Effect of Some Construction Factors of Bi-layer Knitted Fabrics Produced for Sports Wear on Resisting Ultraviolet Radiation


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Abstract

Ultraviolet rays represent a very low fraction of the solar spectrum which damages all living organisms and their metabolisms. Such radiations can cause a variety of symptoms, from basic tanning to extremely malignant skin cancers, fabrics with correct design specification, absorbers, and finishing methods, can play a very important role as a shielding system against the deterious effects of Ultraviolet rays.

This study will stress on bi-layer knitted fabrics because knitted goods of all kinds are widely popular due to their flexibility ability to adjust, stretch when worn to a specific shape and their general comfortable wear. Knitted fabrics are widely used in Sportwear, summer clothes, under wears and Childs' clothes due to their excellent stretch and recovery, porosity, air permeability. Also knitted fabrics especially weft knitted fabrics are easier to be produced, and less cost compared to woven fabrics. Because of this fact, most previous research concerns woven structures that are typically less porous and offer higher protection against UV. The possibility of obtaining knitted fabrics with sufficient UV protection factor is of great interest, however, as knitted fabrics are more suitable for both sports and casual summer fashion garments. Current literature on the UV protection factor of knitted fabrics is very small and mostly concerns fabrics developed in machines with relatively large gauges This study is trying to find a solution for this problem by studying the Influence of weft knitted fabrics Construction with its' different parameters for Protection against Ultraviolet Radiation in sportswear applications.

Keywords: Ultraviolet protection; blended Bamboo and cotton yarn; knitting fabrics; bi-layer knitted fabrics

1. Introduction

Protective textiles have become an integral part of technical textiles. Protective textiles apply to garments and other fabric-related items designed to protect the wearer from adverse effects on the environment that can result in injury or death. as protective fabrics often have to withstand the effects of many harsh environments, such as extreme heat and cold, fire retardant, water and oil repellent, toxic chemicals and gasses, bacterial/viral protection, mechanical hazards, wound dressing, pH, Thermo-Sensitive, radiation, etc. In some situations these textiles may be used to protect the environment from pollution, such as clean rooms, and dust adsorption. Developing new technologies to improving performance and comfort in sportswear design need to be addressed from second skin clothing to outerwear.

1.1. Sports wear

Outdoor fitness helps people to feel healthier on a physical, emotional and social context, because low stress rates and high level of physical exercise can reduce common health issues including elevated blood pressure, obesity, heart disease, cancer and psychological disorders. Spending time in natural environments is now considered an important
preventive medicine activity due to the positive physical, emotional, social and environmental effects of Ultraviolet Radiation. [24]

Consumers expect high performance from sportswear. Developments in active sportswear fabrics are aimed at achieving high versatility and comfort. Sportswear must protect the wearer against rain, snow, cold, heat and UV rays. Sportswear manufacturers use innovative textile technologies to meet the demands for better performance of athletic and leisure activities such as drape, comfort, fitness and ease of movement, as well as the versatility of sportswear customs in sports such as skiing, mountaineering, snowboarding and alpine running. [25, 26]

Ultraviolet ray protection has become an essential practical prerequisite for anyone to spend long hours in outdoor sports such as warming up outdoor, golf, cricket and tennis. A little reduced drag force can improve performance in high-speed games and make a difference in a highly competitive environment, so that textile movement analysis and health tracking during sport training can provide precise and detailed performance enhancement results. [27]

1.2. Effects of Ultraviolet Radiation

Ultraviolet Radiation is described as "the portion of the electromagnetic spectrum between the x-ray and the visible light". [28] The ultraviolet radiation band is composed of three regions 1) UV-A (320 – 400 nm) which produces few visible reactions on the skin but has been shown to decrease the immune response of skin cells, 2) UV-B (290 – 320 nm) which is the one most responsible for skin cancer growth and 3) UV-C (200 – 290 nm) which is completely absorbed by the ozone which prevent it to reach Earth. [29]

In the early 1990s, effects of ultraviolet solar (UV) radiation on human skin were recognised. High UV radiation can lead to skin damage such as sunburn, allergies, premature aging of the skin, and even skin cancer. [30]

1.3. Ultraviolet Protection using Textiles

Apart from a drastic reduction in sun exposure, the most frequently recommended form of UV protection is the use of sunscreens, hats and proper clothing selection. Since cloth is made of absorbable fibres, which can absorb and block most of the radiant energy incident, and prevent it from reaching the skin by reflect or scatter radiant energy.

The capability of a fabric to block UV depends on several parameters including fibre chemistry; fabric construction, in particular porosity weight and thickness, moisture content and fabric wet processing history such as dye concentration, fluorescent whitening agents, ultraviolet absorbers and other finishing chemicals which may have been applied to textile material [24, 25, 29, 31].

Quantitative testing to determine how a garment should be used to protect skin from UV ray, either by in vivo laboratory experiments or by in vitro experimental measurements Two terms are used: 1) Sun Protection Factor (SPF) for in vivo analysis and 2) UV Protection Factor (UPF) for in vitro instrument assessment. [31]

UV-protective shields are classified into various UPF level categories based on their measured UPF according to international standards (In compliance with the Australian/New Zealand standard (AS/NZS 4366-1996), the UV Protection Factor (UPF) for blank and examined fabrics has been determined using the UV-Vis spectrophotometer. The UPF values of examined fabrics was measured through absorption spectroscopy. The link to control has been taken as rain. The UPF value was calculated using the following equation from the transmission spectra of the examined fabrics within the range 280–400 nm. [19, 36-39]

$$\text{UPF} = \frac{\int_{\lambda_1}^{\lambda_2} (E_\lambda \times S_\lambda \times \Delta \lambda) \, d \lambda}{\int_{\lambda_1}^{\lambda_2} (T_\lambda \times S_\lambda \times \Delta \lambda) \, d \lambda}$$

where $\lambda_1$ and $\lambda_2$ are 280 and 400 nm respectively, $E_\lambda$ is the relative erythema spectral effectiveness, $S_\lambda$ is the solar spectral irradiance in Wm$^{-2}$·nm$^{-1}$ ($E_\lambda$ and $S_\lambda$ values were obtained from the National Oceanic and Atmospheric Administration database (NOAA)), $T_\lambda$ is the spectral transmission of the sample obtained from UV spectrophotometric experiments and $\Delta \lambda$ is the difference between measurable wave length between measurable wavelength

1.4. Mechanism of UV protection

If a fiber surface is subjected to radiation, it may be reflected, absorbed, transferred or conveyed via the fibers. The total amount of radiation that is
emitted, absorbed or transferred depends on a variety of factors, including fiber thickness, fabric cover factor, fiber surface smoothness, and the presence or absence of fiber debutants, UV absorbers, and colors. The effect of the type of fiber on the sun protection factor (SPF) is different. Cotton and silk, for example, have no protection for UV radiation, because light can pass through them without being completely absorbed.

In the other hand, polyester and wool have higher SPF as these fibers can absorb UV radiation, while Nylon is among these extremes. If the fibers absorb all the incident radiation, then the only source of the emitted rays is the distance between the yarns, and then the effective SPF can be determined according to the following equation: SPF (max)= 1/1-cover factor, and hence near microfibers have better UV protection than normal-sized fibers of the same weight and structure. [40-42]

UV-resistant fabrics’ general requirements are UV resistance agronomic nature, comfort, light weight, longevity, easy maintenance, dimensional stability, colour fastness and the appearance of preservation after repeated washing. It is very important to have a proper choice of fibres, fabric size, weight and finishes so that the fabric meets these requirements. [20]

### 1.5. Mechanism of UV protection

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2. Experimental

2.1. Materials and methods

The bi-layer knitted structures were prepared using Polyester microfiber (75/144 detex) with lycra 20 detex in bonding layer, cotton (40 Ne), Modal (40 Ne) and blended yarn of 50/50 and 70/30 bamboo/cotton (40 Ne) back, in the face were prepared using two groups first polyester75/35 + viscose75/24 and the second 70/30 bamboo/cotton (30 Ne) in face. All samples were produced in circular multi-track weft knitting machine (TERROT I3P 148) with 28 inch diameter, 48 feeders, 18 gauge and 1680 × 2 needles. In this experimental work, the bi-layer fabric is developed in which the inner layer is made of polyester that is hydrophobic and has good wicking rate. The outer layers is made up of regenerated fibre such as Modal or bamboo or viscose which has more absorption character and rapid evaporation. The yarn which has to form as an upper layer is fed into the dial needle and as an under layer is fed into the cylinder needle. And the bonding layer using a needle from dial and needle from cylinder like interlock gating.

The two bi-layer knitted structures were developed: one is 6 course repeat in which dial needles knit at 2nd, 5th feeders and cylinder needles knit at 1st, 4th feeders. The bonding layer takes place 3rd, 6th feeders like interlock gating.

2.2. The second structure is developed with 6 course repeat the tuck frequency takes place at 1st and 4th feeders, the cylinder needles form tuck stitch at first needle in first feeder and the second needle in of 4th feeders every repeat. The visual appearance of the structures and the graphical representation of the bi-layer knitted fabric is shown in Figure 1 and Characterization

Table 2: The graphical representation of the bi-layer knitted fabric

<table>
<thead>
<tr>
<th>Structure</th>
<th>Dial needles: Two tracks</th>
<th>Cylinder needles: Two tracks</th>
<th>Feeders F1, F2 and F6</th>
<th>X Knit stitch; o Tuck stitch; - Miss stitch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure 1:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DN1</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td>-</td>
</tr>
<tr>
<td>DN2</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>CN1</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>CN2</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Structure 2:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DN1-Dial Needles Track 1; DN2-Dial Needles Track 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DN1</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>DN2</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>CN1</td>
<td>O</td>
<td>-</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>CN2</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>O</td>
</tr>
</tbody>
</table>

Table 3: Sample code and specifications of produced sample

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Code</th>
<th>F1, F4</th>
<th>F3, F6</th>
<th>F2, F5</th>
<th>Fabric structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>B1</td>
<td>polyester 75/35 + viscose 25/24</td>
<td></td>
<td></td>
<td>Structure 1</td>
</tr>
<tr>
<td>2</td>
<td>B2</td>
<td></td>
<td></td>
<td></td>
<td>Structure 2</td>
</tr>
<tr>
<td>3</td>
<td>B3</td>
<td></td>
<td></td>
<td></td>
<td>Structure 1</td>
</tr>
<tr>
<td>4</td>
<td>B4</td>
<td></td>
<td></td>
<td></td>
<td>Structure 2</td>
</tr>
<tr>
<td>5</td>
<td>F1</td>
<td></td>
<td></td>
<td></td>
<td>Structure 1</td>
</tr>
<tr>
<td>6</td>
<td>F2</td>
<td></td>
<td></td>
<td></td>
<td>Structure 2</td>
</tr>
<tr>
<td>7</td>
<td>F3</td>
<td></td>
<td></td>
<td></td>
<td>Structure 1</td>
</tr>
<tr>
<td>8</td>
<td>F4</td>
<td></td>
<td></td>
<td></td>
<td>Structure 2</td>
</tr>
<tr>
<td>9</td>
<td>D1</td>
<td></td>
<td></td>
<td></td>
<td>Structure 1</td>
</tr>
<tr>
<td>10</td>
<td>D2</td>
<td></td>
<td></td>
<td></td>
<td>Structure 2</td>
</tr>
<tr>
<td>11</td>
<td>D3</td>
<td></td>
<td></td>
<td></td>
<td>Structure 1</td>
</tr>
<tr>
<td>12</td>
<td>D4</td>
<td></td>
<td></td>
<td></td>
<td>Structure 2</td>
</tr>
<tr>
<td>13</td>
<td>H1</td>
<td></td>
<td></td>
<td></td>
<td>Structure 1</td>
</tr>
<tr>
<td>14</td>
<td>H2</td>
<td></td>
<td></td>
<td></td>
<td>Structure 2</td>
</tr>
<tr>
<td>15</td>
<td>H3</td>
<td></td>
<td></td>
<td></td>
<td>Structure 1</td>
</tr>
<tr>
<td>16</td>
<td>H4</td>
<td></td>
<td></td>
<td></td>
<td>Structure 2</td>
</tr>
</tbody>
</table>
Figure 1: photo image of the bi-layer knitted fabric
a) face of Structure 1  b) back of Structure 1 c) face of Structure 2  d) back of Structure 2

3. Results and Discussion

3.1. Effect of produced fabric structure on weight and thickness

The effect of fabric structure on the both fabric weight and thickness are shown in

Table 4 and the data showed that, fabrics with structure 1 is heavier and thicker than fabrics with structure 2 which is due to the tuck stitch in the structure 2 which make accumulation of yarn in stitches at tucking laces, that make the fabric heavier in weight per unit area and thicker in thickness.

Furthermore, changing the yarn in feeders F1 and F4 for the fabric face from "polyester 75/35 + viscose 75/24" to "bamboo -cotton (70-30%) 30/1" led to increasing the weight of producing fabrics, that is due to bamboo -cotton (70-30%) is heavier than polyester 75/35 + viscose 75/24.

3.2. Effect of produced fabric structure on bursting strength

Fabrics' construction has an effect on fabrics' burst resistance which shown in Figure 2. The bursting strength of the samples with Structure 1 is higher than that of samples with Structure 2, because structure 1 consist of plain (knit) stitch which are diminishing the loop length compared with tuck stitch and held stitches, the form and diameter of plain stitches of tuck stitch. That is meaning that,
structure 1 construction give samples a high strength, high dimension stability than structure 2.

In addition, for back materials, samples with cotton fibres have the highest value of bursting strength compared with other samples. Samples with bamboo-cotton (70-30%) have the lowest value of bursting strength, followed by modal and then bamboo-cotton (60-40%). The lower bursting strength of fabrics with bamboo fibres, due to the lower strength of bamboo fibres. [47] Furthermore, for face materials, samples with face polyester 75/35 + viscose 75/24 are higher in bursting strength than samples with face bamboo-cotton (70/30) due to the lowest values in elongation at breaks of bamboo fibres than polyester fibres. [48]

3.3. Effect of produced fabric structure on air permeability

Fabrics’ construction has an effect on fabrics air permeability which shown in

**Figure 3.** The air permeability of the samples with

**Table 4:** Standards Test methods of the properties measured in this study

<table>
<thead>
<tr>
<th>Code</th>
<th>F1, F4</th>
<th>F3, F6</th>
<th>F2, F5</th>
<th>Fabric structure</th>
<th>Thickness (mm)</th>
<th>Weight (g/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td></td>
<td></td>
<td>F1/F2</td>
<td>Cotton 40/1</td>
<td>0.701</td>
<td>240.4</td>
</tr>
<tr>
<td>B2</td>
<td></td>
<td></td>
<td>F1/F2</td>
<td>Modal 40/1</td>
<td>0.710</td>
<td>243.6</td>
</tr>
<tr>
<td>B3</td>
<td></td>
<td></td>
<td>F1/F2</td>
<td>Bamboo-Cotton (40-60%) 40/1</td>
<td>0.717</td>
<td>245.8</td>
</tr>
<tr>
<td>B4</td>
<td></td>
<td></td>
<td>F1/F2</td>
<td>Bamboo-Cotton (70-30%) 40/1</td>
<td>0.721</td>
<td>255.1</td>
</tr>
<tr>
<td>F1</td>
<td></td>
<td></td>
<td>F1/F2</td>
<td>Cotton 40/1</td>
<td>0.875</td>
<td>247.3</td>
</tr>
<tr>
<td>F2</td>
<td></td>
<td></td>
<td>F1/F2</td>
<td>Modal 40/1</td>
<td>0.777</td>
<td>243.3</td>
</tr>
<tr>
<td>F3</td>
<td></td>
<td></td>
<td>F1/F2</td>
<td>Bamboo-Cotton (40-60%) 40/1</td>
<td>0.799</td>
<td>247.3</td>
</tr>
<tr>
<td>F4</td>
<td></td>
<td></td>
<td>F1/F2</td>
<td>Bamboo-Cotton (70-30%) 40/1</td>
<td>0.893</td>
<td>251.7</td>
</tr>
<tr>
<td>D1</td>
<td></td>
<td></td>
<td>F1/F2</td>
<td>Cotton 40/1</td>
<td>0.824</td>
<td>252.0</td>
</tr>
<tr>
<td>D2</td>
<td></td>
<td></td>
<td>F1/F2</td>
<td>Modal 40/1</td>
<td>0.810</td>
<td>262.5</td>
</tr>
<tr>
<td>D3</td>
<td></td>
<td></td>
<td>F1/F2</td>
<td>Bamboo-Cotton (40-60%) 40/1</td>
<td>0.809</td>
<td>265.1</td>
</tr>
<tr>
<td>D4</td>
<td></td>
<td></td>
<td>F1/F2</td>
<td>Bamboo-Cotton (70-30%) 40/1</td>
<td>0.810</td>
<td>269.9</td>
</tr>
<tr>
<td>H1</td>
<td></td>
<td></td>
<td>F1/F2</td>
<td>Cotton 40/1</td>
<td>0.821</td>
<td>256.8</td>
</tr>
<tr>
<td>H2</td>
<td></td>
<td></td>
<td>F1/F2</td>
<td>Modal 40/1</td>
<td>0.810</td>
<td>269.5</td>
</tr>
<tr>
<td>H3</td>
<td></td>
<td></td>
<td>F1/F2</td>
<td>Bamboo-Cotton (40-60%) 40/1</td>
<td>0.831</td>
<td>268.6</td>
</tr>
<tr>
<td>H4</td>
<td></td>
<td></td>
<td>F1/F2</td>
<td>Bamboo-Cotton (70-30%) 40/1</td>
<td>0.841</td>
<td>272.6</td>
</tr>
</tbody>
</table>

Figure 2: Influence of different weft knitting structures, face types and yarn materials on fabrics' bursting strength.

Figure 3: Influence of different weft knitting structures, face types and yarn materials on fabric's air permeability.
3.4. Effect of produced fabric structure on UV protection factor

Fabrics construction has an effect on fabrics UV protection factor, as shown in Figure 4, samples with structure 2 had the lowest rates of UV protection factor compared to samples with structure 1, because structure 2 consist of Tuck stitch which has more porous and open voids compared to knit stitch which make it less compacted and hence allow the free passage of UV radiation through the fabric compared to samples of structure 1.

On the other hand, for back materials, samples of cotton yarns have scored the highest values of UV protection factor compared with other samples, where samples with bamboo-cotton (70-30%) had the lowest values of UV protection factor, followed by sample of modal yarns and bamboo-cotton (60-40%). In addition, for face materials, samples face polyester 75/35 + viscose 75/24 were higher in UV protection factor than samples with face bamboo-cotton (70/30) due to higher hairiness effect in face bamboo-cotton (70/30) than face with polyester 75/35 + viscose 75/24, resulting in spinning technique, which help in blocking the fabric voids and decrease the free passage of UV radiations through the fabric, compared to face with polyester 75/35 + viscose 75/24 which are filament yarns.

3.5. Effect of produced fabric structure on water vapour permeability

Fabrics’ construction has an effect on fabrics’ water vapour permeability which shown in Figure 5. The water vapour permeability of the samples with structure 2 is lower than the water vapour permeability samples with structure 1, because structure 2 consist of tuck stitch which make it heavier in weight per unit area and thicker in thickness. For face materials, samples with face polyester 75/35 + viscose 75/24 are higher in water vapour permeability than samples bamboo-cotton (70-30%) due to polyester 75/35 is a synthetic material which are filament and haven’t hairiness and It absorbs little water vapour.

3.6. Quality measurements

Quality was measured by radar chart as shown in Figure 6 and Figure 7. Quality Assessment of samples in the study was measured by using radar chart (Figure 6) which means comparing the spaces of Radar (Figure 7) which represents some physical and mechanical properties of each sample and that also determine its quality while using. By comparing the spaces of all samples, we arranged them from the largest space to the lowest one as in both diagram. It can conclude that, sample (D4) achieved the highest space of in the radar chart flowed by B2, B3, B4.
4. Conclusion

Effect of different fabrics’ material on UV protection properties: bamboo fabrics gave better protection against UV radiations than cotton and modal fabrics. Knit fabric structure has the greatest influence in the UPF. Tuck stitches, although generally associated with low UPFs, may have a positive or negative effect depending on how they are combined and repeated within the knit structure and positive effect for air permeability and negative effect bursting strength.

All samples have been found with UPF > 15, with six of them reaching UPF values above 40 (D2, D3, D4, H2, H3 and H4). This is because bamboo is used in different proportions between samples. By using one of these samples we can be pretty sure that the final knitwear will have a high UPF, taking into consideration that coloration and post-knitting wet treatments, like washing, will further increase the UPF. Sample (D4) achieved the best results among the research samples to produce UV-resistant sportswear fabrics.

5. Conflicts of interest

“There are no conflicts to declare”.

6. Acknowledgments

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