# HIGH ACTIVE SPORTSWEAR

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***Abstract***: *Sportswear is highly technical oriented clothing which enhances the performance with special functionality whereas functional requirement depends on the nature of sport, climatic conditions and amount of physical activity. In high active sports like tennis and soccer, heat stress is great concern due to high amount of metabolic heat generation which leads to severe sweating. In these conditions, the thermo physiological comfort of sportswear is an important criterion not only because of well being of wearer but also its effect on their performance and efficiency. Moisture transmission through fabric in form of vapour as well as liquid mainly determines the comfort in these hot and humid conditions. The fabric for active wear are specially constructed in terms of geometry, packing density and structure of the constituents fibres in yarn as well as the construction of the fabric in order to achieve the necessary dissipation of heat and moisture. Innovative materials like modified fibre cross-section, microfibers, biomimetic fabric structures, finishes, reported to have excellent moisture transmission properties such as drying rate, wicking and absorbency. This paper reports the thermo-physiological comfort aspects of sportswear, effects of fibre parameters like shape, geometry; yarn constructional parameters; fabric structural parameters; finishes and innovative material for sportswear.*

***Keywords:*** *High active sportswear, Innovative products, Knitted structure, Moisture transmission, Thermo physiological comfort*

## 1. Introduction

In recent times, Active sports have become highly competitive with increased participation all over the world. There has been enormous market growth for sportswear over last 20 years. Global sportswear market including performance, outdoor, sportswear inspired clothing and footwear grew by 7.5% with market of $244bn in 2012 (Eurometer International, 2013). The global wholesale market share for sportswear clothing is worth $41.5bn and its target is to reach $126.3bn by 2015 as per report published by global industry analyst GIA (Global market review, 2009). As per the market demand, sportswear can be categorized in to four categories; performance sportswear, basic sportswear, sports related leisurewear and sports related fashion clothing (Rigby, 1995).

Functional requirement of Performance sportswear depends on the nature of sport, climatic conditions and amount of physical activity. The wear comfort is an important quality criterion in any sportswear as it not only does the physiological function but also enhance the performance of sportsperson. The high level of metabolic heat is produced which leads to high level of sweat rate in the whole course of game. Sweat rate for active sports like tennis and soccer is 1.5- 2 l/h and it can go up to as high as 2.5 l/h in hot and humid conditions due to additional convective and radiative heat loads (Shirreffs, 2005). In these conditions, heavy sweating takes place so Liquid moisture transport become most important which is determined by wicking properties of the fabric. Liquid moisture flows along the capillary paths formed due to porous structure of textile which is further modified by various fibre, yarn and fabric constructional parameters. The vapour pressure gradient acts as a driving force in the transmission of moisture from one side of a textile layer to the other and moisture vapour transmission take place by diffusion process. Sorption-desorption is another important process to maintain the microclimate during transient conditions. Moisture transfer can also take place while air is flowing over a moisture layer. This is known as the forced convection method (Das and Alagiruswamy, 2010).

In conditions where wearers sweat a lot (e.g., high level bodily activity), it is not only desirable for the fabric next to the skin to absorb liquid rapidly but also to transport it through the fabric promptly to avoid the discomfort of the fabric sticking to the skin. Liquid transfer through a porous structure involves two sequential processes – wetting and wicking. Wetting is the initial process involved in fluid spreading. In this process the fibre-air interface is replaced with a fibre-liquid interface.

## 2. Factor Affecting Thermo-Physiological Comfort Properties

Fibre cross-sectional shape plays an important role in liquid moisture transmission properties of fabric. The most commonly used fibre for active sportswear is polyester. Tetrachannel and hexachannel cross-sections offer more surface area for liquid transmission and gives better wicking ability and faster drying (Fangueiro *et al.* 2010). Polyester with trilobal and triangular cross-sections also reported to improve liquid moisture transmission as compared to normal polyester with circular-cross section. Filaments with higher shape factor have better wicking rate due to their higher specific surface area (Das *et al.,* 2008). Five-leaf cross-sectional shaped filament (Wang *et.al*, 2008) showed enhanced wicking as compared to circular fibre due to higher capillary forces generated by larger specific surface area. Knitted fabrics made by using microfibre polyester showed excellent moisture related comfort properties, like absorption, wicking and rate of drying. Small size of capillaries in micro denier yarn increase the capillary pressure which drive the water transfer in to the capillaries and results in higher wicking (Srinivasan *et al.* 2007).

Fabric, with quick absorption and fast releasing of moisture capability, can be made by addition of small amount of hydrophilic fibres with polyester. It gives surprising level of wearer comfort and wearer performance but the amount of fibres is very crucial to the moisture management and drying capability. It was reported that 10% and 15% cotton blends are more comfortable than 5% and 20% cotton blends. Polyester-cotton blends reduce texture roughness compared to 100% PET (Katz, 1999). Combinations of polyester with thermo-regulating viscose outlast gives better wicking ability but poor drying capability (Fangueiro *et al.* 2010). In comparison to polyester-cotton spun yarn, profile polyester filament in core as well as cover of composite spun yarn showed better absorption capacity due to hydrophillicity of cotton and better diffusion rate due to higher siphoning capacity of polyester filaments (Su *et al.* 2007).

Yarn twist and yarn linear density are influencing factor in moisture transmission. Moisture management properties, tested on MMT, like absorption rate, spreading speed and maximum wetted radius reported to decrease with higher wetting time of fabric at high twist coefficient and higher linear density of cotton yarn (Odzil *et al.*, 2009). Fabric made up of different types of hollow yarns showed higher heat and moisture transmission with fast drying as compared to fabric made of normal yarns (Mukhopadhyay *et al*., 2011). It has been suggested in another study (Uttam *et al*., 2013) that thermo-physiological properties of hollow yarn fabric depends on yarn packing coefficient, inter yarn porosity and fabric thickness.

Knitted fabric structure is used in most of the active sportswear. Single jersey fabric reported to have better wickability and higher absorption as compared to knitted structures having knit tuck combination like pique and honeycomb (Patil *et al., 2009)*. Two layer knitted fabric structure is very popular for sportswear application. Inner and outer layer of these fabrics are completely separate and unique with distinct functionality. Liquid water transfer from inner to outer layer depends on hydrophillicity of both layer and to great extent on their difference. More water can be transferred from inner to outer layer if inner layer shows poor water absorption while outer layer shows higher water absorption. The inner layer made of hydrophobic filament and outer layer made of hydrophilic fibre is preferred in two layer fabric (Long, 1999). Two layer fabric made by using 30% *Tencel*® and 70% polyester in the outer layer gives better moisture absorption and buffering, equal moisture spreading, same drying rate, equal wet cling behaviour, a much better balance of water vapour permeability, thermal comfort and a less synthetic look and touch as compared to 100% polyester (Firgo, 2006). Wool is having low surface energy, so when it is used as inner layer with cotton on the outer layer showed good moisture management properties and transfer liquid sweat giving much dry feeling on the inner side (Zhou, 2007). During Subjective wear trial, two-layer polyester-cotton fabric showed poor Performance in dampness and comfort rating as compared to 100% polyester and *Coolmax*® interlock knitted structure (Kalpan and Okur, 2012). The plain plated fabrics with cotton and bamboo in outer layer and *Coolmax*® in the inner layer showed good water absorption whereas fabrics knitted with polypropylene filament and cotton yarn combination showed worst ability to absorb water. The plain plated weft knitted structure reported to have better dryness sensation as compared to two-layer combined structure knitted with same yarn (Bivainyt and Mikucioniene, 2011).

Biomimetics of plant structure in knitted fabric can improve the water absorption and one way transport property of the fabric (Sarkar *et al.*, 2009). These fabrics possess a significantly greater initial water absorption rate, one-way transport capacity and air permeability (Chen *et al.*, 2009), however their water vapour permeability found to be less than their control fabric due to increases fabric thickness (Chen *et al*., 2011). Biomimetic warp knitted fabric with branching structure has been developed using two guide bars with polyester and nylon (Chen *et al*., 2012). This fabric showed significantly faster initial water absorption rate, improved water spreading speed and lower air resistance than conventional control fabric with same material. Another example of biomimetic clothing was inspired from pine cone. This fabric has many tiny spikes on the outer layer which would open to cool down the body during hot climate and then again flatted down to trap air and provide insulation in cold climate (The Engineer, 2004).

## 3. Innovative sportswear Products

Some high performance fibres like Coolmax®, Thermolite®, Thermocool® are being offered by Advanced Fiber Technology (ADVANSA) for various sportswear applications. Coolmax® active is a high tech fibre made from specially engineered four channel and six channelled polyester fibre which forms a transport system with an increased surface area that pulls moisture away from the skin to the outer layer of the fabric and keeps the wearer cool and dry (COOLMAX® fabric, n.d). For active sports in cold climate, Thermolite® is very popular. Hollow core fibres trap in air for great insulation and provide warmth and comfort without weight. The large surface area allows the fast evaporation of perspiration and wearer stays dry 50% faster than cotton (INVISTA's THERMOLITE® fabric, n.d).

Sportwool® is a unique fabric developed for active sportswear by commonwealth scientific and industrial research organization (CSIRO) Australia. It is basically a two layer moisture management fabric with wool on the inner side and synthetic fibre on the outer side (Sportswool, n.d).

Toray offered many moisture management fabrics like Stunner QD® and Field sensor®. Stunner QD® is nylon woven fabric which quickly absorbs, disperses and evaporates perspiration for quick drying. Fieldsensor TM® has brushed inner side which provides insulation and moisture management which makes it suitable for winter active sportswear (Moisture management woven fabric, n.d).

Fabric Coating with micro-encapsulated phase changing material has been exploited by Outlast (Outlast® technology, n.d). Products with Outlast technology buffer changes in humidity and temprature in microclimate and external environment (Figure 2). They maintain constant body temprature by absorbing excess body heat when temprature starts rising due to heat production and releasing it when temprature falls during cooling (Apparel magazine*, 2007)*.

Inotek® fibre is innovative biomimetic fiber. When it absorbs moisture, it shrinks thin sturcture causing microscopic air pockets to open and increase the breathability. This response is reversible and fibres come back to original dimension in dry conditions (fibre2fashion, 2013). Skin® 400 series is elastane incorporated warp knitted innovative compression athletic wear which can increase the oxygen delivery to active muscles by dynamic gradient compression (skins, n.d). Biomimetic swimsuit Fastskin developed by Speedo® is inspired from shark skin. The denticles of shark's skin and super stretch property of fabric can enhance the performance of swimmer by shape retention, muscle compression and reduced drag coefficient (Benjanuvatra *et al.*, 2002).

## 4. Major findings of the research done on comfort characteristics of high active sportswear

- The structural characteristics of fabrics, like structure type, fabric porosity, fabric tightness and fabric thickness, and the structural characteristics of filaments, like the cross-sectional shape of filaments and filament denier, have considerable effects on heat and moisture transfer through polyester knitted sportswear. Fabric thermal resistance significantly correlates with fabric porosity for samples with same fabric structure. For similar construction fabric, air permeability and relative water vapour permeability found to be significantly correlated. An increase in fabric tightness significantly decreases air flow and moisture vapour flow through fabric. Float knitted structure showed highest permeability to air due to its open structure (Manshahia and Das, 2013a).

- Wicking rate and the wicking properties of the fabric improve with filament of higher shape factor. Filaments with lower linear densiy offer higher surface area to wick and showed better in-plane wicking as compared to coarse filaments. For interlock structure, wale-wise wicking height is found to be higher than course-wise wicking height. In-plane wicking takes place in ellipse patterns for interlock fabrics and water touches the edge faster in the wale-wise direction due to a substantial difference of wicking between the wale-wise and course-wise directions. For all types of fabric construction, absorbency found to be higher for thick fabrics. The filament shape significantly correlates with the specific low rate which increases liquid moisture transmission. An improved liquid moisture flow has been observed in plated structure with filament having higher shape factor on the inner side (Manshahia and Das, 2013b).

- Filament with higher shape factor enhances the liquid movement by offering larger specific surface area. For different cross-section shape, contact angle of material also varied due to change in geometry. The effect of filament shape factor of inner side of fabric is more pronounced as compared to filament shape factor of outer side. Fabric with tetrachannel on both sides shows excellent moisture management properties whereas fabric with circular shaped filament on both side showed poorest moisture management among all the samples (Manshahia and Das, 2013d).

- Permeability to air and moisture vapour as well as liquid moisture transmission properties found to be higher at lower range of elastane% and elastane stretch. Fabric thermal insulation found to be higher at higher values of elastnae stretch and elastane%. Yarn twist also plays a significant role in determining heat and moisture transfer through fabric (Manshahia and Das, 2013e).

- Fabric knitted at longer loop length has more permeability to air and moisture vapour with better absorption and overall moisture management capacity but lower in-plane wicking as compared to fabric knitted at shorter loop length. The thermo-physiological comfort characteristics of plated fabric found to be deteriorate with increase in elastane linear density. Moisture vapour and liquid moisture vapour transmission found to be less for coarser elastane. Filament shape factor significantly increase the fabric liquid transmission and overall moisture management capacity, however fabric becomes less permeable to air and moisture vapors at higher shape factor (Manshahia and Das, 2013c).

- Interface pressure reduces with time due to mechanical deterioration of fabric during prolonged repetitive movement at knee position. Pressure drop and elastic recovery found to be significantly affected by fibre and fabric constructional parameters like fabric loop length, linear density and cross sectional shape. Fabrics knitted with lower loop length, coarser elastane and modified cross-section of polyester filament show higher interface pressure with lower rate of pressure drop and good elastic recovery (Manshahia and Das, 2014).

**References**

[1] Bivainyt A and Mikucioniene D (2011), Fiber and Textiles in Eastern Europe, 19, 6, 64-70
[2] Chen Q, Fan J T and Sarkar M (2009), Textile Research Journal, 10, 3, 343–350
[3] Chen Q, Fan J T and Sarkar M K (2012), Textile Research Journal, 82, 11, 1131-1142)
[4] Chen Q,Fan J,Sarkar M K and Bal K(2011), Textile Research Journal, 81, 10, 1039–1048
[5] Compression Technology, Skins, <http://www.skins.net/en-US/why-skins/compression-technology.aspx>
[6] COOLMAX® fabric , Accessed on 15 July 2013, <www.coolmax.invista.com>
[7] Das A and Alagirusamy R (2010), *Sciences in Clothing Comfort*, Woodhead Publishing India Pvt. Ltd., New Delhi, India.
[8] Das B, Das A, Kothari VK, Fanguiero R and de Araújo M (2008), Fibers and Polymers, 9, 2, 225-231
[9] Fangueiro R, Filgueiras A and Soutinho F (2010), Textile Research Journal, 80, 15, 1522–1530
[10] Fangueiro R, GonçalvesP, Soutinho F and Freitas C (2009), Indian Journal of Fibre and Textile Research, 34, 12, 315-320
[11] Firgo H (2006),Tencel® high performance sportswear,LenzingerBerichte,85, 44-50
[12] Global Market Review of Active Sportswear and Athletic Footwear – Forecasts to 2016 (2009), Just-style, 07, 78-88
[13] INVISTA's THERMOLITE® fabric, <http://www.invista.com/en/brands/thermolite.html>
[14] Kalpan S and Okur A (2012), Indian Journal of Fibre and Textile Research, 37, 46-54
[15] Katz M (1999), *United States Patent* 5,888,914
[16] Long H (1999), International Journal of Clothing Science and Technology,11,4, 198-205
[17] Manshahia M. and Das A. (2013a), RJTA, 17, 3, 50-60
[18] Manshahia M. and Das A. (2013b), RJTA, 17, 3, 38-49
[19] Manshahia M. and Das A. (2013c), Journal of Textile Institute, http://dx.doi.org/10.1080/00405000.2013.826419
[20] Manshahia M. and Das A. (2013d), Moisture Management of High Active Sportswear (accepted for publication in Journal: Fibres and Polymers)
[21] Manshahia M. and Das A. (2013e), Thermo-physiological comfort of Compression Athletic Wear, (accepted for publication in Journal: Indian journal of fiber and textile research)

[22] Manshahia M. and Das A. (2014), Fibers and polymers, 15, 2, 414-421
[23] Mukhopadhyay A , Ishtiaque S M and Uttam D (2011), Journal of The Textile Institute, 102, 8, 700-712
[24] New biomimetic fibres to revolutionize textile sector (2013), fibre 2 fashion, <http://www.fibre2fashion.com/news/textile-news/newsdetails.aspx?news_id=120745>
[25] Odzil N, Supuren G and Ozcelik G(2009), , TekstilveKonfeksiyon, 3, pp. 218-223
[26] Outlast® technology, Accessed on 15 July 2013, <http://www.outlast.com/en/technology>
[27] Patil U J, Kane C D and Ramesh P (2009), Journal of Textile Institute, 100, 5,457-465.
[28] Pine cone cloths (2004), The Engineer, <http://www.theengineer.co.uk/news/pine-cone-clothes/267046.article)>.
[29] Rigby D (1995), Present and future markets for sports and leisurewear, World sports active wear,32-38
[30] Shirreffs S M (2005), The sweating response of elite soccer player to training in heat International Journal of Sports Medicine, 26, 90-95
[31] Sportswool,<www.csiro.au/Organisation-structure/Divisions/CMSE/FibreScience/Sportswool.aspx#a1www.totayentrant.com/functions.html>
[32] Sprortswear Market Research report by Euromonitor, Euromonitor International, 2, 2013
[33] Srinivasan J, Ramakrishnan G, Mukhopadhyay S and Manoharan S(2007),A study of knitted fabrics from polyester micro denier fibres, Journal of Textile Institute, 98, 1, 31–35
[34] Su C, Fang J and Chen X (2007), Textile Research Journal, 77,10, 764-769
[35] Wang N, Zha A and Wang J (2008), Fibers and Polymers,9, 1, 97-100
[36] Zhou L (2007), Textile Research Journal, 77, 12,951-956

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