Chapter 5
Fibers for Sports Textiles

Muhammad Umair and Raja Muhammad Waseem Ullah Khan

Abstract Sports textiles mainly consist of both sportswear and sports equipment, because different natural and synthetic textile-fiber-based products are used in both categories. Sportswear has a vast range of wearing items which can be classified as sports-inspired wear, outdoor wear, performance wear, and leisure wear. Different functional fibers are used in sportswear to get desired results having different properties like comfort, thermal conductivity, cold and heat indices, and stretch and recovery. Similarly, there is a vast range of sports that include hiking, snow sports, cycling, mountaineering, hockey, baseball, squash, and sailing, using a range of sportswear for both fashion and functionality. The outfits and equipments used in these sports are also composed of different functional and high-performance fibers like polyester, acrylic, nylon, spandex, polyolefin, aramid, and carbon. For various attires' manufacturing, synthetic fibers and their blends with different natural fibers, i.e., cotton, hemp, bamboo, silk and wool, are also used. The advanced countries are using their strengths in the field of materials and engineering technologies to develop new functional fibers. Now a days, composite fibers and fiber reinforced composite material based light weight products are used in sports goods with improved strength and functionalities.

Sportswear has a wide range of wearing items that can be classified as sports-inspired wear, performance wear, and outdoor wear. Leisure apparel has great importance in the sportswear. The significant grown interest in active indoor and outdoor sports, and leisure pursuits resulted in a substantial increase in the consumption of textile fibers and fabrics in sports for two decades. There are so many factors due to which the interest is rising, including the growth of indoor and outdoor sports facilities,

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increased considerations of well-being and good health, increased leisure time, and functional sportswear [1].

5.1 Sportswear Sectors

There is a vast range of outdoor sports include football, tennis, hiking, snow sports, cycling, mountaineering, and sailing with a wide range of leisurewear for both fashion and functions. The main stakeholders of the textile industry are based on these product manufacturers who use the latest technologies. They use the most updated processes and advances in high-performance fibers and high-functional materials to complete the requirements of various types of consumers and market needs. A massive increase in female participation in professional and outdoor sport is also a high impact factor for the new trends in sportswear. In the global market, the volume for each product may vary according to the type of end-use applications. High-value products always stay at the top of the price scale with low volumes, and these products are very particular products in which quality, performance, and design are major determining factors. This segment of the textile industry is growing at a higher rate. Different textile materials solely or with a combination of other flexible materials are used to develop sports footwear, and sportswear for other types of sports, *e.g.*, football clothing, athletic clothing, skiing clothing, and protective clothing [2].

The largest market in the world for sportswear is the United States, which comprised the one-third of the overall global sale and China is 2nd largest market with a 10% share. The economic growth of BRIC (Brazil, Russia, India, and China) is significant in recent years, and these countries have a powerful effect on the trade of sportswear [3].

5.2 Fibers Used in Sportswear

Fibers have a wavy structure that is responsible for many characteristics of the fabrics that have a significant value for the performance of sportswear and functional clothing. Sportswear is a combination of multiple attributes; for example, it gives functional support, protects the athlete from injury, enhances performance, promotes sporting activity, and offers the wearer comfort. The most crucial factor that contributes to the comfort of the wearer is moisture and thermal balance which results in proper micro-climate of the skin. Natural silk fiber has long been a valuable commodity. After the discovery of Nylon fiber, Du Pont Co. started its production in 1939 [1]. Both natural and synthetic fibers are used in sportswear. The details of a few of these fibers are discussed in the following sections.

5.3 Natural Fibers

5.3.1 Cotton

Cotton is characterized as a white stringy strand covering seeds collected from the cotton plant [2]. It is gathered from the plant by handpicking or by machine picking. Cotton is the most significant fiber in the material world. Various assortments of cotton are being utilized in the sports industry [4]. Cotton fiber has large amorphous portion and this is why the air can be in and out through cotton fiber. So, the fabric made by cotton fiber is quite comfortable to use.

5.3.2 Hemp

Hemp is one of the long-lasting fibers in terms of performance. A linen-like drape, hemp is commonly used separately or in combination with other fibers in some outdoor products [5]. Ropes are one of the most important pieces of gear for mountaineering and one of the first to be used to secure climbers. Originally they were crafted from natural fibers such as hemp or manila ropes [6]. Hemp is used to make a variety of commercial and industrial products, including rope, textiles, clothing, shoes, insulation, and biofuel.

5.3.3 Bamboo

Bamboo is one of the world's fastest-growing plants, growing in around three months to a maximum height, reaching maturity in 3 and 4 years and spreading rapidly over large areas. The fiber origin is currently being advertised as an eco-green-sustainable fiber, due to the relatively fast-growing and the ability to grow without fertilizers or pesticides. Bamboo fabric is soft, durable, with properties that are moisturizing and insulating. It also has some antibacterial properties and is resistant to odors. For items such as casual sportswear, base layers, t-shirts, and yoga clothes, bamboo fiber is commonly used [7].

5.3.4 Wool

Wool is a protein-based fiber that usually comes from sheep and other animals, including goats and llamas. Wool and its blends can be used in knitted, woven, and felt constructions as well as accessories throughout the sports layering process. [8]. The amount of crimp corresponds to the fineness of the wool fibers. A fine wool

like Merino may have up to 40 crimps per centimetre (100 crimps per inch), while coarser wool like karakul may have less than one (one or two crimps per inch).

5.3.5 Silk

Silk is derived from silkworms that live on mulberry leaves in large trays, usually indoors. This sort of silk is called cultivated and is produced on large farms owned by industry. The silkworms are bred humanly, which means that the wild silk cocoons are harvested using natural methods only after the cocoon spontaneously emerges from the moth [9]. Several kinds of wild silk, produced by caterpillars other than the mulberry silkworm, have been known and spun in China, South Asia, and Europe since ancient times. E.g. production of Eri silk in Assam. However, the scale of production was always far smaller than for cultivated silks. The process of silk production is known as sericulture. Silk has a smooth, soft texture that is not slippery, unlike many synthetic fibers. Silk is one of the strongest natural fibers, but it loses up to 20% of its strength when wet.

5.4 Synthetic Fibers

5.4.1 Polyester

In 1993, cooperation between Patagonia and Malden Mills led to the early development of recycled polyester fiber (from Wellman Inc.) for use in Synchilla fleece made from plastic soda bottles that diverted waste from landfills. PCR filament yarn was later made from 30 to 50% post-consumer products (containers, polyester uniforms, tents and clothing) for linings and shell fabrics. At the end of life, the fabric could be recyclable if it consists of one form of fiber. Consumers may, in theory, return a polyester garment for transmission to a processor to be made into fiber or downgraded to other plastic types. Polyester is a synthetic petroleum-based fibre, and is therefore a non-renewable carbon-intensive resource. Polyester fibers are sometimes spun together with natural fibers to produce produtc with blended properties. Cotton-polyester blends can be strong, wrinkle- and tear-resistant, and reduce shrinking. Synthetic fibers using polyester have high water, wind and environmental resistance compared to plant-derived fibers. For sportswear, polyester is favored due to its lightweight, inexpensive processing, slow dyeing, longevity, easy-care properties, fast drying, hydrophobic for nature, and wicking. However, the hydrophilic coating can be given to the polyester filament fabrics. Therefore, with its hydrophobic center and hydrophilic coating, polyester fiber-based fabrics allow it to wick moisture away from its skin-to-outer surface contact with the environment. Polyester is

often combined with other natural fibers to extract its benefits to maintain moisture control and longevity.

5.4.2 Spandex

The typical elastomeric fibers classification process is based on elastic elongation and chemical composition. Elastomeric fibers based on polyurethane show the extensive range of elongation and elastic recovery efficiency. Unlike spandex, this type of fiber contains more than 85% segmented polyurethane formed by a diisocyanate reaction with polyethers or polyesters and subsequent polyurethane unit cross-linking. Spandex is used in various sportswear because it is lightweight and provides the ability to move freely [10, 11]. The elasticity and strength (stretching up to five times its length), of spandex has been incorporated into a wide range of garments, especially in skin-tight garments. A benefit of spandex is its significant strength and elasticity and its ability to return to the original shape after stretching and faster drying than ordinary fabrics. For clothing, spandex is usually mixed with cotton or polyester, and accounts for a small percentage of the final fabric, which therefore retains most of the look and feel of the other fibers.

The major categories in which spandex fiber is used are; (a) Athletic/aerobic/exercise equipment (b) Socks and tights (c) Tracksuits and tops (tennis/polo) (d) Cross-country running suits (f) Professional swimwear (g) Running jerseys and shorts.

5.4.3 Acrylic

Acrylic fabric is lightweight, warm, and soft to the touch. Acrylic fiber is usually blended with natural wool fibers or used to mimic wool not for its properties. There are now at least 30 different acrylic fibers [12]. Many of them, including Acrilan, Courtelle, Creslan, Dralon, Zefran, Verel, Crylor, etc., are already well known [13]. Similarly, in Modacrylic fibers the fiber-forming material is any long chain of a synthetic polymer composed of less than 85%, but of acrylonitrile units at least 35% by weight [13, 14].

5.4.4 Nylon

Nylon 6 and Nylon 6,6 are the most common forms. Nylon 6 is made of caprolactam, which is produced through a series of reactions using coal tar materials. The resulting filament is not going to be strong enough and has very high extensibility. Monofilament is of great strength and smoothness single, strong strand of filament. In the

form of monofilaments, approximately 90% of all polyamide fibers are processed. In car tires, fishing ropes and networks, gliders tow ropes, sailing clothes, conveyor belts, carpets, tapestries, draperies, nylon fibers are used [15, 16].

5.4.5 Polyolefins

The two most important polyolefin fibers are polypropylene and polyethylene. Polyethylene has a simple, linear chain structure consisting of a backbone of carbon and small side groups of hydrogen. Such a structure makes crystallization simple. There are three common grades of polyethylene. Polyethylene with low density (LDPE), polyethylene with high density (HDPE) and polyethylene with high molecular weight. It is the type of ultra-high molecular weight polyethylene used to make high modulus fibers. The UHMWPE fibers are high strength and high-modulus fiber, which give them commercial importance [17]. Fibers of less than 0.3 dTex (denier) thickness are considered microfibers. Because of their high surface area compared to ordinary fibers, microfibers find their use in air filters, dust wipes, etc. Polyester and nylon are currently used in the production of microfibers. Yet grades of rayon and acrylic goods micro-denier' are on the horizon. As long as micro fiber technology has been around, ultra-micro fiber technology has existed as well. These are fibers that are less than 0.3 dtex, especially within the 0.1 dtex range. Such fibers can be made using several different processes, all requiring the breaking of a larger fiber into many smaller ones [18]. Ultra-fine linear density (less than 0.1 dtex/f), fineness lower than the finest silk. It has a very soft and luxurious hand with a touch of silk or suede. Microfibers dry in one-third of the time as compared with the ordinary fibers. Microfibers are friendly to the environment [19, 20].

5.4.6 Advanced Thermo-Regulation Fibers

Thermo°Cool® is a combination of channeled shaped fibers, and hollow fibers create additional fiber spaces that enable better air circulation and significantly improve the evaporation capacity of the product. Outlast: The fiber includes Outlast PCM (phase change materials) [21]. These fibers are spun into yarns and are intended for those fabrics that are worn next to the skin. The Outlast® technologies uses the PCM that absorb, store and release the heat for optimal thermal comfort. Outlast® technology has the ability to continually regulate skin's microclimate. As the skin gets hot, the heat is absorbed, and as it cools, that heat is released. Similarly, Outlast® Technologies, commonly referred to as Outlast, also develops and sells phase change materials (PCMs) in the United States and internationally. Outlast offers Thermocules, a microencapsulated phase change materials, which are incorporated into fabrics and fibers for absorbing, storing, and releasing excess heat. The company's products

comprise temperature regulating textiles, fabrics, fibers, and knits. Its products are used in outdoor sports, bedding, apparel, and footwear applications.

5.4.7 Carbon Fiber

Carbon fibers (alternatively CF, graphite fiber) are fibers about 5–10 micrometers in diameter and composed mostly of carbon atoms. Carbon fibers have several advantages including high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion. These properties have made carbon fiber very popular in aerospace, civil engineering, military, and motorsports, along with other competition sports. The carbon (diamond-type) has a covalent structure and is an extremely hard material. Buckminster Fullerene or Buckyball, with a molecular composition such as C60 or C70, and carbon nanotubes, are the latest additions to various forms of carbon. Carbon nanotubes (CNTs) are short, thin carbon atom cylinders structured in a graphic lattice structure. These contain carbon nanotubes that are single-walled and multi-walled.

Nevertheless, it is vital to study the basic structure and characteristics of graphite to understand these aspects of carbon nanotubes [22]. These are usually between 5 and 20 nm in diameter and between 1 and 100 μm in length, which gives them a very high aspect ratio [23].

5.4.8 Aramids

In 1965, Stephanie Kwolek, a DuPont research scientist, discovered that, under certain conditions, para-aminobenzoic acid could be polymerized and solubilized to form a spinnable rigid-rod liquid crystalline solution. This finding can be known as the beginning of aramid fibers. The polymer obtained through the reaction of p-phenylenediamine and terephthalic acid was later found to be stronger. It should be noted that researchers at Monsanto made important contributions, but Monsanto chose not to sell an aramid fiber [24]. Aramids are mostly available in two types i.e. para-aramid and meta-ramid. Aromatic polyamides were first introduced in commercial applications in the early 1960s, with a meta-aramid fiber produced by DuPont as HT-1 and then under the trade name Nomex. It has excellent thermal, chemical, and radiation resistance for a polymer material. In 1973 DuPont was the first company to introduce a para-aramid fiber, which it called Kevlar, to the market; this remains one of the best-known para-aramids and/or aramids. In 1978, Akzo introduced a similar fiber with roughly the same chemical structure, which it called Twaron. Due to earlier patents on the production process, Akzo and DuPont engaged in a patent dispute in the 1980s. Twaron subsequently came under the ownership of the Teijin Company. In 2011, Yantai Tayho introduced similar fiber which is called Taparan in China.

5.5 Properties Required in Sportswear

Clothing is a basic human need that protects the body from environmental and climate hazards. In technical terms, features are required that relate to the functionality rather than just the basic requirement. High performance is a desirable attribute that requires calming activity for professionals. High-performance textiles cover a wide range of textiles that focus on the end-use breath of operation. These include different categories such as textiles for personal protection, textiles for the protection of medical health, and textiles for the protection of sportswear. Protective textiles are necessary to fulfill the practical clothing specifications laid down in the relevant regulations. From using natural fibers, there has been a shift from using more synthetic fibers for high-performance textiles [25]. Following major properties are required in the fibers for sportswear applications:

5.5.1 Comfort

The term comfort is defined as "a lack of discomfort" or "a neutral state as compared to a more active state." Comfort can also be described as an enjoyable state of sensory, psychological, and thermo-physiological harmony between humans and their climate. The ease of the wearer is linked to the wearer's sensational discomfort when the skin is touched by part or with the whole garment. These include sensations of tactile, thermal, and moisture. For functional operation and quality, movement is essential. Clothing designs, therefore, need to integrate versatility features. The wearer's physiology and the role to perform are vital to the wearer's safety and comfort [17].

5.5.2 Temperature and Wind

There have been several attempts to include the physical weather parameters (temperature, wind, relative humidity, and radiation) in a single climate chart. Windchill is also a combination of ambient temperature and wind speed. Windchill can be used to predict the risk of exposed skin freezing and to predict a decrease in manual dexterity. As a cold injury risk estimator, the wind chill index is part of an ISO standard (11079, 2007). For heat, by increasing convective and evaporative heat loss, the wind has a cooling effect [26]. High humidity increases air thermal stress and does not matter to the cold. Leithead and Lind (1964) published a list of all fatal heatstroke events in the United States. A straight line beyond which the casualties occurred can be drawn. The combination of ambient temperature and relative humidity is referred to as the United States' heat index (HI) and Canada's humidex [27, 28, 29].

5.5.3 Sustainability

Sustainability is a broad discipline, giving insights into most aspects of the human world from business to technology to environment and the social sciences. Sustainability is one the newest degree subjects that attempts to bridge social science with civic engineering and environmental science with the technology of the future. When we hear the word "sustainability" we tend to think of renewable fuel sources, reducing carbon emissions, protecting environments and a way of keeping the delicate ecosystems of our planet in balance. In short, sustainability looks to protect our natural environment, human and ecological health, while driving innovation and not compromising our way of life. It focuses on meeting the needs of the present without compromising the ability of future generations to meet their needs. The concept of sustainability is composed of three pillars: economic, environmental, and social—also known informally as profits, planet, and people.The sustainability movement has contributed to a reduction in the use of petroleum-based materials to partially plant-based products. For example, in protective clothing, such as Sorona fabrics, plant-based fibers and fabrics are used. By 2030, the climate impact of the apparel industry alone is forecasted to almost match today's annual US greenhouse gas emissions, emitting an equivalent of 4.9 gigatonnes of carbon dioxide. Choosing recycled polyester, local or organic cotton and water-saving fibers such as Tencel and hemp, has a lower environmental impact. It also sends a clear message to producers, that there is a high demand for eco-friendly products. In order to make a positive environmental impact, recycling, shifting to renewable energy, eco-friendly processing methods, smarter design, and efficient consumption methods are crucial.

5.5.4 Cold Weather Sports Clothing

Outdoor sports are often carried out under harsh environmental conditions. In Antarctica, the lowest temperature ever recorded on Earth was −89.2 °C. Professional athletes and an increasing number of amateur athletes, either in polar or mountain regions, are subjected to climatic conditions with very low temperatures. The sportswear must offer the best possible comfort in addition to providing full cold protection. The main challenge is to preserve the clothing's thermal insulation in all climatic conditions, especially in the presence of wind [1].

5.5.5 Moisture Production and Transport

One of the most important factors to consider in the cold is the development of the body's moisture and how this moisture is transferred through the layers. The condensation of water vapor in the clothing and the accumulation of this condensation

will determine the clothing's thermal insulation, as the water's thermal conductivity is about 25 times greater than that of air.

Sensitive suddenness is produced by the sweat glands and depends on factors such as age or fitness level. The amount of water vapor transferred through the body depends on the relative humidity of the skin and, more specifically, on the disparity of water vapor pressure between the skin and the atmosphere, reaching approximately 20–25 g/h for a person under standard environmental conditions (20 °C, 50% RH) [30].

5.5.6 Thermal Insulation

As air is one of the strongest insulators, the main goal of cold defense clothing is to absorb as much air as possible between the various layers of clothing and to prevent air movement and transfer of heat between the layers of skin. A mixture of three or four layers is the most common concept in cold weather sports clothing. These layers consist of a skin-friendly base layer (underwear), one or two middle layers, mainly used for thermal insulation and an outer shell for weather protection (i.e., wind and rainfall). The number of (middle) layers can be increased when required in icy conditions; we can see on the market clothing concepts consisting of six or even seven layers [25].

5.5.7 Mechanical Properties

These are some mechanical properties that can affect the performance of fibers as well as sportswear. A small diameter is relative to its size of a grain or another microstructural unit. This helps in a bulk form to achieve a higher fraction of the theoretical strength than that possible. This is a direct consequence of the so-called size effect, whereby the smaller the scale, the lower the probability of getting a critical scale imperfection that would consequence in material failure. Therefore, its strength decreases even for material in its fibrous form as its diameter increases. A very high degree of flexibility that is always a hallmark of a high-modulus material with a small diameter. This versatility allows for the use of a range of techniques for producing composites with these fibers that are reinforced with fabrics, chains, cords, and threads. A high aspect ratio (length/diameter) that allows transferring a very large fraction of the applied load into the rigid and robust fiber in a fiber-reinforced composite through the matrix. A fibrous material has the most distinctive characteristic of having properties that are strongly biased along its length. A fibrous material having high aspect ratio and may be highly flexible. It is possible to produce such a versatile fiber into yarn, which in turn can be braided, knitted, or woven in very complex shapes and forms [31].

5.5.8 *Stretch and Recovery*

Because of the increased comfort demand, the stretch fabrics have become a standard in sportswear apparel. Elastomeric structures are used to improve comfort of the fabrics in sportswear. The market is becoming more attractive for tighter compression garments. The natural movement of the body stretches the skin by 10–50% and the strenuous movement in sports would require less resistance from clothing and rapid recovery.

5.6 Fibers for Sports Equipment

The sporting goods industry in the later decade of the twentieth century was a boom to the advanced composites market. Today, in seven of the ten most popular outdoor sports and recreational activities, composites are used in items. In skis, fishing rods, bowling balls, tennis rackets, spars/shafts for kayak paddles, windsurfing masts and frames, hockey sticks, kites, and bicycle handlebars, glass and carbon-reinforced composites (alone or in combinations with other fibers) tend to substitute wood and iron. Market research firm Lucintel (Irving, TX, US) predicts a retail value of US$ 5 trillion in the international sporting goods sector, taking in US$ 110 billion/year alone in the United States. Bicycles remain the highest-profile market for the use of composites. In other words, the use of composites in bikes is important as it allows for significant weight savings, so the less material used is better. The challenge facing by the bicycle manufacturing industry is the lack of strictly enforced standards for the design and manufacture of carbon fiber composite bike frames. In the watersports market, there has recently been significant activity, particularly in the area of stand-up paddleboard fins. Composite World has covered many applications in which concerns about customer-specific performance standards and increasing respect for the safety of their environment by participants in watersports have come together in innovative composite designs.

5.7 Composite Materials-Based Sports and Equipment

Skis board, skiing, and snowboards are made up of composite materials that are directly linked to the safety and quality of life of the participants, and the construction of the skis and the material is more complicated. Wooden light and cheap, but it is out of shape to be easily affected by humidity. Ski fiber composites are ideal for any kind of ice, snow and easy maintenance.

5.7.1 Surfboard

The surfboard is a critical piece of equipment for surfing. Since the Hawaiians began surfing on wooden planks, the modern surfboard has come a long way in design and construction. The modern surfboard is light and solid, handmade from foam by professional shapers, and finished with a coat of fiberglass. But this isn't a static art; surfboard design's cutting-edge shifts as quickly as a cold surfer does on a windy day. Surprisingly, though it may seem, the material science of "fast" windsurfing boards is as sophisticated as racing boats. The board's base consists of an extruded foam polystyrene filler wrapped in fiberglass as shown in Fig. 5.1 [32]. Many spun graphite fiber strands embedded in a PVC resin matrix are wrapped around the heart. In turn, four layers of high-stiffness E-glass fiber weave enclose this PVC/fiber composition. Finally, the whole is contained within a composite of glass-fiber-reinforced epoxy, with Kevlar's extra fiber reinforcement in parts likely to be exposed to additional wear and tear. Obviously, only specialist companies can manufacture surfboards of this complexity. Some enthusiasts, however, like to build their panels. Kits can be purchased using extruded foam polystyrene (EPS) as a core product from which boards are made. This is then lined with resin-shaped glass fiber (or Kevlar fiber) weaving. More recently, a moldable polyethylene copolymer was used to make simplified surfboard constructions [6].

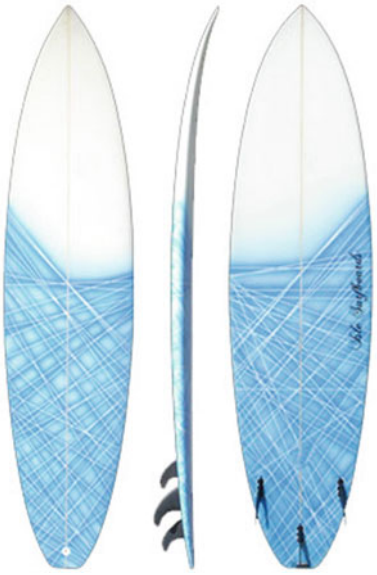


Fig. 5.1 Surfboards

5.7.2 Sailing Boat

A boat is, as we all know, a form of watercraft primarily designed to travel in near-shore areas or inland waterways such as rivers and lakes. Of course, what makes a boat different from a ship is its smaller size, and less ability to carry compared to the latter. However, a boat's definition—its size, shape, and capability—varies by purpose. Kevlar helps to make hulls lighter, stronger, and much less likely to break under pressure. Although a boat is described in the modern naval terms as a watercraft that is small enough to carry a ship abroad, some boats are measured up to 1,000 feet long. Likewise, several boats are intended to provide service, not in near-shore areas, but the offshore setting. Canada Spirit Open 60 yacht, as shown in Fig. 5.2 [33], took part in the 2008 Vendome round-the-world solo challenge [6].

Fig. 5.2 Sailing and boating

Fig. 5.3 Hiking shoes

5.7.3 Hiking Shoes

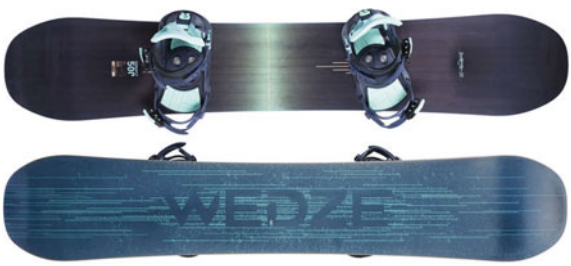
The difference between walking and hiking is grim. While both activities include walking on foot, many people classify themselves as merely walkers or hikers. Comparing the two events and opposing them helps to differentiate the two. Hiking boots are specially made footwear that protects the feet and ankles during outdoor walking activities such as hiking. They are one of the hiking gear's most valuable things, as their consistency and reliability can determine the ability of a hiker to travel long distances without injury. Manufacturers of hiking boots shown in Fig. 5.3 [34], use Kevlar for durability in uppers, soles and laces.

5.7.4 Snowboard/Ski Board

Manufacturers of snowboards like shown in Fig. 5.4, use Kevlar as a building material to help increase board stability, reduce chatter (vibration), and reduce weight. Kevlar helps decks keep their "pop" longer in skateboards and resist breakage. Kevlar is used for lightweight impact and abrasion resistance surfboards [6].

Kevlar helps make high-performance skis and ski boots smoother, stiffer, and more flexible and improves vibration damping. The qualities expected for high-performance skis are speed, stability, and good maneuverability. Kevlar tubing

Fig. 5.4 Snowboards



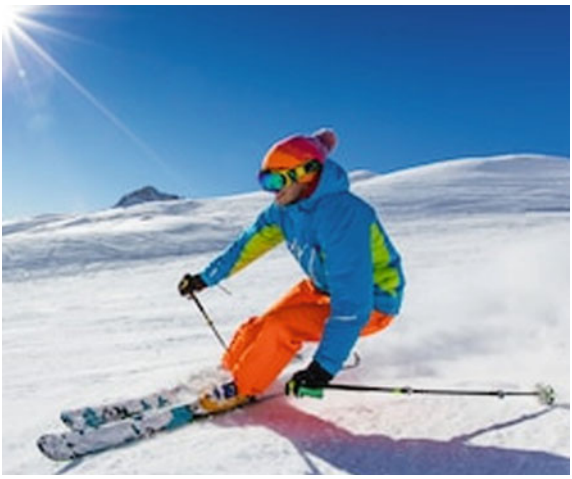


Fig. 5.5 Skis boards

allows ski poles as shown in Fig. 5.5, to be lighter, stronger, and more stable. Kevlar provide lightweight protection for racers for gloves used in slalom competitions [6].

5.7.5 Bicycle

The stick with carbon fiber tube and aluminum alloy joint was developed in the mid-1980s by Italy, France, Britain, and the United States. Its frame is chrome-molybdenum steel frame which is lightweight and strong, and its stiffness is higher than a normal steel frame. The well-known German rider, who won the Ulrich/mount men's cycling road race, is made of carbon fiber-reinforced composite material support, just 715 kg of weight. The products used for the bicycle as shown in Fig. 5.6 [35], frames are dominated for production roadsters by steel and steel alloys such as low or medium carbon steels or for competition cyc1es chromium-molybdenum-manganese steels. Certain components are made of copper, steel, titanium, and fiber/epoxy carbon composites.

The construction of the bicycle frame is a challenging environment for applying the new lightweight composite materials. Such new materials provide the frame with a lightweight structure with very high strength and durability, high rigidity, and excellent resistance to fatigue and corrosion. These include high rigidity (carbon fibers), better resilience (Kevlar fibers), and enough resistance to damping (ceramic fibers) [6].

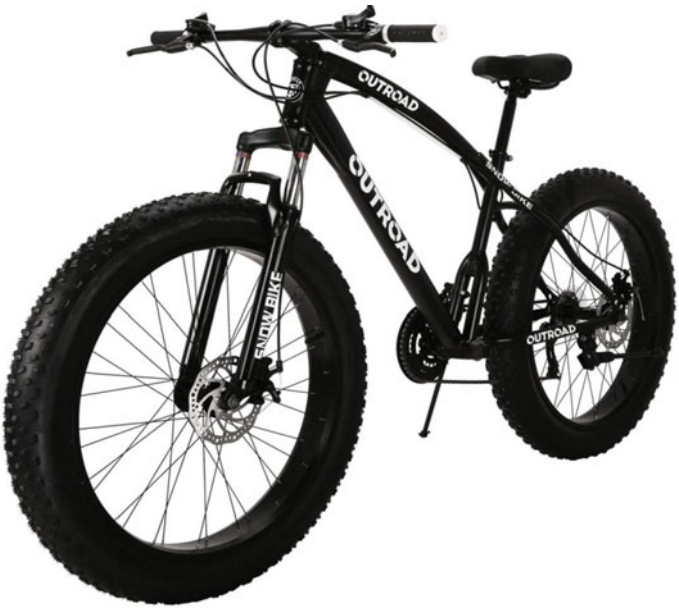


Fig. 5.6 Bicycle made from high-performance fibers

5.7.6 Sports Racket

Today's world's big, middle-class tennis rackets are made mostly of carbon fiber composite materials. Several companies like the United States Chemold used carbon fibers in a tennis racket. Big tennis rackets as shown in Fig. 5.7 [36], can be made of carbon fiber composite materials, which has better shock-absorbing performance. Compared to other materials, carbon fiber used in tennis rackets has different advantages; creates a large tennis racket: wood compared to the past, under the same weight, the racket area can increase about 115 times, the cable tension rises by 20–45% on average.

Kevlar construction in tennis, racquetball, squash, and badminton racquets, as shown in Fig. 5.8 [37], prevent cracking and breakage. Kevlar strings do not stretch,

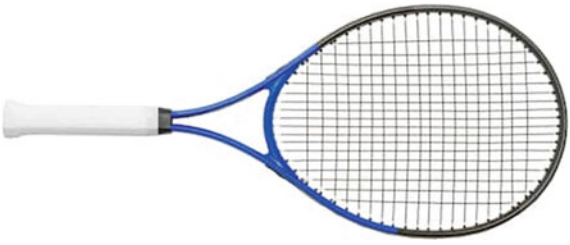
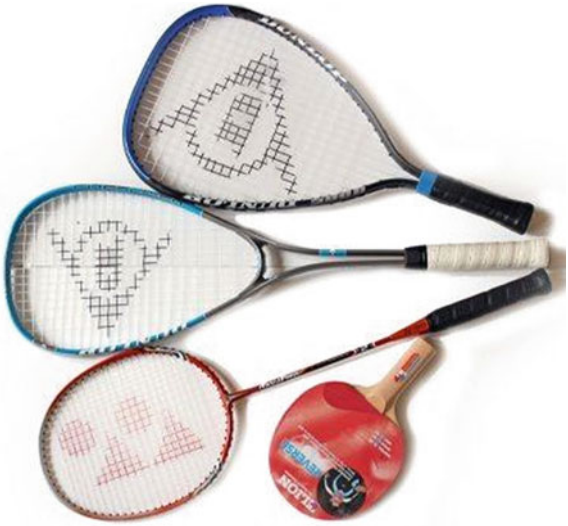


Fig. 5.7 Different types of rackets

Fig. 5.8 Tennis racket

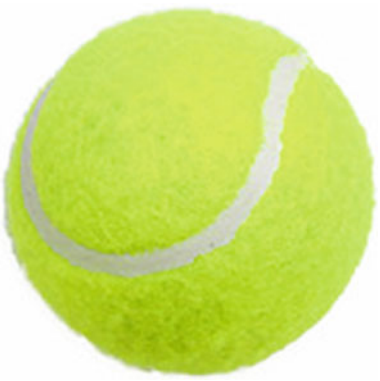


and split less often than traditional strings. Kevlar is also used for vibration-damping purposes, and to protect against damage to the carbon fiber, the leading protection of ultra-rigid lightweight tennis rackets. Many tennis shoe models on the upper toe portion have used Kevlar to prevent the abrasion that occurs when players drag their toes during a serve.

5.7.7 Tennis/Squash Balls

Originally made of a solid rubber core, tennis balls are covered by a flannel stitch, as shown in Fig. 5.9 [38]. This was subsequently improved by hollowing the core

Fig. 5.9 Tennis ball



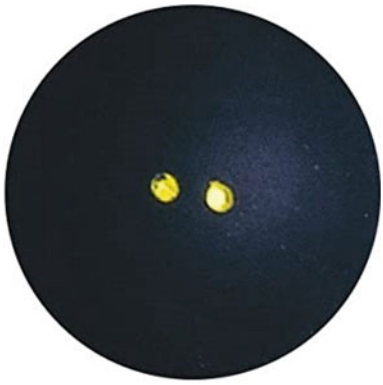


Fig. 5.10 Squash ball

and pressuring it with gas. Chemicals that generate gas inside the ball are added before the balls are sealed. To achieve a uniform thickness of the wall and a high degree of reproducibility, it is necessary to mold the separate twin half-shells. A synthetic nylon and wool composite now replaces the flannel cloth, and a vulcanized rubber seam replaces the cloth stitching used earlier. High-styrene resin, cellulosic fillers, aramid plastic resin, and (recently) unsaturated carboxylic acid copolymers (combinations of two or more polymers) are used in balls. The outer casing cloth has a high content of wool (50–60%), but nylon fibers make up the balance of the fiber content for optimum bounce properties.

Like tennis, squash players have four different ball styles to choose from, each varying in size, weight, and rebound properties. Besides these variations, a squash ball's dynamic behavior is also affected by the court wall's temperature and material. Therefore, an acceptable surface friction value is required to create the right rebound angle array. In particular, the high deformation of an impacted squash ball requires excellent durability for the joint between the ball's two half-shells. Squash balls, as shown in Fig. 5.10 [39], have traditionally been made of carbon-black impregnated rubber compounds that tended to mark the squash court's walls. Most balls, however, are now based on polymer materials. A squash ball's manufacturing process is not the same as a tennis ball; however, the exact specification of the material is a closely guarded secret.

5.7.8 Hockey

Many players in ice and field hockey opt for reinforced Kevlar sticks because they help them to be lightweight and keep their shape better than fiberglass or wood, as shown in Fig. 5.11 [40]. Kevlar helps to prevent a sharp break when a stick breaks, which can injure another player. Goalie masks use Kevlar for both ice hockey and field hockey, as it helps with resistance to light impact. Kevlar even helps to protect

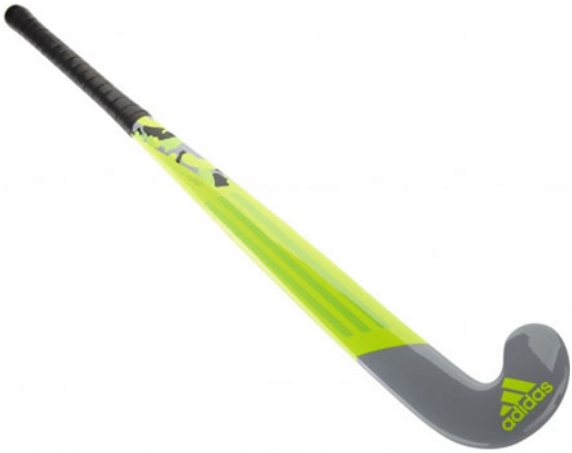


Fig. 5.11 Hockey stick

spectators. It is woven into the big nets hanging between the ice rink walls and the fans sitting on the path of errant shots [6].

5.7.9 Motorbike Racing

A motorcycle is a two-or three-wheeled motor vehicle, also called a motorbike, cart, or cycle. Motorcycle design varies widely to suit a range of purposes: long-distance travel, commuting, cycling, a sport like racing, and off-road riding. Stiffness, impact tolerance and thermal abrasion tolerance have made Kevlar more popular with motorcycle component manufacturers and protective clothing manufacturers. Kevlar can be used in motorcycle tires, wheels, drive belts, composite parts, shoes, jackets, gloves, and helmets, as shown in Fig. 5.12 [41].

5.7.10 Baseball

Baseball bats shown in Fig. 5.13 [42] made with Kevlar have improved vibration damping, slower swing speed, and a more prominent "sweet spot" on the part of the bat where hitters prefer contact with the ball.

5.7.11 Canoes and Kayaks

Many canoeing types are known and used as sports include canoe sailing, canoe polo, playboating, intense surfing, whitewater slalom, and surf skiing. Some recreational

Fig. 5.12 Racing motorbike

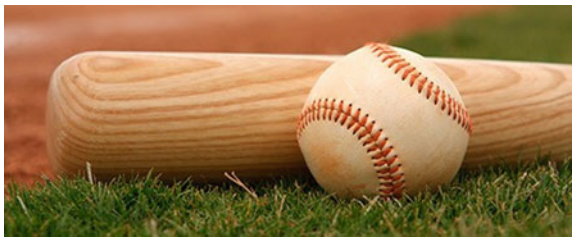


Fig. 5.13 Baseball and baseball bat

uses include small-scale sailing, whitewater, sea kayaking, and canoeing. Hulls of Kevlar made canoes and kayaks, as shown in Fig. 5.14 [43], are easier to carry and navigate because they are lighter than those built from other materials, with better

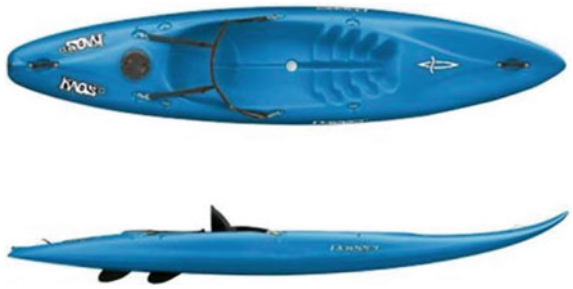


Fig. 5.14 Canoes and kayaks

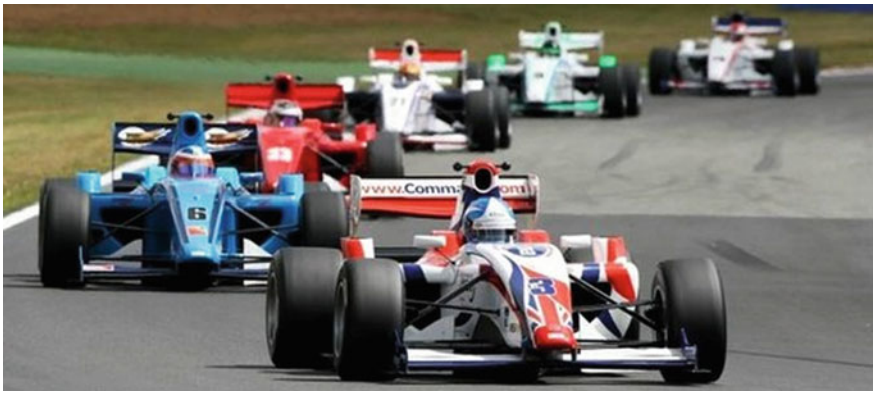


Fig. 5.15 Formula 1 racing Car

impact resistance. Besides, placing Kevlar in paddles helps to increase strength, durability, and resistance to impact.

5.7.12 Racing Cars

For NASCAR ® racecar bodies and air barriers, Kevlar fiber replaces fiberglass-reinforced plastic because it does not crack or leave debris on the ground after a collision, which can lead to improved protection and shorter delays. Kevlar® is used in the HANS system. This lifesaving reinforcing attachment protects the driver's head and neck, which helps to withstand impact forces that are powerful enough to destroy the vertebrae of the neck. For greater comfort and safety, helmets, suits, and gloves use a combination of Kevlar fibers and DuPont™ Nomex ® flame-resistant fibers. Formula 1 cars, as shown in Fig. 5.15 [44], use Kevlar belts to help retain wheels that fall off during collisions, stopping them from flying off the track and into the stands.

5.8 Conclusions

The advanced countries have been using their strengths in the field of materials and engineering technology in recent years. The application of composite materials in the field of sporting goods has rendered remarkable accomplishments unceasingly. For example tennis racket skeleton is made using carbon fiber, aramid fiber, or ceramic fiber-reinforced composites. Ski sticks are developed with laminated composite materials. Paddle, golf, and hockey sticks are also developed using advanced composite materials. In the area of sports equipment, fiber-reinforced

composites have developed a larger market. The tougher standards are that the fiber-reinforced composite material added to the sporting goods, is the standard in the growth of the sporting goods industry in the twenty-first century. Kevlar has become a popular choice for both equipment manufacturers and customers in the search for lighter, and stronger, sporting goods. Even appealing to athletes, outdoor enthusiasts and anyone else looking for better performance in sports goods.

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