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Evaluation of Athlete Physiology and Performance in Different National Sport Clothes

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Abstract

Comfort is an important aspect especially in sports clothing, where the users perspire so much and sweat is in liquid moisture form. Clothing also influences an athlete's physiology and performance during exercise. To determine the performance of various sportswear made of cotton and mostly used synthetic fibers (polyester, micro-polyester, channeled polyester, polyamide, and polyester/elastane) eight different athlete t-shirts were used in this experiment. Mechanical properties, air permeability, thermal resistance, and moisture management properties of the fabrics were measured. According to the results, it was determined that a very porous warp knitted structure has the highest Overall Moisture Management Capacity (OMMC) and air permeability, while it has the lowest thermal resistance. Cotton fabric has lower air permeability and bursting strength; however, it is a better heat insulator. In addition to this, since it is hydrophilic and absorbs water, it has been identified as "Good" in the case of moisture management property. Coolmax fabric has the highest maximum wetted radius, and it allows moisture to evaporate easier and provides quick drying.

Keywords: Sports Textile; Moisture Management; Sweat Transfer; Thermal Resistance

Introduction

Sport is an area that receives great attention and is subjected to a significant amount of investments. In the past years, the attraction towards sports and exercise has increased significantly. Thus, the number of people who exercise increased simultaneously. Considering its relevance to society and the economy, it is not surprising that other sectors are encouraged to develop innovative solutions in the area of sports [1,2]. This rise affected several sectors, especially in the textile sector. Sports clothing, shoes, and equipment have become a focus of textile companies. Therefore, many studies examine the innovations regarding this sector. In this research, the relationship between sports textile and sports performance is widely studied. The aim is to understand how various types of textile materials affect the performance and health of the athlete [3].

Sport Textile

Sport textile products include sports clothing, climbing ropes, parachute fabrics, sailing canvas, any type of shoes that are used during exercise such as running shoes, gym shoes, sleeping bags, ticking's, etc. [4]. These products are expected to have certain standards in terms of adaptation to weather conditions, heat-insulation, water-resistance, comfort, flexibility, high-strength, air permeability, hygiene, dirt repellence, flame retardancy [2]. Therefore, the textile sector works to produce these in-demand types of fabrics [3]. In the textile sector, one of the basic factors while producing is to choose the right type of fabric, providing extra care for the features of fibers and the structure of the textile's surface. Sport textile has a wide scope [5]. For instance, microfiber fabrics are quite in-demand today. This type of fabric contains a channeled structure and therefore provides good quality of air permeability

[3]. Fabric type may easily affect the comfort and physiology of the person and lead to several problems such as excessive sweating, intense changes in body temperature, extra weight, inadequate protection against impacts, low resistance against water, low air permeability [2,6].

The characteristics of fabric in terms of fiber type and geometry may easily influence moisture evaporation [7]. Some studies analyze the factors that affect body heat while exercising [8]. Studies indicate that textiles that are hydrophilic (cotton etc.) have a positive effect in terms of balancing body heat. On the other hand, hydrophobic textiles (polyester, nylon, etc.) affect thermal comfort negatively during exercise [9]. However, after the development of channeled engineered fibers, synthetic fibers have a large application in comfortable clothes. Moisture transport properties of textiles are maintained by perspiring both in vapor and liquid form. Water vapor can pass through the fabric using diffusion, absorption, and desorption of vapor. Wetting and wicking are effective methods of liquid moisture transfer [10-12].

Fabrics and Sports Relation

When one exercises in an environment where the temperature is above average, heat is lost from the body through sweating. For this reason, the preservation of body temperature is quite essential during exercise [13]. The same principle is valid in environments with low temperature when the person who exercises uses special clothes to prevent heat loss [14]. Therefore, several studies may be found in the literature on sweating [15-21]. In terms of comfort provided by sports clothing, one can be affected in several ways: ergonomic, physiological, psychological, and skin-related [22,23]. Physiology may be affected by the type of fabric depending on thermal properties and permeability. Psychological effects are related to fashion and individual choices. Ergonomic comfort includes the ability to move without any restrictions to the body, depending on the elasticity of the clothing. Lastly, skin-related effects can be explained as the direct contact of fabric to the skin such as the softness of material [9]. The quality of sport cloth is directly linked to the comfort it provides to the athlete during exercise. Comfort is particularly an important issue since it directly influences the athlete's performance and health. In case an athlete or anyone who exercises chooses a sports clothing with good air and moisture permeability, the person is expected to have a lower heart rate and body temperature compared to a person who chooses clothing with inadequate permeability [24-26]. Regarding the clear effect of sports clothing quality to sports performance and human health, it is important to use fabrics that have a good quality of air and moisture permeability and thermal features. There are various types of factors that affect the quality of clothing such as the structure of the fabric and the type of fiber that is used [9].

Thermal Comfort: The major benefit of sweating while exercising is heat preservation. The body can keep its temperature on a normal level through sweating. Body temperature maintenance is important to provide a balanced internal environment for all physiological systems to work. The mentioned situation is named heat acclimatization. Heat acclimatization decreases heat strain and also increases duration against heat [27]. Therefore, it provides thermal comfort for the body. However, when the moisture on the skin cannot be evaporated because of the covering sports clothing, this may cause the person to lose a greater amount of heat [28,29]. Therefore, it is important for the clothing to allow for air and water permeability. Otherwise, body temperature is expected to increase and result in thermal discomfort [30].

Water Loss: Water loss may be quite influential to the balance of the body affecting the thermoregulatory system, cardiovascular system, endocrine system, metabolic functions, etc. [31]. Water loss may impact athletic performance quite severely. Many studies in literature analyzed the relationship. According to some of the research, water loss does not influence athletic performance [32-35]. However, other studies suggest otherwise, stating when water is lost from the body by 5% of the body weight, sports performance tends to be reduced [36,37]. Also, when water loss is 3% of body weight, muscle strength is expected to be decreased. Similarly, at a percentage of 2% or 3%, maximal aerobic power is affected negatively. In circumstances where the sports environment has a high temperature, the reductions in performance may be even higher [31,36]. In a textile preferable used for sport application, moisture and heat management are the key issues that have to be ensured for appropriate thermos physiological comfort [38]. The aim of this study is to investigate and compare the properties of different commercially available athlete fabrics.

Previous Studies: Several types of research have been made to understand how different fabrics that are used in sports clothing affect the human body during exercise. One study analyzed physiological aspects that can be influenced by the sports clothing using three types of fabric: 100% Tencel fibers, 100% polyester fibers, and a mix of both. According to the results, the mixed fabric type provided the best outcomes in terms of efficiency for the subjects [54]. Differences between the natural and synthetic types of fabrics and their effects on the regulation of body temperature are also analyzed in the literature. Some studies state that the fabric type that is used in the clothing is quite influential during exercise. When there is a more muscular activity, the body temperature rises [39,40].

Other than the specific issue of thermoregulation, many studies can be found on the influence of fabric type on heart rate, blood pressure, and oxygen level during exercise [41-45]. One research was conducted with the purpose to analyze the relationship between fabric type in sports clothing and thermal comfort people during sports. Subjects were asked to wear clothing with natural and synthetic fibers during and post- exercise [46]. After concluding the study, the researchers found out that cardiovascular and respiratory systems are highly affected by the material type. Another research also focused on the sports clothing fabric types' of influences on athletes and their physiology. Volunteer athletes were asked to try three different sports clothing made of various types of fabrics: 100% cotton fibers, 35%/65% cotton-polyester mix fibers, and 100% polyester fibers. Different physiological parameters such as air permeability, moisture permeability, and thermal properties were studied. All three types of fabric demonstrated variating results on the subjects' bodies and athletic performances. On the contrary to this present study, the researchers concluded that 100% polyester fabric provided better results in terms of physiology and performance [9].

Materials and Methods

In this study, 8 different athlete t-shirts used in different national teams were used. They are summarized in (Table 1). They were obtained from an international supplier. After conditioning of the t-shirts for 24 hours under the standard atmosphere conditions (20 ± 2°C temperature and 65 ± 4% relative humidity), fabrics were tested for their physical properties. The structural properties of the fabrics are also given in (Table 1). Fabrics were produced from cotton, polyester, micro polyester, polyamide and polyamide/elastane yarns. The structural, mechanical and comfort characteristics of eight different fabrics were investigated. Mass per unit area was measured according to EN12127 standard, thickness was measured according to ISO 5084 standard. In order to determine mechanical performance of the fabrics, bursting strength values were measured according to ISO 13938-2 in 7.3 cm2 test area in Tru Burst Bursting tester. Air permeability tests were processed (by FX3300-Tester) according to ISO 9237 standard (Test area: 5 cm2, 100 Pa air pressure). Thermal resistance of the fabrics was tested according to ISO 11092 standard by using skin model. Thermal resistance, Rct, temperature difference between the two faces of a material divided by the resultant heat flux per unit area in the direction of the gradient [12]. The Moisture Management Tester (MMT) was used to test the liquid moisture management capabilities of textiles. It is designed to detect the liquid moisture transport properties in multiple directions [47,48].

Table 1: Fabric properties of the athlete t-shirts used in the experiment.

Fabric Code	Fabric thickness (mm)	Fabric weight per unit area (g/m^2)	Wales per cm (wpc)	Courses per cm (cpc)	Material	Structure	National Team
1	0,40	172	38,7	34,0	98% microfiber polyester/2% elastane	1 x 1 interlock	Argentina
2	0,45	187	39,3	39,3	98% microfiber polyester/2% elastane	1 x 1 interlock	Italy
3	0,48	205	19,7	19,7	100% Cotton	Supreme	Spain
4	0,34	167	10,0	15,3	100% polyester	Rashel Net Front Guide Bar 2-3/2-1/2-3/1-0/1-2/1-0 Back Guide Bar 1-0/1-2/1-0/2-3/2-1/2-3	
	France						
5	0,40	162	32,0	30,0	100% polyester	Double face pique	England
6	0,36	198	56,0	28,7	100% polyester (Coolmax)	1 x 1 interlock	Japan
7	0,38	157	15,3	13,7	100% Polyamide	Rashel Net Front Guide Bar 1-0/1-2/1-0/1-2/2-3/3-4/4-5/5-6/6-7 Back Guide Bar 6- 7/6-5/6-7/6-5/5-4/4-3/3-2/2-1/1-0	Ireland
8	0,63	171	35,3	34,0	95% Polyester /5% elastane	1 x 1 interlock	Portugal

When moisture is transferred on fabric surface, the contact electrical resistance of the fabric changes and it changes according to two parameters: the components of liquid and the water content in fabric structure. Since the liquid properties are constant, the measured electrical resistance is associated with the water content in the fabric structure [49-51]. In order to simulate sweating, a special solution was prepared and is given onto the fabric. In this test design, the surface on which test liquid is dropped is designed as an inner surface that will be in contact with human skin surface. Overall Moisture Management Capacity (OMMC) is an index that is calculated by the instrument. It indicates the liquid transport properties of the fabrics. It is a key factor to indicate the overall capability of the fabric to manage the transport of liquid moisture [12,47,48,49,51]. When it is higher, the overall moisture management capacity of the fabric will be higher too.

Results and Discussion

In order to determine whether the effects of fabric type on the measured parameters are significant or not, variance analysis were carried out and the p values are given in (Table 2). p values

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were examined according to the significance level of α = 0.05. Water content and water location vs. time graphics indicate water content change on face and bottom surfaces of the fabrics and total wetted areas after the measurement. The wetting times of the top and bottom surfaces of the tested double-faced fabrics are given in Figures 1- 9. Wetting time – WTT (top surface) and WTB (bottom surface) are the time period in which the top and bottom surfaces of the fabric just start to get wetted respectively after the test commences [47]. Maximum Wetted Radius (MWRtop and MWRbottom) are indicators of maximum wetted ring radius of top and bottom surfaces of the fabrics. Max Wetted Radius (mm) values of the test fabrics are given in Figure 5. According to Figure 10, Fabric 6 has the highest maximum wetted radius values, which means test liquid is transferred along the fabric easily. It is the result of the channeled fibers that increases the number of capillary channels between the fibers. Since liquid moisture is transferred along the fabric by capillary forces, Fabric 6 has the best performance among the investigated fabrics.

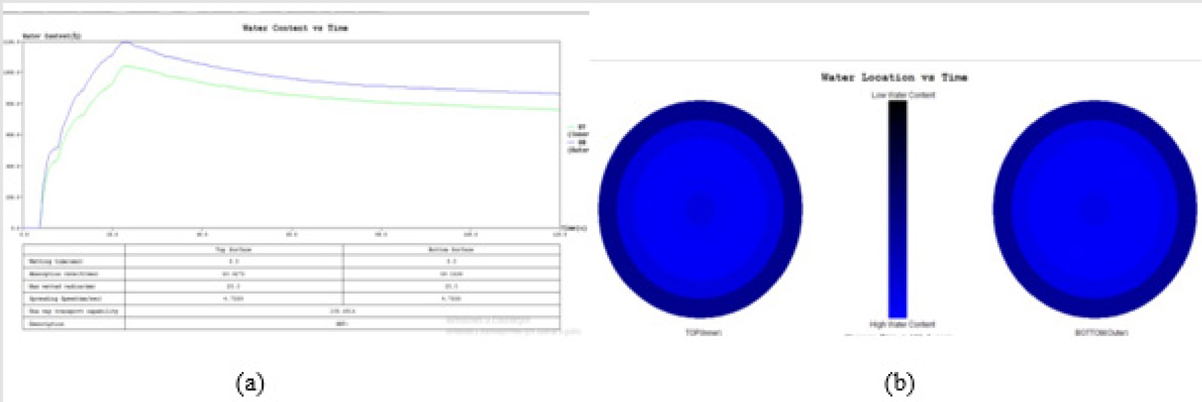

Figure 1: Water content vs. time (a) and water location vs. time (b) changes of fabric1.

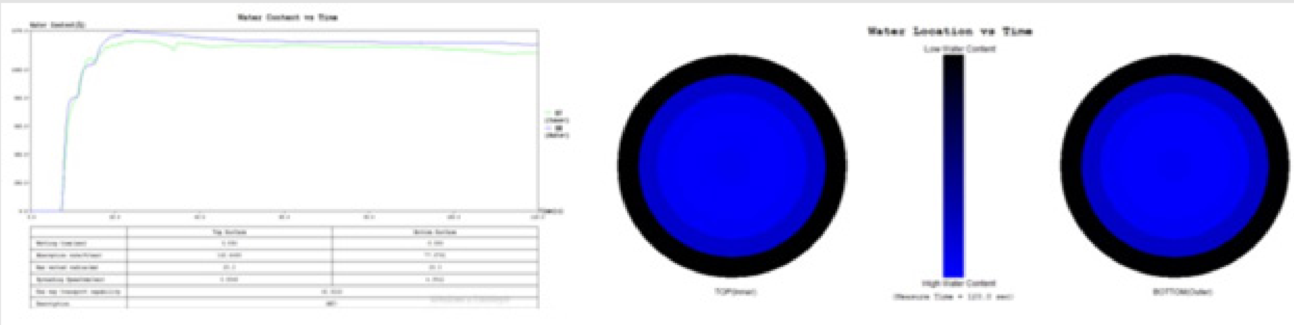

Figure 2: Water content vs. time (a) and water location vs. time (b) changes of fabric2

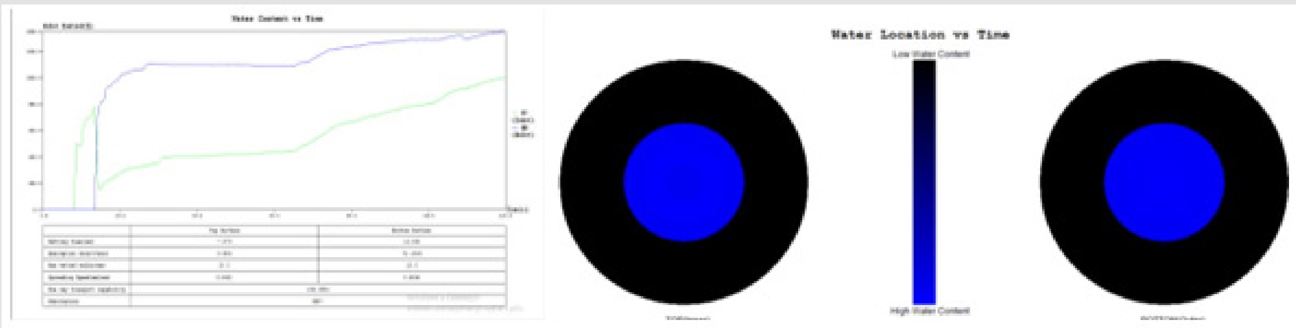

Figure 3: Water content vs. time (a) and water location vs. time (b) changes of fabric3.

When microfibers are used in the structure, the fabric and fiber surface is enlarged; therefore, moisture is transported via more channels, since a better capillary effect is achieved [52]. For this reason, Fabric 1 and fabric 2 have high max wetted radius values. On the other hand, due to the hydrophilic character of cotton, some of the test liquid is absorbed by the cotton fibers, which results in lower moisture spreading along the fabric Spreading Speed (mm/sec) is defined as the accumulative spreading speed from the center to the maximum wetted radius [43]. The accumulative spreading speed (SS) is calculated according to the given formula:

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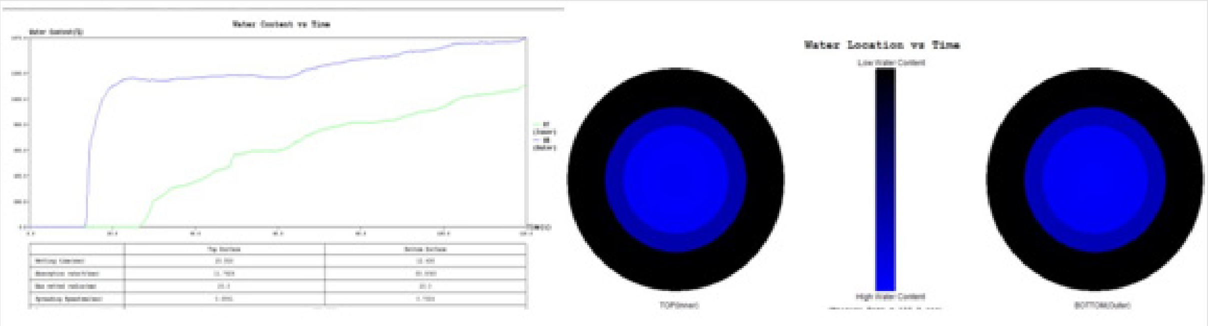

Figure 4: Water content vs. time (a) and water location vs. time (b) changes of fabric4.

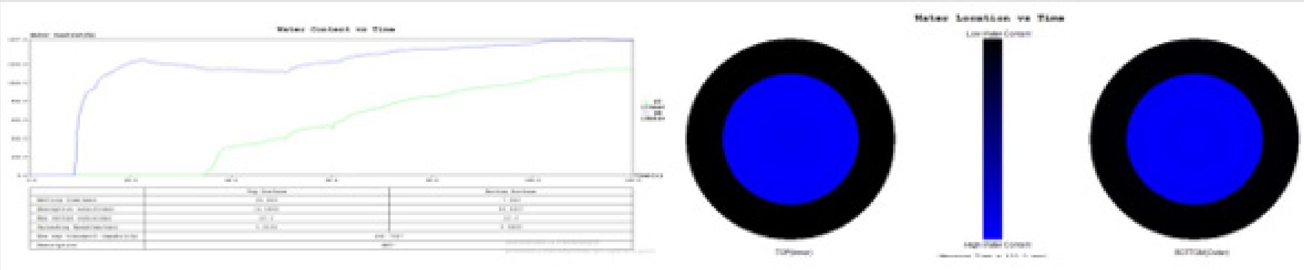

Figure 5: Water content vs. time (a) and water location vs. time (b) changes of fabric 5.

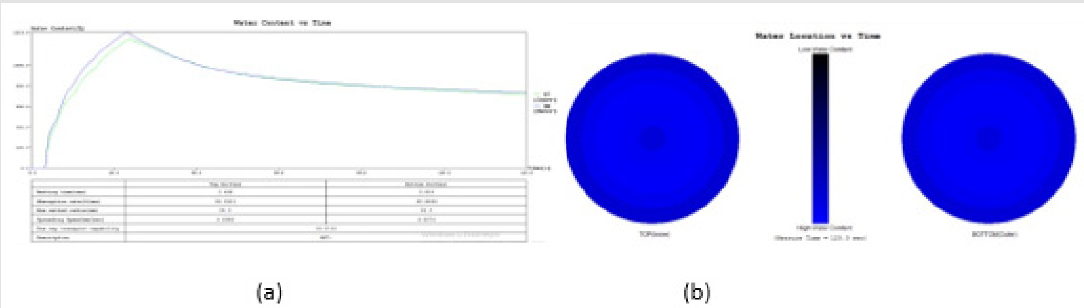

Figure 6: Water content vs. time (a) and water location vs. time (b) changes of fabric6.

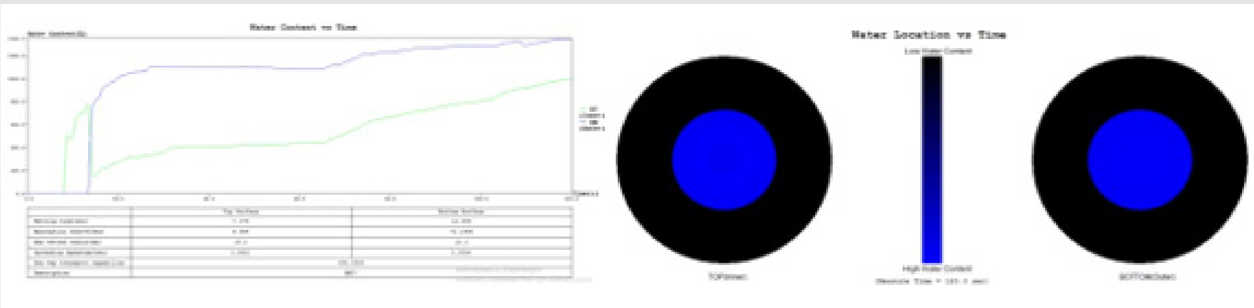

Figure 7: Water content vs. time (a) and water location vs. time (b) changes of fabric7.

$$SS_{top} = MWR_{top} / andSS_{battom} = MWR_{battom} / t_{wrb}$$

t_{wrt} and t_{wrb} are the times to reach the maximum wetted rings on the top and bottom surfaces, respectively [49]. Spreading speed test results are given in Figure 11. According to the results, it can be seen that Fabric 6 has the best performance, due to the channeled fibers in the structure. However, Fabric 7 has comparatively lower spreading speed value. Test liquid transferred by capillary forces between the synthetic fibers. Due to the very porous structure of the web, there is a smaller number of fibers that forms capillary tubes for moisture transfer. For this reason, low spreading speed value is measured. Fabric 3 (cotton) has also low spreading speed value. It is because of the hydrophilic characteristic of cotton, which quickly absorbs the water molecules, and it is entrapped in the structure. Thus, moisture transfer in the fabric direction is found comparatively lower. Spreading speed values of other fabrics were found between 2.8 mm/sec and 4 mm/sec.

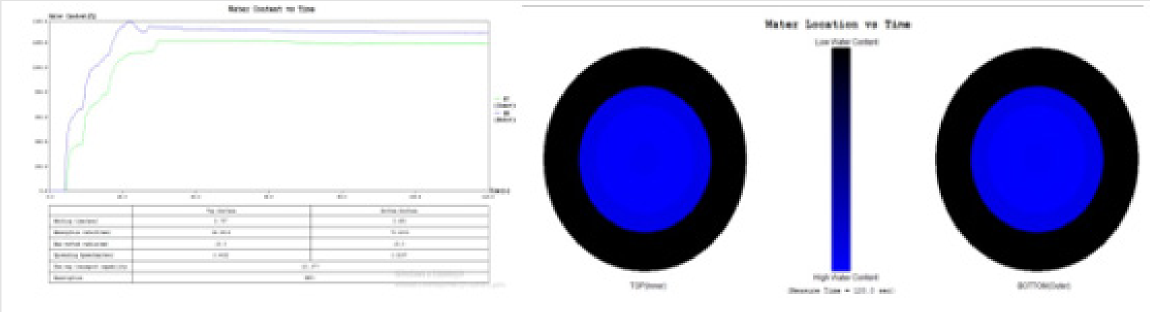

Figure 8: Water content vs. time (a) and water location vs. time (b) changes of fabric8.

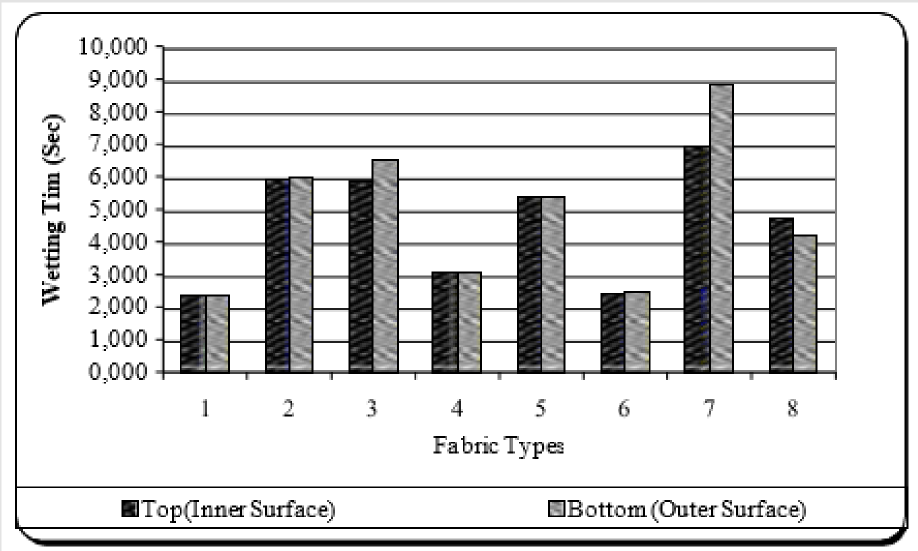

Figure 9: Wetting time (sec) values for the fabrics.

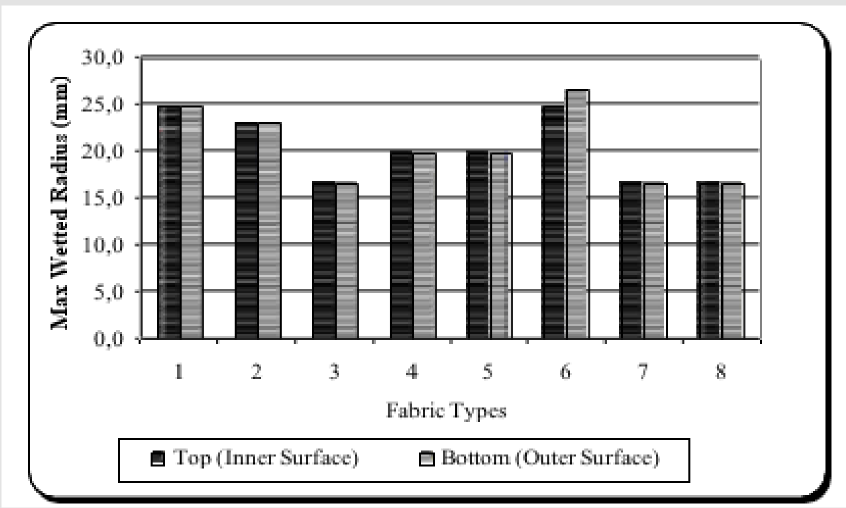

Figure 10: Max Wetted Radius (mm) values for the fabrics.

Overall Moisture Management Capacity (OMMC) is an index to indicate the overall capability of the fabric to manage the transport of liquid moisture, which is calculated by the software of the instrument [53]. According to the OMMC values of the fabrics (Table

3), fabric 7 has the highest value and identified as "very good", due to its fabric construction. The dropped test liquid easily goes through the large pores of the fabric, and it increases OMMC value. It is followed by fabric 3, which is made of cotton and it is identified as "good" according to its overall moisture management property. Air permeability results are depicted in Figure 12. According to Figure 12, it can be seen that fabric 7, which has large pores in the structure, has the highest air permeability. Fabric 6, which has the highest density, has the lowest air permeability. Fabrics that have elastane yarn inside are tighter than the others and therefore they have low air permeability values. Cotton fabric, which is produced from staple fibers, has a hairy and thick structure and it causes low air permeability. Bursting strength values of the fabrics are given in Figure 13.

Table 2: The p values of variance analysis.

	MMT TEST RESULTS									Thermal Resistance	Air Permeability	Bursting Strength
	TOP				BOTTOM							
Parameter	Top Wetting time	Top Absorption rate	Top Max wetted	Top Spreading Speed	Bottom Wetting time	Bottom Absorption rate	Bottom Max wetted radius	Bottom Spreading Speed	OMMC			
Fabric Type	0,000*	0,000*	0,220	0,000*	0,000*	0,008*	0,159	0,000*	0,002*	0,006*	0,000*	0,000*

Table 3: OMMC values of test fabrics.

Fabrics	1	2	3	4	5	6	7	8
OMMC Values	0,5447	0,4411	0,5956	0,4426	0,3903	0,5085	0,6095	0,5816
Moisture management category	Good	Good	Good	Good	Poor	Good	Very Good	Good

Evaluation: 0-0,2: Very poor, 0,2-0,4: Poor, 0,4-0,6: Good, 0,6-0,8: Very good, >0,8: Excellent.

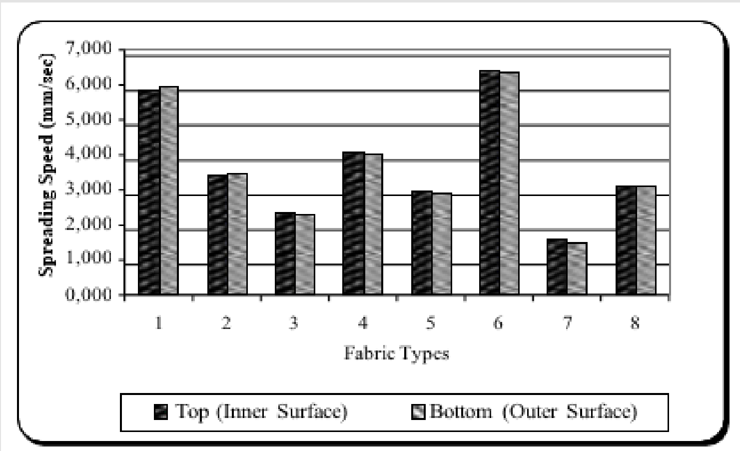

Figure 11: Spreading Speed (mm/sec) values for the fabric.

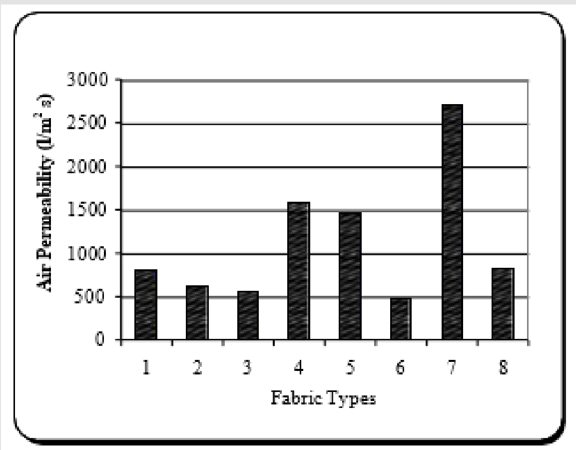

Figure 12: Air Permeability values for the fabrics.

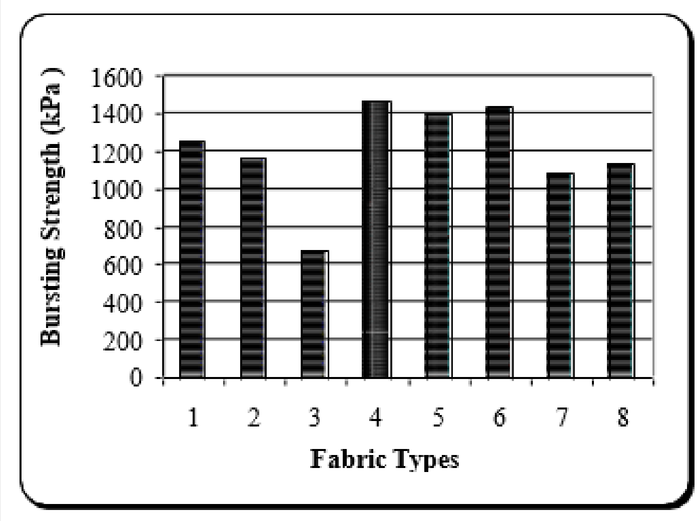

Figure 13: Bursting Strength values for the fabrics.

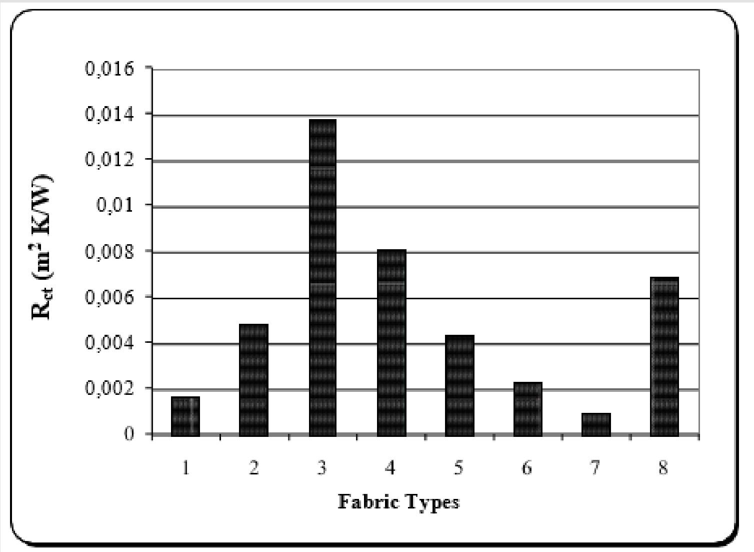

Figure 14: Thermal Resistance results of the fabrics.

As it can be seen from the figure, fabric 3 (cotton fabric) has the lowest value, due the lowest fiber strength of cotton. Fabric 4, Fabric 5 and Fabric 6 have the highest values, which indicate that, these fabrics will reflect very good performance during the usage. It is a result of the 100% polyester fiber content in the fabrics. When elastane yarn is used in the structure, mechanical performance of the fabric decreases, however, fabric stretch ability increases. According, to the thermal resistance test results Figure 14, it can be depicted that, fabric 7 has the lowest thermal resistance, while fabric 3 has the highest. That means, thermal insulation of cotton-based fabric is the highest than all other samples. First reason of this is the staple fibers that create a hairy and bulky structure and, in this situation, entrapped still air inside the fabric is higher and this provides higher heat resistance. Secondly, thermal conductivity of cotton is 71 mW/m K, while it is 140 mW/m K for polyester fiber and 250 mW/m K for polyamide fiber [54]. For this reason, cotton material is less conductive, but more resistant to heat transfer. Large pores of Fabric 7 enable heat to transfer easily from one side to the other. Thus, in case of thermal resistance Fabric 7 has the lowest value.

Conclusion

Sports clothing is one of the factors that influence an athlete's physiology and performance during exercise. Sports textile is a growing sector and offers several types of fabrics. In this concept, eight different athlete t-shirts, which are produced from cotton, polyester, micro-polyester, polyamide, and polyester/elastane were obtained and investigated for their moisture management, thermal and mechanical properties. Since synthetics have higher tensile strength than cotton fibers, all synthetic fabrics have higher bursting strength values than cotton fabric which means, they have good durability. However, in the case of comfort characteristics, the results are different. In the case of moisture management properties, fabric 7 and fabric 3 have high OMMC values, indicating that they have successful moisture management property. Fabric 7 is a warp knitted fabric and it has large pores inside that help liquid water to transfer. Cotton fiber has high water absorption capacity and is still used in different functional structures to maximize moisture transport properties. According to the results, it can be stated that water can be absorbed by cotton fabric (fabric 3) successfully and it is identified as “good” for moisture management property. Air permeability is related to the porosity of the structure and fabric 7 has the highest value for this reason. Fabric 3 (cotton fabric) and Fabric 6 which have the highest fabric density have low air permeability since they have low porosity and a more compact structure.

In the case of thermal resistance results, cotton fabric has the highest thermal resistance value, due to the low thermal conductivity and the entrapped air inside the fabric, which acts as a thermal barrier. However, Fabric 7 has the lowest thermal resistance. The porous structure of this fabric affects the thermal resistance and decreases its insulation property. The large pores increase liquid moisture, air, and heat transfer property. In conclusion, it was found that by using porous fabric constructions and synthetic fibers, air-permeable moisture management, thermally conductive and durable fabrics can be produced. In addition to this, nylon and polyester sports clothing work as an obstacle to the physiology and performance of athletes. However, cotton with its good moisture management property is still a suitable sportswear material and provides a quick sweat-absorbing property.

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