2.2 ACTIVE WEAR AND SPORTSWEAR FABRICS

2.2.1 Introduction

Sportswear textiles belong to a category called sporttech, which is one of the mainstream technical textiles. This rising interest is due to a number of social factors that include increased leisure time, increased considerations of wellbeing and good health, growth of indoor and outdoor sports facilities and the ever-increasing pursuit of the adult population of activities outside the home or workplace. More healthy lifestyles are leading to greater sports participation, more sports have been invented and many old sports have become popular.

The active wear and sportswear sector of the textiles industry is extremely broad. It can range from specialist sports apparel worn by professional athletes, to sportswear worn by everyday consumers for its fashion value. In active and endurance sports, the performance of a sportswear is synonymous with its comfort characteristics[30]. A multitude of end-uses for sports and active wear requires a similarly broad range of functional properties. For example, wind proofing and high thermal insulation are required for skiwear, whereas efficient thermoregulation and moisture management are useful in football shirts.

The diversity of applications and the fashion appeal of sportswear and activewear has fuelled its tremendous growth over the last few years. Nowadays consumers demand higher levels of comfort, design and easy care in all types of clothing. This means that in sportswear, where thermophysiological comfort can significantly enhance the performance of the wearer, the use of innovative textile products and materials is increasingly common[31].

Sports garments, particularly the layer worn next to skin, are key to the physiological comfort of an athlete, and their attributes in this aspect are critical to the athlete’s performance. The desirable attributes of functional comfort sportswear are as follows:
Optimum heat and moisture regulation; Good air and water vapor permeability; Rapid moisture absorption and conveyance capacity; Absence of dampness; Rapid drying to prevent catching cold; Low water absorption of the layer of clothing just positioned to the skin; Dimensionally stable even when wet; Durable; Breathability and comfort; Easy care performance; Lightweight; Soft and pleasant touch; Smart and functional design. It is not possible to achieve all of these properties in a simple structure of any single fiber[32].

2.2.2 Development Concept and Requisite Function

There are basically three types of sports players: top-level professionals in constant pursuit of victories and record-breaking, who primarily require functional power with aesthetic appeal; the seriously competing amateurs involved in sports clubs and school sports, who as potential future top-line performers need to have sportswear with at least minimum functional effectiveness and at a reasonable cost; and those who enjoy sports activities for its benefits in respect of health hobbies and social contact, who also need the material to provide a minimum physical function but where the accent is rather on comfort and sensitivity. Key functional aspects for top-level competition sports are super light weight, low fluid resistance, super high tenacity and stretchability.

For those seeking comfort and healthy pursuits, critical features include thermal retention, UV-resistance, cooling capacity, sweat absorption and fast drying, vapour permeability, water proofing, and anti-bacteria / odour to provide relaxation without fatigue. From the sensitivity viewpoint, surface texture, handle, luster, colour variation, transparency and comfort in wear are important factors in fabric engineering. For instance, an active sportsperson that wears poor breathable sportswear will experience an increase in their heart rate and rectal temperature more rapidly than one who wears breathable sportswear. Hence fabric breathability (moisture and air permeability) and thermal properties should be tailored in order to meet the requirements of sportswear. The type of fibre (natural, synthetic or blend), the fabric structure (woven or knitted) and fabric constructions (densities of yarns, fabric thickness, etc.) are amongst the parameters that may affect the thermal and breathability properties of sportswear fabrics[33]. Studying these properties of sportswear fabrics is important, but at the same time, it is so important to connect them with the performance of an athlete when wearing this kind of clothes during the course of exercise. Generally four different aspects can define wear comfort: physiological, psychological, ergonomic and skin sensorial aspects. Thermal insulation, breathability and the heat and moisture transportation process are a fabric’s physical properties that can affect the comfort sensation from a physiological point of view. The psychological aspect can include personal preferences, fashion, ideology, etc. Ergonomic wear comfort depends mainly on the garment’s pattern and fabric elasticity, which influence the clothing fit and freedom of movement. Skin sensorial wear comfort characterizes mechanical sensations caused by the direct contact of clothes to skin (e.g. softness, smoothness). For sportswear one can find that the physiological aspect is extremely important because of its major effect on the efficiency and performance of athletes. Thermal comfort refers to sensations of hot, cold, or dampness in clothes and is usually associated with environmental factors such as heat, moisture, and air velocity. Water/moisture vapour transmission and air permeability are important factors that affect the thermal comfort of sportswear. Several studies have been conducted on the role of determining thermal parameters in the human body during the performance of exercise[34]. Investigators have found that hydrophilic textiles, such as cotton seem to have beneficial influences on the thermal physiological response as well as on overall comfort during and after exercise compared to hydrophobic textiles such as polyester, nylon and polypropylene. A rise in the core temperature, heart rate, amount of sweat, and metabolic heat production was found to be greater in subjects wearing clothing ensembles made of weak hygroscopic material versus clothing ensembles made of strong hygroscopic material in various exercise conditions[35, 36]. Table 2.1 lists the sets of required functions of materials targeted towards the various classes of sportswear[37, 38, 39].

Table 2.1: Required function on the main sportswear

Sportswear	Required function
1 shirts for tennis, volleyball, golf (+slacks), football, rugby, baseball uniform, athletic (+shorts), track suits	Sweat absorbing, fast drying, cooling
2 skiwear, wind breakers, rainwear	Vapour permeability, water proofing
3 skiwear, wind breakers, track suits	Sunlight absorbing and thermal retention
4 swimming race and skating costume, ski jumping and downhill skiing suits, cycling costume	Stretchability, opacity
5 swimwear, snowboard wear, baseball uniform, football uniform	High tenacity, heat melt resistance to abrasion

Many sports are performed in warm environments e.g. the venue of the summer Olympics has been in warm climates for most of the recent games. This introduces two issues with clothing: firstly high exercise intensities in general will produce heat stress, that requires optimal clothing design to reduce risks, and secondly, those needing to wear protective clothing will be very uncomfortable even at low exercise levels and due to the restrictions on heat loss posed by their protective clothing are even more at risk for hyperthermia. So in general there is more comfort issue and a heat stress issue.

Comfort is often seen as an irrelevant issue when top performance is discussed. However, experience from many other areas (e.g. military performance) has shown that discomfort has similar effects on performance as adding an extra task, thereby negatively affecting the personal performance. Hence, optimizing clothing in terms of comfort as well as performance are important goals for the clothing industry. The most important features of clothing to be worn in warm or hot environment are:
-minimizing any negative effects on heat loss
-maximizing any positive effects on heat loss.

Clothing will normally reduce heat loss due to its resistance to heat and to water vapour transfer. This negative effect can be reduced by selection of appropriate materials with low resistances, but mainly by the design e.g. one important design feature is the introduction of air flows (ventilation) into the clothing.

A positive effect of clothing on heat loss can be achieved by increasing the effect of evaporation efficiency. This again is related to ventilation, but can also be achieved by wicking of sweat from the skin into the textile which subsequently spreads the sweat over a larger surface from where it therefore can be evaporated at a higher rate. This effect is not so important when the athletes skin is fully wet all over the body, but wherever sweat distribution is unequal, the wicking of sweat may improve heat loss.

2.2.3 Drawbacks of Present Sportswear

The present sportswear lack in absorption of sweat and hence leads to stickiness and clogging of pores. This leads to increase in body temperature and brings down the performance of the player.

Activewear needs to provide a thermal balance between the heat generated by the body while engaging in a sport and the heat released into the environment. Normal activewear garments do not always fulfill this requirement. The heat generated by the body during a strenuous activity is often not released into the environment in the necessary quantity resulting in thermal stress. On the other hand, during periods of rest between activities, the human body generates less heat. The wearer may become uncomfortably cold, and, in the extreme, hypothermia is the possibility[40]. The normally used fabrics in sportswear are single jersey fabric made of 100 per cent polyester, nylon, acrylic and polyester cotton blends which lack in absorption of sweat and hence lead to stickiness and clogging of pores[41].

The main function of sportswear fabrics are to protect from wind and adverse weather as well as to insulate. Most woven fabrics for weather protection used to be polyvinyl chloride coated. The PVC coating guarantees absolute water proofness but it has one serious drawback – it does not allow air to permeate. From sportswear functionality requirements, the physical attributes of sportswear can be determined and from these attributes, the required physical properties of fibre that can be used to produce sportswear also can be determined.

2.2.4 Fibres in Active Sportswear

2.2.4.1 Natural fibres

Cotton

Cotton offers next-to-skin comfort and hence is a preferred fibre for undergarments. Cotton fabrics have a pleasant feel or 'handle'. They are cool in hot weather. Much of the comfort of a textile material depends upon its ability to absorb and desorb any moisture. A garment that does not absorb any moisture at all will tend to feel clammy as perspiration condenses on it from the skin. Cotton fibres, however, are able to absorb appreciable amounts of moisture, and having done so they will get rid of it just as readily to the air. Cotton garments are therefore comfortable and cool, passing on the perspiration from the body into the surrounding air[42]. Knit cotton T-shirts and cotton underwear are preferred for their absorbency and ease of care[43, 44, 45].

100% cellulose fiber garments are widely used for general sports clothing and street wear, but the only fabrics actively promoted for high performance sportswear are made from synthetic fibers. Consumers and sportswear manufacturers have the view that cellulosic fibers are unsuitable for use in sportswear for high activity where sweat production needs to be dealt with. The reasons for this view of cellulosic fabrics are real and need to be addressed if the use of cellulosic fabrics in sportswear is to be increased. Cellulosic fabrics absorb water into the fiber structure and become heavy. This leads to stretching of the fabric, sticking to the skin and when activity ceases the fabric may feel cold against the skin. Higher levels of moisture absorbed in the fabric mean longer drying times. The slow-to-dry and cold-when-wet characteristics of cotton make this material unsuitable in conditions in which there are high levels of moisture-either perspiration or precipitation and where the ambient temperature is low. In order to deliver positive properties of cellulosic fibers and to eliminate the negative aspects of performance, a new approach is needed[46].

Wool

Wool fibres have the highest moisture regain of all fibre at a given temperature and relative humidity. Hence wool is able to absorb more moisture than cotton before becoming saturated and is a good insulator even when wet. Also wool has a natural degree of water repellence in gentle or misty rain, which adds to both thermophysiological and sensory comfort. However, wool is slow to dry and has a high wet surface coefficient of friction. As a result, there is a risk of skin abrasion when using wool. In recent years Merino wool sportswear skin layer ranges significantly increased their market share.

Silk

Silk is a soft, strong natural fibre and has luxurious handle. It has good wicking ability. Silk also has high thermal conductivity and therefore feels cool to the touch. Silk is not, however, an easy fibre to care for, which is a disadvantage in sportswear that is worn frequently.

2.2.4.2 Regenerated cellulose fibres

Viscose rayon

Like cotton, viscose is 100% cellulose but it contains a higher proportion of amorphous material. This makes it more absorbent than cotton. In addition, the slightly irregular surface of viscose fibres contributes to comfort against the skin when worn. Fabrics composed of viscose fibres, however, are difficult to launder. This limits their value for exercise and sports clothing. It is not preferred next to skin as it holds water (13% moisture regain) in sportswear. The outer layer of knitted hydrophilic portion of the twin layer sportswear can be of viscose rayon, which absorbs 2-3 times more moisture than cotton.

Modal

Like other types of rayon, originally marketed as "artificial silk," modal is soft, smooth and breathes well. Its texture is similar to that of cotton or silk. It is cool to the touch and very absorbent due to the largest contact angle compared with viscose and lyocell. Modal absorbs moisture more quickly than cotton. In many ways, modal acts like cotton, but it also has some significant advantages over cotton. Even after repeated washes it remains as supple and absorbent as it was on the day it was made. Hence, keeps cool during summers and warm during the winters.

Lyocell

As the possibilities to expand cotton fibre production are limited, there is considerable potential for a further increase in production of ‘cellulosics’ especially viscose rayon fibre. However, conducting the viscose process in a way that is fully compatible with even the most stringent environmental regulations is most demanding, which explains that the search for alternative processes to generate cellulosic fibres has continued over time. The most promising of these approaches with potentially bright future prospects is the amine oxide procedure which uses the monohydrate of N-methylmorpholine-N-oxide (NMMO, 1)- or more generally a mixture of NMMO and water to directly dissolve pulp without prior derivatization of the cellulose. The generic term ‘lyocell’ is commonly used to designate the industrial process, the fibre produced therein, and NMMO / cellulose mixtures. Lyocell fibres are thus cellulosic fibres produced by an ‘organic solvent spinning process’, they are classified as separate category within the group of cellulosic man-made fibres. The development of lyocell was driven by the desire for a cellulosic fibre which exhibited an improved cost / performance profile compared to viscose rayon[47, 48].

Lyocell has numerous advantages over rayon and modal in its properties as well as its manufacturing process. One of the major “claims to fame” of lyocell is its ability to absorb excess liquid (perspiration) – at a rate of fifty percent more than cotton – and quickly release it into the atmosphere. In doing so, lyocell supports the natural ability of the skin to act as a protective shell to regulate body temperature and maintain water balance. At the same time, lyocell’s moisture management does not give bacteria a chance to grow. Moisture is directly absorbed from the skin and transported to the inside of the fiber, rather on the surface where bacteria could grow. Nanofibrils are the key to the performance of lyocell, which is the first cellulose fiber to use this nanotechnology. Fibrils are tiny components (little "hairs") which make up the fiber. The unique structure of the fibrils allows the production of textiles which, until now, could only be dreamed of. The controlled and regular arrangement of these tiny fibrils leads to new functional properties. The nanofibrils are hydrophilic (meaning they have a strong attraction to absorbing water) and optimize absorption of moisture with excellent cooling properties. By contrast, synthetic fibers do not absorb moisture. A subjective feeling of well-being depends considerably on moisture absorption and on surface structure of the fibers. Rougher fibers can lead to skin irritation. The reason for the fine surface of the fiber is low fiber stiffness. The microscopic surfaces of lyocell fibers, due to the nanofibrils, are smoother than the surfaces of modal, cotton and wool, reducing skin irritation. It is the combination of this extremely smooth surface of lyocell and excellent moisture absorption that makes lyocell textiles feel so soft and pleasant to the skin, making them ideal for active wear, clothing for sensitive skin and home textiles such as bedding[49]. Three generations of regenerated cellulose fibers, such as viscose, modal and lyocell fibers are among the most important fibers from the point of textile and environmental aspects due to the natural structures and properties.

2.2.4.3. Synthetic fibres

For every active sport, synthetic fibres are preferred because they do not retain moisture and therefore do not get heavy upon sweating like cotton does. Synthetic fibres offer the major requirements in today's high technology sports uniforms:

Warmth, wind resistance, moisture wicking and lightness; comfort and feel of natural fibres; style and a variety of colours.

Polyester

Polyester is the single most popular and most common fibre used in active wear and sportswear. In its unfinished state, polyester fibre is hydrophobic and has a much lower water absorption capacity than, for example, cotton fibre, but its wicking rate, although slow compared with some other synthetic fibres, is faster than that of cotton. It is also cheap to manufacture and easy to care for and has excellent washing and wearing properties.

Polyamide

Polyamide fibres such as nylon 6 and nylon 6.6 have higher moisture absorption rates and better wicking ability than polyesters but dry more slowly. They are more expensive than polyester fibres and the use tends to be limited to swimwear and cycling clothing or as reinforcing fibre in blends used for sports socks. A number of variants of polyamide fibres are available, for example, anti-microbial, high-wicking and extra soft grades.

Polypropylene

Polypropylene fibres are used increasingly in sportswear although their percentage share of the market is still quite small. The fibres have very low moisture absorbency but excellent wicking ability. As polypropylene does not wet out, its thermal insulation is retained during and after strenuous activity.

Acrylics

Acrylic fibres are generally used in sportswear and active wear in the form of high pile fleece fabrics. In this application they are crimped, creating bulky fabrics with good thermal insulation. They have low water absorbency but can effectively wick liquid sweat. They are also light in weight. Their disadvantages are that they are prone to static build-up and have a tendency to pill during wear.

Elastomeric fibres

Elastomeric fibres are able to stretch over 500% without break. Elastomeric fibres are frequently used in small quantities in garments to increase stretch and support. Swimwear may for example contain 15–40% of elastomeric fibre and knitted sportswear 3–10%. Elastomeric fibres do not affect the thermophysiological comfort of garments that contain them.

2.2.4.4. Specialised synthetic fibres

Synthetic fibre can be modified during manufacture to improve its thermophysiological and sensory properties. A number of different techniques are available for producing such fibres, including the following:

Block copolymers can be added to the base polymer before extrusion.

• Fibres can be extruded with different cross sections.

• Fibres can be coated after treatment.

One of the most common modifications made in order to provide improved comfort is the use of superfine fibres or microfibres with the filaments having a linear density well below 1 decitex. The use of these fibres enables very dense fabrics to be created in which the fibre surface is significantly increased and the space between the fibre is reduced. This leads to the increase of capillary action for better thermal regulation.

Modified polyester

Specialised polyester fibres have been developed in order to produce a more natural handle, to increase absorbency, to provide better thermal resistance and to reduce static. Another technique employed is the introduction of voids into the core of the fibre. These help to improve wicking and thermal resistance.

Polyester microfibres are now widely used in sportswear. They are used in both underwear and outerwear. If treated with a fluorocarbon finish, fabrics made from polyester microfibres have a high resistance to water penetration while still remaining permeable to moisture vapour. Fabrics made from polyester microfibres also combine improved handle with strength and durability.

Modified polyamides

Specialised polyamide fibres include Hydrofil, produced by Honeywell. Hydrofilia is a polyamide block copolymer containing 85% nylon 6 and 15% polyethylene oxide diamine. This modification provides significantly improved water absorbency, up to the levels associated with celullosic fibres. Polyamide microfibres such as Tactel Micro, Microfine, Supplex and Microfibre, all from DuPont, are used in fabric to produce superior wind protection, a soft feel and good moisture vapour transmission.

2.6.4.5. Fibre blends

Two or more fibres may be blended into a single yarn to improve the thermophysiology and other properties of the individual components. Knitted fabric made from polyester/wool blends or polypropylene/wool blends, for example, can improve wicking and insulation properties of single fibre in single layer fabrics.

2.2.5. Developments

The 1980s was a period of highly fruitful innovation in sportswear garments. The sportswear industry has not only seen in market diversification for fibrous materials but also contributed towards the elevation of textile science and technology to a level of approaching that of high tech industrial sectors. The producers of sportswear have been concentrating their efforts on improving their strategic position, productivity, added value product assortment and niche positions in order to expand their markets.

Clothing for the leisure sports is difficult to design as far as physiological requirements are concerned since these are often contradictory because of the differing climate and activity conditions. It is not a simple task to optimize sportswear as regards thermo-physiological and sensorial comfort. On the other hand, leisure sports are characterized by the fact that maximum physical performance is not always achieved and that active phases are interspersed with rest phases. In addition, a leisure sportsperson often wears his/her clothing for several hours.

Over the past two decades the advances were made in technologies of spinning fibres and yarns, the production techniques for functionally designed knitted and woven fabrics as well as in the highly functional coating and laminating technologies. All these resulted in some of the most interesting fabrics which possess the desired qualities of good tactile properties, thermal insulation, stretch, quick liquid absorption ability to evaporate water while staying dry to the touch and being capable of transporting perspiration from skin to outer surface and then quickly dispersing it, the performance category that has seen as large number of innovations is that of moisture management, which is directly related to comfort.

These fabrics are engineered by using either micro porous or hydrophilic membranes, and the water vapour transmission through these membrane is achieved by the physical process of adsorption, diffusion and absorption. With the advanced technology, however, natural fibres like cotton and tencel are making a comeback in high-performance outdoor activities. For example, cotton can be made wind proof, breathable, and water resistant. For heavier fabrics, such as track suits and jogging suits, nylon, polyester, acrylic, and their blends with acetate, cotton and wool are used. These fabrics may be brushed inside for warmth and are cut loosely for comfort.

Knitted fabric is the most common fabric structure for base layer sportswear due to greater elasticity and stretchability compared to woven fabrics, which is very important for freedom of movement in sports[50]. With the possibility of various combinations of fabric constructions and yarns used, knitted fabric appears to be the ideal base for functionally adaptive sportswear. Knitted fabrics also mostly have uneven surfaces. This makes them feel more comfortable in the aspect of tactile sensations caused by the textile being in direct contact with the skin, in comparison to smooth-surfaced woven fabrics of similar fibre compositions. In addition, the smaller number of fabric contact points with the skin warranted by the uneven surface could also result in reduced clinging sensation when the skin is sweat-wetted[51].

It is now well established that no single fibre or blend of different fibres can make ideal sportswear. The pre-requirements of ideal sportswear are rapid transport of perspiration away from the body and then its rapid evapouration. This can be achieved by two or more layers of different fabrics. The next layer to the body acts as a rapid wicking layer and the layers above act to absorb this perspiration and evaporate the moisture rapidly. This evaporation takes the body heat away. To also take full advantage of two components 'integrated' knitted structures can be used which are better than single layer fabrics.

Competitive athletes are always looking for ways to improve performance and take a millisecond or two off their times or other measures of success. Accomplishing this by studying fabric types, how garments are constructed, and the effect that can have on an athlete has been going strong for the last decade—and a growing number of elite and Olympic athletes can confirm the efforts have been successful[52].

Moisture handling properties of textiles during intense physical activities have been regarded as major factor in the comfort performance. Actually the comfort perceptions of clothing are influenced by the wetness or dryness of the fabric and thermal feelings resulting from the interactions of fabric moisture and heat transfer related properties. For the garment that is worn next to skin should have

a) Good sweat absorption and sweat releasing property to the atmosphere, and
b) Fast drying property for getting more tactile comfort.

It has been found that frictional force required for fabric to move against sweating skin (resulting from physical activities, high temperature and humidity of surroundings) is much higher than that for movement against dry skin. Which means, the wet fabric, due to its clinging tendency, will give an additional stress to the wearer.

In removing the liquid sweat from the skin, some textile manufacturers claim that moisture absorbency of the fiber is important and hence cotton or viscose is a necessary component for the sportswear, which is next to the skin. While others say that fibers in these garments should not absorb moisture, so that moisture or perspiration is wicked away from the skin to outer layers of clothing from whence it can evaporate into atmosphere. However, a lot will depend on the degree of activity contemplated. In fact, so far as cotton is concerned, the synthetics should be preferred in clothing of active sports as they do not retain moisture and this has the advantage of keeping garments lighter than the cotton when it is wet. Also synthetic fibers have some added advantage of quick dry and good shape retention property. Most of the modern textile materials use the basic idea of capillary action for sweat absorption and fast drying.

Sports clothing can be worn for different reasons. In many sports protective clothing is worn, e.g. hockey gear protects against certain impacts. Clothing may also protect against the weather (mountaineering, skiing, sailing clothing). In many sports clothing is minimized however, in an attempt to limit any negative heat loss and motion (e.g. running). A long distance runner consumes about 4KJ kg $^{-1}$ km-1. If running time is 16km/h the metabolic rate (and heat production rate) is 471 W/m^2 for runner weighing 75 kg with a body surface is of 1.8m^2. Running for an hour at this speed in 30 ^{o}C and 60% relative humidity with minimal clothing (mini shorts) would allow a reasonable heat balance and just a small rise in core temperature. Putting on a running dress (shorts and T-shirt) reduces evapourative cooling as well as convective cooling. These various applications all relate to heat exchanges at the skin, either limiting or promoting it. Hence a good understanding of what happens at this interface is important for optimal sports clothing design.

Reducing clothing insulation and, in particular, water vapour resistance is another measure in order to improve heat balance and maintain performance. Reducing vapour resistance by 5 Pa m^2/W (20%) results in less heat storage and almost 2 ^{o}C lower increase in core temperature.

This would allow the runner to increase the running speed to about 16km/h and his performance is improved. The runner must be aware of this and select a garment with low vapour resistance as possible, as the gain is significant, in particular during heavy exercise in warm humid climates[53].