netherland) with radiation peak at 253.7 nm. The other generator was utilized in direct exposure to sunlight. Since UV radiation is maximum and the sun radiates directly at 2-2:30 p.m., the measurement of UV-C radiation was conducted under natural conditions at this time. The UV-C radiation generator lamp was employed under experimental conditions. With regard to the first stage, it acted as a point light source (with a 1 cm diameter hole) and in another stage, it was used as an extended light source.

In each test, the measurements were replicated three times and the mean of the three measurements was determined as the test measurement. Hand-Lux-UV-IR-Meter device (LEYBOLD Co., Germany) was employed to measure the intensity of UV-C radiation. The obtained results were incorporated in Formula 1 and the extent of the passage of UV-C rays, absorption coefficient, and UPF of the textiles was calculated eventually. To measure the extent of the passage of UV-C rays resulting from the point artificial light source, a hole with a diameter of 1 cm was utilized as the point light source. The textile pieces were placed on the UV radiation device so that it would act as a textile on human skin.

The complex of textile and receptor were placed 1, 5, and 9 cm away from the light source, and in each test, the textiles were exposed to direct UV-C generator lamp. This process was replicated three times with intervals of 10 s, and finally, the average of the three measurements was recorded as the final measurement. To measure the extent of the passage of UV-C rays resulting from the extended light source, a UV generator lamp was withdrawn from its cover and placed inside a non-metal frame horizontally. The complex of textile and receptor was placed 20 cm away from the radiation source and all of the rules of test measurement against point light source were replicated in this study.

To measure the extent of the passage of UV-C radiation resulting from the natural light source, the test was performed at 2-2:30 p.m. since at this time UV radiation is maximum and the sun radiates directly. During this test, the textile pieces were placed on UV-C radiator receptor in an open-air area with no shadow; therefore, the shadow of objects and buildings does not influence the level of radiation exerted to the complex of textile and receptor. In this test, the measurements were replicated three times and the mean of the three measurements was determined as the test measurement.

The UPF in the textiles was measured as follows: The extent of the passage of UV-C rays was calculated firstly through different textiles. Subsequently, the UPF in textiles was calculated according to Formula 1 using the inverse division of the extent of passage through the textiles. Eventually, the obtained results were analyzed in SPSS software (Version 22).

In the statistical analysis, the assumption of data normality was initially examined by the Kolmogorov-Smirnov test, which suggested that the data did not have a normal distribution. Therefore, the Kruskal-Wallis test, which is a nonparametric and one type of analysis of variance test, was employed to compare the mean of the groups. Moreover, P-value less than 0.05 was considered statistically significant.

Results

Figure 1 represents the extent of the passage of UV-C rays (in terms of w/m2) through a pure cotton textile and cotton textiles coated with nanomaterial against point artificial light generator at distances of 1, 5, and 9 cm, respectively. Moreover, Figure 2 illustrates a comparison and extent of the passage of UV-C rays (w/m2) through pure cotton textiles and cotton textiles coated with nanomaterial against natural light generator and extended artificial light.

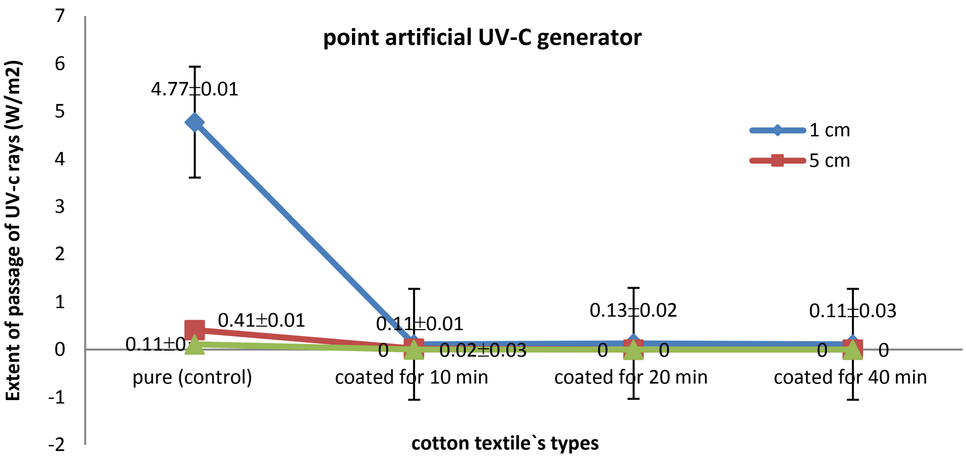

Figure 1. The extent of passage of UV-C rays (W/m^2) emitted from the point artificial light generator through cotton textiles coated with nanomaterials and pure cotton textile

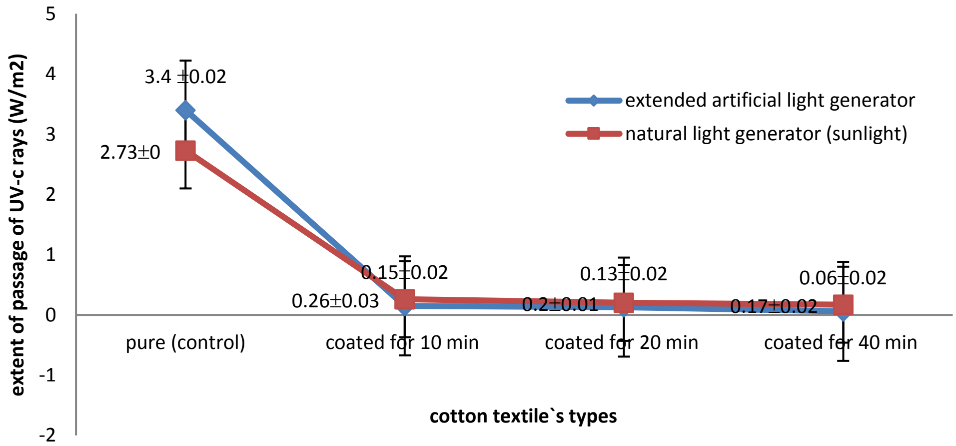

Figure 2. Comparison and the extent of passage of UV-C rays (W/m^2) through pure cotton textile and cotton textile coated with nanomaterial against extended artificial light generator and natural light generator (sunlight)

Table 1. The extent of average passage of UV-C rays (w/m^2) through pure cotton textile and cotton textile coated with nanomaterial against point artificial light generator (at distances of 1, 5, and 9 cm) as well as extended artificial light generator and natural light generator (sunlight)

Type of UV-C radiation generated		Type of textile	Extent of passage of UV-C rays Mean ± standard deviation	P-Value
Point artificial light generator	At a distance of 1 cm	Cotton coated for 10 min	0.11 ± 0.01	0.052
		Cotton coated for 20 min	0.13 ± 0.02	
		Cotton coated for 40 min	0.11 ± 0.03	
		Pure cotton	4.77 ± 0.01	
	At a distance of 5 cm	Cotton coated for 10 min	0.02 ± 0.03	0.024
		Cotton coated for 20 min	0.0	
		Cotton coated for 40 min	0.0	
		Pure cotton	0.41 ± 0.01	
	At a distance of 9 cm	Cotton coated for 10 min	0.0	0.012
		Cotton coated for 20 min	0.0	
		Cotton coated for 40 min	0.0	
		Pure cotton	0.11 ± 0.0	
Extended artificial light generator		Cotton coated for 10 min	0.15 ± 0.02	0.020
		Cotton coated for 20 min	0.13 ± 0.02	
		Cotton coated for 40 min	0.06 ± 0.02	
		Pure cotton	3.40 ± 0.02	
Natural light generator (sunlight)		Cotton coated for 10 min	0.26 ± 0.03	0.014
		Cotton coated for 20 min	0.21 ± 0.01	
		Cotton coated for 40 min	0.17 ± 0.02	
		Pure cotton	2.73 ± 0.0	

Table 2. The UPF value of pure cotton textile and cotton textile coated with nanomaterial against extended artificial light generator and natural light generator (sunlight)

Type of UV-C radiation generated	Type of Textile	UPF of Textile Mean ± standard deviation	P-Value
extended artificial light generator	Cotton coated for 10 min	6.87 ± 0.74	0.052
	Cotton coated for 20 min	7.97 ± 1.01	
	Cotton coated for 40 min	18.65 ± 5.62	
	Pure cotton	0.29 ± 0.0	
natural light generator (sunlight)	Cotton coated for 10 min	3.87 ± 0.38	0.024
	Cotton coated for 20 min	4.84 ± 0.14	
	Cotton coated for 40 min	5.93 ± 0.64	
	Pure cotton	0.37 ± 0.0	

Table 1 summarizes the mean passage of UV-C rays (w/m2) against point artificial light generator (at distances of 1, 5, and 9 cm) as well as extended artificial light generator and natural light (sunlight). The mean±SD values, as well as P-values, obtained at 0.052, 0.024, 0.012, 0.02, and 0.014, respectively, with a significant level of $P<0.05$. In addition, Table 2 tabulates the UPF in textiles against extended artificial light generator and natural light (sunlight) and the mean±SD value, as well as P-values, obtained at 0.019 and 0.014, respectively, with significant level of $P<0.05$.

Discussion

The utilization of a suitable textile for the production of clothes in line with the profession of people has always been a concern for authorities and workers in different professions. Furthermore, the cotton textile is one of the most widely used textiles around the world, which is of great interest thanks to inexpensiveness, beauty, the light weight, and availability.

Based on Figure. 1, the extent of the passage of UV-C rays in the coated textiles in proportion with the coating time has a sensible reduction, where the textile with 10-min coating lets more UV-C rays pass, compared to 40-min coated textile. In addition, at the distance of 5cm, the passage of UV-C rays through the coated textiles reaches zero. Regarding the distance at 9 cm, almost no ray passes through the coated textiles, and all of the rays are absorbed by nanoparticles coating.

According to the results presented on Figure. 2, the extent of the passage of UV-C rays is maximum with respect to the artificially extended light generator and natural light generator (sunlight) in pure cotton textile. However, in the coated textiles, given the time of coating, it has a sensible reduction and UV-C rate passage reaches its minimum value in the 40-min coated textile.

Seyfollahzadeh et al. conducted a study on the effect of TiO_2 nanoparticles on white wool/polyester textiles. In this investigation, it was stated that TiO_2 nanoparticles absorbed UV rays causing the resistance of the textile to the effects of these rays. In this study, the oxidation method (cation and anion) was utilized to attach TiO_2 nanoparticles to the textile surface [19]. The results of the abovementioned study are consistent with those obtained in this study. Moreover, in this study, it was indicated that the manner of attachment of TiO_2 nanomaterial did not have a sensible effect on the absorption of UV rays.

The comparison of the passage of UV rays in Figure. 2 indicated that the ray radiated from the extended artificial light generator enjoyed a greater passage potential in the pure cotton textile when compared with the ray emitted from the natural light generator. Furthermore, the data indicated that the nanomaterial coated on the textile surface has caused less passage of UV rays that exposed on textile surface, thereby causing greater absorption of UV rays.

The antimicrobial effects of textiles treated with TiO_2 nanoparticles were investigated in a study conducted by Sundaresan et al. In this study, nanoparticles with a size of 7-12 nm and anatase morphology were synthesized, and dry padding method was utilized to attach nanoparticles to the fiber surface. In this study, it was stated that most UV rays descended on the textile surface are absorbed by TiO_2 nanoparticles, and did not cross it [20]. The results of this study are also in line with the results in the present study. The latter showed that greater number of nanomaterials on the textile surface led to the higher levels of UV ray absorbtion, thereby enhancing the UPF in textile.

Based on the data in Table 1, the extent of the passage of UV rays (w/m^2) declines with the prolongation of the coating duration of nanomaterial on the cotton textile surface, compared to the pure cotton textile. In the cotton textile, which was coated with TiO_2 nanoparticles for 40 min, the minimum extent of passage was recorded against any type of UV radiation generator, whereas the pure cotton textile has the maximum passage of UV rays. Therefore, a significant difference ($P<0.05$) was observed between textiles coated with TiO_2 nanoparticles and pure cotton textile in terms of the extent of passage.

According to Table 2, the UPF value of pure cotton textile increases with the increase in the duration of coating with nanomaterial. Moreover, the observed inconsistencies in the obtained data indicated that the UPF of coated textiles has a greater intensity against extended artificial light generator, compared to the natural light generator. It can be attributed to the absorption of UV-C rays by TiO_2 nanoparticles.

Hatch et al. performed a study on the protective effect of three types of skin protectors. This study examined the protective effect of skin lotions, sunscreen materials, and clothes against aging of the skin resulting from sunlight. It was stated that clothes have greater protective effects as they cover the entire surface of the body, legs, and hands. It was also propounded that due to their low UPF, cotton textiles should be reinforced with UV radiation absorbent materials in order to have a protective effect against sunlight [21]. The results of this study are also in line with the results of the present study. It was observed that TiO_2 nanomaterial was a very suitable absorbent for UV rays and enhanced the UPF of cotton textiles considerably.

Based on the results in Table 2, the UPF value of the textile also increases with the prolongation of the nanomaterial coating duration on the textile surface. The cotton textile coated with the nanomaterial for 40 min has the maximum UPF, whereas pure cotton textile has the minimum UPF value. In addition, the cotton textile coated with the nanomaterial has a higher UPF against extended artificial light generator when compared with the natural light generator. Therefore, a significant difference ($P<0.05$) was observed between cotton textiles coated with TiO_2 nanoparticles and pure cotton textile regarding the extent of growth of UPF.

Fatahi Asl et al. studied the UPF in different types of textile including woolen, plastic, cotton, and polyester woolen textiles. They stated that cotton textiles have a far lower UPF than other types of textile, and showed absolutely no absorption against the UV rays [9]. The results of this study are also in line with the findings of the present study.

Furthermore, the protection against UV rays from welding was investigated in a study carried out by Moradpour et al. They investigated the intensity of exposure to non-ionizing radiations influenced by the type of welding process. Given the overexposure of welders to UV-B radiation in unshielded conditions, the utilization of clothes with UPF of 50 is necessary to provide better protection [22]. The results of this study are also in line with the findings of the current study.

The results of this study show that cotton textile has a very low absorption against UV-C rays, and TiO_2 nanoparticles are absorbent of UV-C rays. The amount of rays absorbed by the textile also grows with an increase in the number of nanoparticles attached to the textile surface or the duration of coating of nanoparticles leading to an increase in UPF.

In this study, due to the shortage of financial credits, it was not possible to evaluate other raw materials and other synthetic methods of nanomaterials. Therefore, it is suggested that further studies examined the most inexpensive, available, and efficient nanomaterial synthesis methods. Moreover, due to lack of access to x-ray diffraction devices as well as scanning electron microscopes and transmission electron microscopes, there was no possibility to provide the audience with more images and information.

Conclusion

The final result of this paper is that pure cotton textile should not be used in preparation of clothes to be used throughout the day or in regions where UV-C radiation is high, such as geographical regions with direct sunlight radiation or places including operation room, laboratories, isolated rooms, pediatrics ward, welding and cutting workshops, and for children and those with a thin and sensitive skin. This is because due to its very low UPF, cotton textile has a very trivial potential for absorption of UV-C rays. It is better to equip this textile with nanoparticles including TiO_2. Coating TiO_2 nanoparticles on textile using electro-spinning method is an inexpensive and simple method with no environmental contamination. Further, this method enjoys a relatively high efficiency in comparison with other methods, causing reduction of materials consumed, and diminished price of the final product accordingly. This method can easily use in industry via electroris devise. Moreover, coating nano materials using electro-spinning method provides this possibility for textile to be washable without removal of the nano layer. This method can be performed and operated on different types of textile with any type of thickness.

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