# Part I

## Current sportswear market

# 2
# Market overview

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## 2.1 Introduction

To understand the scale of development of textiles in sport, it is necessary to appreciate the extraordinary development of sport itself and its all-encompassing nature. As leisure pursuits expand, so must the use of textiles to service this market, which must surely also include sport. The crossover between sport and leisure is blurred. It is no longer sensible to take a purist's view of what constitutes sport and what constitutes leisure. Is the highly trained professional marathon athlete taking part in sport while the weekend jogger is following a leisure pursuit? Is the high-tech fabric produced for the professional athlete to be denied to the amateur?

To fully comprehend a global market edging its way towards a value of US$100 billion it is necessary to appreciate where it has come from and to be aware of the opportunities which sport (and leisure) provides for the further development of 'textiles in sport'.[1]

Whilst the textile market is a matter of serious business, it should not be forgotten that sport and leisure are essentially about fun and well-being. This should not be overlooked, and one should not overlook, either, the potential in new, refreshed or modernised sporting activities. Almost without fail, every year sees new ways of putting excitement into the market, taking simple sports to new extremes of physical effort or endurance. As each new concept arrives, the market for textiles in sport expands and, as niche markets develop in specific sports, so new twists can be added to the textiles needed to meet the demands of the innovators.

There are figures available on participation in individual activities which, however, may be marginally distorted by what is fashionable and new (see Table 2.1). Some sports endure whereas others are more transitory in their appeal (see Table 2.2). Some individual markets may be too small for manufacturers of bulk merchandise, but might be seen as profitable by others wishing to develop a niche market, such as polo. It is assumed that this sport attracts the rich, those who are familiar with luxury brand names, but a little research will show that it

*Table 2.1* Sports/activity in the United States: participation numbers in 2003

| Sports/Activity | Participants aged 6 and above (in millions) |
|---|---|
| 1 Bowling | 55.0 |
| 2 Treadmill exercise | 45.6 |
| 3 Fishing – freshwater, others | 43.8 |
| 4 Stretching | 42.1 |
| 5 Tent camping | 41.9 |
| 6 Billiards/pool | 40.7 |
| 7 Day hiking | 39.1 |
| 8 Fitness walking | 37.9 |
| 9 Running/jogging | 36.2 |
| 10 Basketball | 35.4 |
| 11 Dumbbells | 30.5 |
| 12 Weight/resistance machines | 30.0 |
| 13 Hand weights | 29.7 |
| 14 Calisthenics | 28.0 |
| 15 Golf | 27.3 |
| 16 Barbells | 25.6 |
| 17 Darts | 19.5 |
| 18 Inline skating | 19.2 |
| 19 RV camping | 19.0 |
| 20 Stationary cycling (upright bike) | 17.5 |
| 21 Abdominal machine or device | 17.4 |
| 22 Tennis | 17.3 |
| 23 Ice skating | 17.0 |
| 24 Soccer (outdoor) | 16.1 |
| 25 Horseback riding | 16.0 |
| 26 Fitness swimming | 15.9 |
| 27 Hunting – rifle | 15.2 |
| 27 Fishing – saltwater | 15.2 |
| 27 Target shooting – rifle | 15.2 |
| 30 Softball – regular | 14.4 |

It is worth noting that, in the 2003 survey, 12 of the top 30 sporting activities are fitness related.

Source: SGMA International, *Sports Participation Topline Report 2004*

is a game played by relatively few people in a handful of countries and the volume of specialised clothing required is very limited. An ordinary polo shirt, to be found in almost any clothing store, will suffice on the field.

Thinking back sixty years, the demand for sports textiles was limited, and there were few if any cycling gloves, specialised footwear and certainly very little in the way of protective coverings for knees and elbows. There were no special insert pads for shorts, no gel-moulding saddles. There were no elastane riding shorts which would help reduce muscle fatigue, and definitely no aerodynamic helmets. Golf clubs often were made of hickory shafts or early forms of tempered steel. Carbon fibre was a long way off. Today the wealth of

*Table 2.2* Trends in selected sports participation analysed over a 16-year period in the United States (in '000s)

| Activity | 1987 | 1993 | 1998 | 2002 | 2003 | 1-year %change | 16-year %change |
|---|---|---|---|---|---|---|---|
| Aerobics[1] | 13,961 | 10,356 | 7,460 | 5,423 | 5,875 | +8.3 | −57.9 |
| Pilates | n.a. | n.a. | n.a. | 4,671 | 9,469 | +102.7 | n.a. |
| Baseball | 15,098 | 15,586 | 12,318 | 10,402 | 10,885 | +4.6 | −27.1 |
| Basketball | 35,737 | 42,138 | 42,417 | 36,584 | 35,439 | −3.1 | −0.8 |
| Volleyball[2] | n.a. | 13,509 | 10,572 | 7,516 | 7,454 | −0.8 | −35.5[3] |
| Badminton | 14,793 | 11,908 | 9,936 | 6,765 | 5,937 | −12.2 | −59.9 |
| Tennis | 21,147 | 19,346 | 16,937 | 16,353 | 17,325 | +5.9 | −18.1 |
| Cycling[4] | n.a. | n.a. | 54,575 | 53,524 | 53,710 | +0.3 | −1.6[5] |
| Mountain biking | 1,512 | 7,408 | 8,611 | 6,719 | 6,940 | +3.3 | +359.0 |
| Swimming[6] | n.a. | n.a. | 94,371 | 92,667 | 96,429 | +4.1 | +2.2[7] |
| Fly fishing | 11,359 | 6,598 | 7,269 | 6,034 | 6,033 | 0 | −46.9 |
| Skiing | 17,676 | 17,567 | 14,836 | 14,249 | 13,633 | −4.3 | −22.9 |
| Snowboarding | n.a. | 2,567 | 5,461 | 7,691 | 7,818 | +1.7 | +269.5[8] |
| Boardsailing/ Windsurfing | 1,145 | 835 | 1,075 | 496 | 779 | +57.1 | −32.0 |
| Sailing | 6,368 | 3,918 | 5,902 | 5,161 | 5,232 | +1.4 | −17.8 |
| Scuba diving | 2,433 | 2,306 | 3,448 | 3,328 | 3,215 | −3.4 | +32.1 |
| Surfing | 1,459 | n.a. | 1,395 | 1,879 | 2,087 | +11.1 | +43 |
| Water skiing | 19,902 | 16,626 | 10,161 | 8,204 | 8,425 | +2.7 | −57.7 |

[1] High impact. Low impact aerobics has fallen by 25.9% in the 16-year period.
[2] Beach. Net volleyball has declined from 35,984 in 1987 to 20,286 in 2003, a decline of 43.5%.
[3] 13-year change.
[4] This refers to recreational cycling. The newer category of BMX cycling only attracts 3.365 million, a 13.4% decline between 2002 and 2003.
[5] 10-year change.
[6] Recreational swimming, as opposed to fitness swimming.
[7] 10-year change.
[8] 13-year change.

Source: SGMA International, *Sports Participation Trends 2004*. The full analysis covers 103 sports and fitness activities. One of the activities is given as Cheerleading, a significant feature of many US sports events. Over 3.5 million people over the age of 6 have this interest

products to serve the different golfing requirements are immense, including high-tech shoes, specialist silver-threaded socks, or antibacterial perspiration-controlling fibres in shirts or shorts.

It was possible to manage without UV-blockers in the fabric of clothing, without non-woven impregnated wipes with sun screen, tan-through gloves and specialist head wear. However, today, suitably attired and protected by these innovations, it is possible to play golf comfortably and safely in any climate, day or night.

This brief reminder should enable one to reflect on the astonishing growth of sports and the sports market in what is a relatively short space of time. A worldwide industry has developed to service its needs and provide extra comfort, performance and protection to its participants, and everyone can be a player.

## 2.2 Think of a sport, think of a textile

Let's examine some of the requirements in just one sport for the moment: golf. Fifty years ago, golfing footwear was a pair of leather golf shoes with spikes, sometimes slightly waterproof. To prevent ingress of water through the sole, some even had a thin steel plate running the length of the sole, sandwiched between it and the insole, but flexible enough to shape to the soles of the feet, but nevertheless steel. Considering the possibility of lightning strikes while playing, this was not very desirable. Today the golf shoe market is vast and a lot safer. In the United States there are some 27 million people who play golf regularly. It appears that they average between two to three pairs of shoes each – to be worn accordingly to match the weather and course conditions of the day. In Florida alone there are over 1,000 golf courses, and across the USA there are enough golf courses – more than 17,000 – to cover the entire state of Connecticut. (Great Britain and Ireland are home to some 2,400 courses; even Belgium finds space for 51 courses.) This means that there are also an incredible number of golf gloves worn out in a year: and an extraordinary variety of gloves are on offer, in hair-sheep leather, in microfibre suede, in combinations of leather and fabric, and even tan-through fabric to meet the demand. Consider the golf shirts, sweaters, windcheaters, waterproofs, caps, hats, socks, skirts, slacks and a host of clothing items used by the 21st century golfer. Then there are the towels to wipe and clean balls, the fabrics required for flags marking the target. Golf bags themselves constitute a market for durable, abrasion-resistant fabric. The clubs require head covers.

Now consider watersports. How many brands of swimwear are there in the world today? Consider the R&D devoted to creating 'faster' swimsuits, the unbelievable technology in design, structure and fibre as well as the choice. When world records are measured in hundredths of a second, it isn't too surprising. At the 2004 Olympics, swimmers were wearing new head coverings, made from materials which would shave another fraction of a second off their performance times.

Consider, too, the vast increase in leisure and holiday time, the unceasing search for fresh holiday resorts in every conceivable corner of the globe and the demand for swimwear that goes with this. To take the water theme a little further, the definition of textiles should be considered: any raw material that can be produced as a woven, knitted or non-woven piece of fabric qualifies. So now consider sailing, which has come a long way since linen sails were the choice of sailors. Nowadays they are produced in just about everything except the usual textile fibres. Glass fibre springs to mind, as do others such as Kevlar and Spectra. Think of the extraordinary range of ropes required across the spectrum of sailing activities.

Besides hemp and linen for rope and sails, the real requirement of early sailors was for waterproof clothing. But with every advance in sporting prowess, so there has developed a need for more specialist clothing. A simple waterproof hat and jacket has been superseded by layered clothing, with each layer from the skin outwards having to provide different properties and benefits. The fibre structure of each individual layer has to work in harmony with the next. Breathability has become the overriding consideration – water vapour and perspiration need to escape without difficulty whereas water should not be allowed in. Membrane technology has grown in importance and complete markets have been evolved as a result of its development.

Inspiration today is sought in the natural world: biomimicry has entered the vocabulary, and no doubt technologists will find textile solutions from the world of natural history and biology. Already there are breathable wetsuits which function in the same way as the pores in the structure of leaves. The world of phase-change materials has also become familiar to an increasing audience, where textiles can be modified to store surplus body heat and release that heat to keep the body's temperature at a mean when it begins to cool down.

Water, of course, is used as the perfect example of understanding the complexities hidden in the term 'phase-change'. Water, ice and steam are all essentially the same. To that, snow should be added – if only to allow the introduction of the vast development in sports requiring either snow or ice. The specialist requirements for clothing are enormous. To give an idea of the scale of the industry it is worth noting that in the Winter Olympics of 1924 there were only five categories of sport. By 2002, there were fifteen.

The phase-change concept is no longer limited to temperature control. Today it can be applied to materials which change according to use – gels which remain soft under certain conditions and then mould to a person's shape when in active use. As a result, shoes and saddles now take on the shape of the sole of the foot or the *derrière* of the rider. Protective wear remains lightweight and soft until required to provide instant impact protection. Deodorising properties can now be encapsulated, as well as fragrances and oils, to create more performance-specific garments and sports clothing.

## 2.3 The future is now

The functions that new technological advances have brought to everyday life can now be incorporated into sports-specific clothing. Soft-switch technology allows the introduction of electrical circuitry and communication systems to be built into the garment. GPS (global positioning systems) life-saving technology can be built into skiwear so that avalanche victims have a better chance of survival. The only requirement, apparently, is imagination. Lateral thinking and the application of concepts developed for one sector of human endeavour can be translated into the world of leisure, sport and textiles.

With each new development, so there is opportunity for the textile industry to broaden its market. Happily, there are indications that consumers will devote more time and money to their leisure and sporting activities. It has been seen that they are more prepared to read explanatory swing-tags and labels when it comes to sportswear as opposed to when making ordinary clothing purchases.

The acquisition of the latest technology is important. Perhaps it is a manifestation of the competitive urge in humankind. Perhaps it is a matter of personal well-being and safety. To the average person, a suit is no more than a suit. When it comes to sportswear, however, it is a different matter. If new technology is going to provide a competitive advantage, then it must surely be worthwhile. Or so the argument would go. If the player will be able to perform that much better by buying into something new, then it must be worth the expense. Everyone wishes to play better, feel better and be more comfortable. Everyone wants to win in some way or another. It is advanced technology in the textile industry that can help supply that basic human need.

## 2.4 The capacity of the market

What is the size of the market? In an adaptation of an old phrase, ‘that is the $64 billion question?’ It is therefore necessary to look at what is already known. Research has always been an excellent way of understanding trends of the future, and the United States is the leader when it comes to research. SGMA International, the Sporting Goods Manufacturers Association based in Florida, states that 55 million citizens in the country play bowls, more than 45 million get involved in treadmill exercise, and nearly 44 million go freshwater fishing (15.2 million go saltwater fishing, another 6 million go fly-fishing). Camping out in tents is practised by just under 42 million people over 6 years of age, while a further 40.7 million play pool or billiards. Basketball is played by 35.4 million and even darts attracts the attention of 19.5 million players. Tennis has only 17.3 million regular players – but just think of the amount of fibre that is required to keep them supplied with balls. According to research published in July 2004 by SGMA International, nearly 40% of all sports apparel spending is for clothing worn by children aged 17 or under.

If that is the United States, what about Europe? How many horse riders are there? For that matter, how many horse blankets are needed and how many tons of fibre are required to produce the vast acreage of fabric needed to keep the horses comfortable? (Horseback riding is a regular activity of 16 million people in the United States.)

All measures and statistics for the overall size of the market could be dwarfed when China enters the equation. China is very much seen as a source of textiles and finished goods for the world market. What if China becomes as taken with sport as, for example, the United States. The Olympic Games provides some clue to the sports which attract the Chinese. As that country's success in recent Olympiads continues, so certain disciplines must become more enticing and exciting for the younger generations. The Olympic Games of 2008, to be held in Beijing, will no doubt further increase participation in a broader spread of activities.

## 2.5 Future market trends

In 2000, the worldwide market was valued at US$92 billion.[2] In 2003 it was estimated that the value of the US sports market was some US$50 billion at retail, which means that participants could be spending almost treble that amount on indulging their sporting and leisure activities. Analysts are already hard at work trying to assess where the market is heading for 2010. The SGMA released a White Paper on the subject in early 2004 but does not place a figure on the value of the market. 'Where the future will take us is, to an extent, a very open-ended question,' said SGMA International president John Riddle. 'Nevertheless, as we produced this report, we spoke with such a large cross section of the sports industry, that we are confident that many of our predictions will be accurate.'

Although the report applies only to the United States, it does provide some food for thought on a wider scale because it points out the need for analysing demographic forecasts. Some of the more interesting facts contained in the White Paper are listed below.

- Eight out of ten sporting goods executives expect joint ventures and alliances to be important growth engines for the future.
- Consolidation in the sporting goods industry will continue to be a significant force throughout the first decade of the 21st century.
- The population growth of children, aged 5 to 19, will increase only slightly between 2005 and 2010, which is the mainstay of the sports-playing, equipment-buying, sports-apparel and athletic footwear-wearing group.
- At retail, there will be an emergence of sporting goods stores keyed to specific sports/lifestyles.
- Power will continue to shift to the retailer from the supplier. The retailer will utilise that strength by demanding more services and concessions from the suppliers.
- The supercentre concept is expected to expand, causing manufacturers to cut costs.
- Private label brands are going to become more prevalent.
- Success, for retailers and suppliers, will require continuous improvements in the use of information technology, especially in the area of compiling/utilising data about customers and their preferences.
- Successful suppliers will have to master all aspects of brand management.

- As private labelling grows in popularity, suppliers must learn that retailers are both their customers and their competition.
- Successful suppliers will be efficient channel managers, providing powerful retailers with exclusive products.
- Sports/fitness companies, government bodies, health care organisations, insurance companies and community-minded groups will work together to promote physical activity.

It is this last point, and the demographic predictions relating to children and birth rates, which will have great significance on the future development of the overall market, not only in the United States but also throughout Europe. There appears to be little doubt that society is becoming obese and that has serious health implications. Years of denigrating the competitive spirit among school pupils in certain countries is now being reversed at a high political level. Governments are urging a return to sport and it is hoped that populations will become leaner and fitter. Future generations will understand the value of staying fit.

The great outdoors should again take on a much broader appeal. All of these political, environmental and social trends will have a bearing on the size and importance of the textile market, and business managers will need to watch them closely in order to develop sales opportunities along the way.

Whilst the United States may have fragmented sports sectors, it remains the largest market. Europe, on the other hand, is fragmented by both individual national attitudes and sports sectors. Football or soccer might be considered the game that crosses all boundaries and cultures. It does represent an enormous market, not only in terms of players, coaches, referees and linesmen, but, more importantly, in terms of spectators. In recent years, the major clubs in Europe have realised the potential of the non-football-playing public. There is an overwhelming passion among many to support a specific club or a specific player, or both. The 'Beckham effect' has had a major impact on the fortunes of the top clubs. It is also what every fabric producer targeting the replica shirt business yearns for. When a top player catches the imagination of fans worldwide, the replica shirt with the player's name or number on it can move in vast quantities. When England's David Beckham started playing for Real Madrid in 2003 it was said that sales of his replica shirt hit the 1 million figure, more than the combined total of all the other replica shirts for the rest of his teammates. The same phenomenon – possibly not in quite the same numbers – can be seen coming out of Formula 1 motor racing.

As long as there are sporting heroes, the consumers will oblige with their desire to emulate them – and the only way is often through wearing matching clothing. So it is fair to assume that the fortunes of the sports textile industry will be linked to the attitudes of fans towards their favourite stars.

## 2.6 The market potential in China

The question, however, which will exercise the best minds in the industry is: China – what if? It is probably more accurate to postulate 'when' and 'how big' rather than 'what if'? The giant brands are already entrenching themselves in China and Nike is said to be opening a further 500 or more stores in 2005, in addition to the 1,200 it already has in the country. The 2008 Olympics – where Adidas is the 'Official Sportswear Partner' – could be the catalyst for sport to really burgeon across the world's most populous nation. There are precedents to be seen. At the Los Angeles Olympic Games in 1984, a 21-year-old Chinese gymnast, Li Ning, won six medals, three of them gold. Twenty years later Li Ning is chairman of a sporting goods firm, selling footwear and sportswear, with annual sales in excess of US$250 million in his home country and the company is planning to expand its retail outlets from its present 2,354 to 3,500 by 2006. The mainland sports goods retailer is also planning a listing in Hong Kong to raise up to HK$600 million to upgrade product design and marketing, ahead of the 2008 Olympics. If he is seen as a role model by other successful athletes, who would not be prepared to forecast a growth pattern for China? There is no doubt that liberalisation in China is opening up the market for sports business, creating opportunities for both domestic and international companies.

Whilst Li Ning's company may seem small by comparison with the €7.15 billion turnover in 2003 of Intersport International, considered the world's largest sports retail organisation with some 4,700 stores in 27 countries affiliated to its logo, who is to say that such giants will not emerge in China? If the sports market in Europe was estimated to be worth some €35 billion in 2003 (it is claimed that Germany, France, the United Kingdom, Italy and Spain account for 80% of the sports goods market in Europe), what worth does one place on the global market if the world's developing countries begin to appreciate the value of sport and leisure as their living standards rise? A foretaste of this probable expansion could be seen by the fact that 202 countries were represented at the 2004 Olympics in Athens. Intersport claims to serve 45 million customers a year in the 27 countries in which it operates. A customer base of 45 million could be seen as miniscule in a country the size of China.

Happily for the textile industry, whatever the future brings, sport should always remain one of the growth markets for its products – as long as the industry retains its ability to innovate and stimulate the dreams of those who participate in sport, even if it is only getting hold of the coconut in a friendly game of Yubee-Lakpee.

## 2.7 Notes

1. Artificial grass has developed strongly as a textile market in recent years and, with the greater emphasis being placed on health and safety, this sector should grow. For

instance, schools in the UK wishing to provide hockey pitches that will be used by both boys and girls must use artificial surfaces on which to play. The Olympic 2004 hockey centre relied on artificial grass. Artificial playing surfaces are becoming more popular as they are largely immune to weather problems and can be used all year round. In 2003, more than 20 companies in the United States were competing for synthetic-turf contracts, compared with just a few in 1999. There is now a Synthetic Turf Council in the United States to establish guidelines for the industry. It is estimated that an average US football pitch uses approximately 13,600 kg of yarn. In order not to lose the lush feel of real grass, some companies have developed hybrid technologies with real grass growing within textile structures.

2. World Federation of the Sporting Goods Industry.

# 3
# Key trends in sportswear design

S BRAMEL, *Sport Première Magazine*, France

## 3.1 Introduction

This chapter will look at how advances in fiber and textile engineering offer a constant flow of new creative directions to garment design and wearer comfort. Innovation in textiles influences sportswear design at two basic levels: from a technical perspective, new textiles enable enhanced performance regarding protection as well as athletic achievement, and at an aesthetic level, they introduce new styling options.

The study of the history of synthetic fibers[1] has shown that new fibers are at the basis of most textile innovation, but they do not always lead to evolutions in garment design. All too often, new materials are simply copied and pasted to traditional garment shapes and assembled using conventional manufacturing techniques. Yet though there are plenty of so-called smart textiles, there are not so many smart garments.

Admittedly, fiber producers benefit from large-scale research and development funding, whereas garment manufacturing evolves at a slower pace. However, the situation is changing, and this is the main topic developed in this chapter. Recent advances made in both textile and garment manufacturing have brought a new generation of smart garments to the market.

When compared with other clothing categories, sportswear design evolves at a faster pace than ready-to-wear, for instance. It is a highly innovative field investing heavily in research and development, pioneering new technologies and concepts, and furthering performance and comfort. This overview of key trends in sportswear design will study both the performance and aesthetic evolution of sportswear from second skin clothing to outerwear. Starting with first-layer garments, it will look at how seamless and stitchless garment construction techniques are introducing enhanced performance and ergonomic designs. Moving on to the outerwear categories of sportswear, the chapter will investigate how the gradual shift in focus from protection to performance and the rise of soft shells are dramatically changing the organization of traditional three-layer garment systems. The emphasis on multifunctional soft shell garments is taking the pressure off waterproof outer shells, now considered of lesser importance. A third section proposes to study how outside influences, especially the interest shown by high fashion and designer labels for sportswear, are modifying the expectations of consumers and drawing renewed attention to sports garment design in general and aesthetics in particular. The last section of this chapter will draw attention to two fundamental yet underdeveloped design orientations: streamlining and fitting. Sports companies have tended to underestimate these two areas, yet they are key aspects that will fuel the evolution of the sportswear market in the future.

## 3.2 First layer: from second skin to power skin

For years the major source of innovation in first-layer garments came from the introduction of new fibers. High-wicking, fast-drying, odor-reducing or UV-blocking fibers have brought new properties to enhance performance underwear but they have not radically influenced their design. Styles most often evolve around the basic T-shirt shape. The rise of all-in-one suits in competition swimming and running, now spreading to winter sports and high-level athletics, is introducing new shapes and volumes to first-layer garments in general. The development of seamless and stitchless manufacturing processes is also opening new design options by making it possible to create garments combining several functions in a single, smooth layer to respond to the specific needs of each body part. These two new fields of research are among the most advanced with regard to enhancing athletic performance.

### 3.2.1 The evolution of performance underwear

Over the past few years, performance first-layer garments have moved into new markets. Although runners and top-level athletes are key and convinced users, synthetic fibers used in sports underwear long suffered from a lasting image of smelly, pilling, shapeless undergarments that no one would want to be seen wearing in public.

The evolution of fiber technology has helped change conventional attitudes and is also making performance underwear more attractive. First-layer garments now increasingly feature designs and patterns that consumers are no longer reticent to reveal (a good example would be Helly Hansen's clever cuts and ingenious placement of its signature striped motif to modernize its styling and remain clearly recognizable). Meanwhile, the market has expanded to mainstream sports brands. The increased competition has encouraged companies to introduce racier styles. The result is that sports undergarments are now designed to be seen.

The wealth of wicking fibers, whether polypropylene, polyester or polyamide (most often now offered in microfine deniers), has created a confusing product offering in which many different labels vie for consumer attention. Gore-Tex has imposed its standard for waterproof and breathable materials in a way that Coolmax or polypropylene never has. Yet basing a product's performance features on fiber choice alone is one of this market's weaknesses. The arrival of new players, surfwear brands in particular, is revitalizing the market by introducing performance underwear based not on specific fiber content but on innovative design, often based on elaborate patchworks of textiles offering varied functions with the added perk of asymmetrical styling. The recent evolution of this market segment has reduced the impact of fiber choice in favor of novel design orientations.

Asymmetry has thus emerged in second-skin garment design as an innovative edge bringing new dynamics to a market once considered irredeemably dowdy. Asymmetrical constructions offer the double advantage of 'cool' design and enhanced performance. Shifting closures to the side makes good sense for layering purposes, improves ease of movement and can even have strong fashion appeal. The trendy nature of these styles has become a major asset of youth-oriented sportswear.

Slinky microfiber knits in bright colors with contrasting trimming and off-center patterns define this new generation of performance underwear. For the first time, these garments offer high performance (wicking, fast-drying, thermal or UV protection) and high aesthetic appeal. Advances made in odor control through bacteriostatic finishes and fibers, new polymers and micro-encapsulation techniques, make these garments much more comfortable on an olfactory level as well. These diverse developments have converged to create a new category of inner/outer or under/over wear.

### 3.2.2 The rise of all-in-one suits

Swimming competitions became headline topics when the first all-in-one swimsuits were introduced at the Atlanta Olympics in 1996. Speedo made waves in Olympic swimming pools with the first generation of body-covering all-in-one swimsuits creating high impact for competition swimming in general and the company's image in particular. The influence of the new look has had many repercussions. It impelled other swimwear suppliers to design their own advanced skin concepts and it attracted new audiences to poolsides. Giving swimming a high-tech edge was not the least of its consequences. The trend has spread to new fields, bringing renewed excitement and media attention to other traditional Olympic competitions. At design level, it also marked a turning point for textile innovation as well as garment construction by introducing biomimetics as a textile and clothing design orientation. Basing its research on sharkskin, Speedo used a powerful marketing tool to promote its ground-breaking swimsuits. Drawing inspiration from nature's secrets has become a major source of innovation in textiles. It is the basis, for example, of Schoeller's water-repellent and easy-care NanoSphere finish inspired by the lotus leaf concept.

The success of all-in-one suits in swimming encouraged sportswear manufacturers to design specific suits for athletics and to redesign those worn by speed skaters and cross-country skiers. Seven different fabrics made up Nike's speed skating suits worn at the Salt Lake City Winter Olympics in 2002. These elaborately constructed suits made of multiple panels addressing specific functions were first developed for cyclists. The varied climates and excruciating conditions of high-level cycling competitions led to novel patchwork designs to enhance athletes' performance, protection and comfort. Textiles offering elasticity, compression, warmth, protection from the sun and aerodynamics are strategically combined and positioned in these high-tech suits. The patchwork design of high-end cycling garments thus paved the way to new approaches in second-skin and first-layer garment design.

This new, multi-textile approach to athletic sportswear is based on progress made in performance knits and fiber innovation. After having for the most part sought to reproduce the skin's functions (microfibers for added softness and wicking, elasthane for ease of movement, special finishes for quick drying), synthetics now seek to enhance the skin's natural performances: new finishes are designed to improve hydrodynamics, precision compression to keep muscles warm (Table 3.1). Traditional swimwear charmeuse thus gained a high-tech edge that gave the whole industry a brighter image with the added perk of attracting new talent.

### 3.2.3 Seamless garments

The development of advanced second-skin textiles has led to renewed interest in seamless and stitchless garment construction. Sportswear companies first developed seamless styles for fitness and first-layer garments. Considered a

*Table 3.1* Evolution in fiber engineering

| Period | | | |
|---|---|---|---|
| 1960s to 1980s | *1st generation synthetics* | | *Function: Imitating the skin* |
| | Elasthane | → | Elasticity |
| | Microfibers | → | Softness |
| | Modified cross-sections | → | Moisture management/wicking |
| | Fleece | → | Thermal insulation |
| | Membranes | → | Waterproofness + breathability |
| | *2nd generation synthetics* | | *Function: Improving on the skin* |
| 1990s | Bacteriostaticity | → | Odor control |
| | UV-blocking | → | Sun protection |
| | Power stretch | → | Muscle compression/Muscle precision |

boon in intimate apparel, seamless knitwear has yet to find a satisfying application in sportswear. The not-so-new knitting technology initially derived from hosiery met with immediate appeal in low-end, one-size-fits-all underwear – hardly an appropriate opening for a new generation of high-tech second skins. The low hanger appeal of these garments has also confined them to commodity markets. This is an unfortunate setback for a technique that merits more attention and investment in time as well as in money. Its development seems to but on structural problems. In the garment industry, hosiery and lingerie makers are the main developers of seamless clothing. Most often they own the machines. Few knitters and fewer sportswear manufacturers have invested in the technology, thereby limiting research.

Since its introduction in the early 1990s, seamless knitting has suffered from the dominant market strategy principally aimed at cost reduction – an understandable situation since seamless knitting machines are generally slower and therefore more costly than traditional flat or circular knitting. The low market appeal of shapeless 'seamless' undergarments has also discouraged research and development. Yet seamless does not necessarily mean shapeless. From a marketing perspective, seamless is in fact a poorly chosen term: most garments so labeled have sewn seams, a fact that can obviously irk consumers. The same situation applies to stitchless garments, a technique transposed from neoprene to (surf) boardshorts and outerwear. Most consumers do not understand the advantage, and often the innovative edge is not immediately understood as such. Welded seams often pucker, making the finished garment lose much of its aesthetic appeal.

This is a useful reminder that a novel technology does not automatically lead to market success. Good design means using an innovative technique to transcend it, and garment design requires a comprehensive approach. When introducing a new technology, a brand must not become hostage to a single-ingredient marketing message. Seamless simply means without seams, it does not necessarily imply performance. Furthermore, the elimination of seams is not the single advantage of seamless knitting; it is even a marketing faux pas: whatever the garment or the design, a sewn seam will inevitably be necessary somewhere. Varying fiber composition to address specific needs (openwork for ventilation, compression for muscle performance) has a higher marketing impact than the more trivial quest for fewer seams and lower prices.

### 3.2.4 Three-dimensional modeling

New measuring techniques that indicate the precise needs of an athlete in action are being introduced and helping to associate seamless garments with genuine performance breakthroughs. Three-dimensional modeling, or bodymetrics, implies taking a broader look at how garments fit and why it is important to combine several types of fibers and textiles: laser cuts, bonded seams, multiple fiber composition targeting specific functions, etc. The design of a seamless leotard entails placing compression features, ventilation panels and various trimming or ornamentation at strategically engineered locations to achieve a high-performance sports garment. This implies graduating knit construction to the body and requires in-depth research and development to be effective.

The three-dimensional approach to design is paradoxically new to sportswear. The main difference between city and sports garments has traditionally been that ready-to-wear takes a three-dimensional approach to design (garments are conceived on mannequins) whereas sportswear companies design two-dimensional or flat garments. For example, the collar of a sports jacket lays flat, while it is impossible to design a flat lapel on a tailored city jacket. For an all-in-one swimsuit, designers must work from a three-dimensional model. This physiological approach to design is fundamental to the development of next-generation sportswear.

As long as seamless knitting is equated with lower costs, the market will neither evolve nor grow. Seamless styles are expensive: each machine can only knit one size at a time and each size requires specific settings. True second-skin garments need to be engineered to adapt to a specific morphology, the opposite of the one-size-fits-all approach. This is yet another example of why new technologies alone will not revolutionize sportswear: seamless knitting requires that engineers and designers work together to develop and fine-tune sizing, fiber choice, composition, and stitching. Leave out one parameter and the garment will not perform as expected.

### 3.2.5 The next step: stitchless seams

The emergence of stitchless garment construction techniques is introducing novel design features to outerwear. The switch to garments that do away with stitching altogether and are entirely heat-sealed is the next step in advanced garment design. The latest generation of high-tech garments is now totally devoid of sewn seams. Bonding is replacing sewing and making close-fitting styles even more streamlined. Laser-cut edges, watertight zippers and trimming can now be compressed into a single indivisible bonded layer. Hems that no longer need to be folded reduce added thicknesses at corners and hems. Designers are combining these new manufacturing techniques with molded and elasticized panels to create stitchless second skins. Leading wintersport specialists such as Arc'teryx, and surfwear brands Burton Snowboards, Rip Curl and O'Neill are opening the way.

The swiftness with which these new manufacturing techniques have been adopted by mainstream labels is an illustration of the dynamics of these new design options. Waterproof and breathable garments involve complex designs and patterns. Any technological breakthrough that simplifies garment construction is immediately welcomed by the sportswear industry that has

*Table 3.2* Timeline of seamless and stitchless manufacturing techniques

| 1960s | 1970s | 1980s | 1990s | 2000s |
|---|---|---|---|---|
| Seamless knitting first developed in hosiery | *1978*: Gore develops the first seam-sealing tapes, followed by the machines to apply them in 1979 | Seamless knitting spreads to lingerie and underwear markets | Laser-cut edges become widespread<br><br>*1996*: Power Lycra (DuPont)<br><br>*1996*: Fastskin all-in-one swimsuit based on bodymetric research (Speedo)<br><br>*1998*: Watertight zippers and micro seam-sealing (Arc'teryx) | *2001*: First seamless performance fitness wear (Reebok)<br><br>*2003*: Thinner (13 mm wide) seam-sealing tapes (Gore)<br><br>*2004*: Stitchless seam-sealed boardshorts (Rip Curl, O'Neill)<br><br>*2004*: 100% laser-cut and stitchless seam-sealed snowboard wear (Burton Snowboards) |

massively outsourced manufacturing to Asia. The high level of competition in this field means companies also focus on staying ahead, or at best abreast, of evolving standards.

Table 3.2 sets out the evolution of seamless and stitchless manufacturing techniques since the 1960s.

### 3.2.6 The influence of advances made in laminating

Leading membrane manufacturers W. L. Gore & Associates and Sympatex Technologies were for many years the only companies to offer laminated textiles, bonding a waterproof and breathable film to assorted fabrics: face fabrics, linings, fleeces, fillers, etc. During the 1990s, laminating machines became widespread, and increased demand helped bring prices down. Laminate waterproof and breathable garments thus became accessible to a wider range of garment manufacturers. In a few years, the waterproof and breathable laminate outerwear category has grown to become the industry standard.

This new benchmark has brought renewed attention to seam-sealing, which is essential to design absolutely watertight garments, and the technique moved to new categories of clothing. It has in the meantime evolved to become less conspicuous. Thinner strips, elasticized tapes and improved glues have contributed to make laminate garments lighter, more flexible and ultimately more comfortable. From a design perspective, the challenge seems to lie not so much in styling as in quality taping. In traditional three-ply constructions, fabric, film and mesh lining are welded into a single composite textile. Though uniform on the outside, the garment interiors very often displayed a network of unsightly taping.

A new aesthetic approach to waterproof and breathable garment design arose when $2\frac{1}{2}$ layer laminates were introduced in the late 1990s.[2] Gore, once again, led the trend with Paclite, now in its third generation. This brought renewed focus on garment linings, which became as important as the outside. It can in this sense be considered a major style breakthrough: in ready-to-wear, the difference between a high- and a mid-end garment depends on how much attention a brand pays to finishing: linings, pocket trimming, seam finishing, taping, etc. With these new bonded finishings, sports garments are achieving more sophisticated looks through cleaner linings.

An example of how ready-to-wear influences sportswear, this new global aesthetic approach to design is gaining ground in sportswear. And it has also furthered comfort. Doing away with mesh linings by adding an extra layer to films, often a silicone-touch finish, makes it easier to slip clothing on, reduces friction within garment layers and enhances the overall freedom of movement offered by the product. Lighter and more versatile, these new and improved shell garments are also more pared in their design. To avoid excessive seam-taping, their design is often simplified, their volumes leaner and closer-fitting. With the rise of soft shells, outer shells tend to emphasize protection above all. Their use restricted now to shielding from foul weather, they no longer require a separate lining fabric.

In much the same way as seamless knitting, the evolution of seaming and laminating has contributed to make outerwear lighter and more compact. This quest for lightness and compactness is not new in sports clothing. Every new generation of synthetic fiber and textile has focused on reducing bulk and weight. This is doubtless a positive trend that any outdoor enthusiast will appreciate and encourage. It is not only a major factor of improved performance, but also of aesthetics. Garment tailoring and design involves elaborate pattern-making and seam-stitching, yet in sports, seams are a major drawback in that they are a source of friction and of added fabric layers and bulk. The reduction, even elimination, of seams through seamless knitting or heat-sealing inevitably leads to new aesthetics: streamlined, compact, clean and pared garments can focus on performance without frills.

On both the aesthetic and technical aspects of this long-term trend, sportswear companies are barely at starting-block stage. Much has to be done to take full advantage of seamless knitting and stitchless manufacturing techniques. Leading brands may be the most visible promoters of these new styles, but smaller labels often are the most advanced. In all cases, streamlined design pairs lower manufacturing costs with novel styling, two positive trends to invest in.

## 3.3 The evolution of layering

Streamlining brings us to another important indicator of future trends in sportswear: the new organization of the classic three-layer garment concept. We have seen how advances made in clothing and garment construction are influencing the design of performance sportswear. Now the rise of soft shell garments is challenging the traditional three-layer protective garment system. New textiles and garments based on air are also redefining comfort and performance by introducing novel design options.

### 3.3.1 The reorganization of the three-layer system

In the classic three-layer garment system, each layer offers a specific function. First-layer garments worn next to the skin are designed to wick away humidity to the outer layers, to stay dry and to offer thermal protection in cold weather. Second-layer garments focus on thermal insulation and are also designed to draw moisture away from the skin to the outer layer. Fleece has been the synthetic material of choice in second-layer clothing. New generations have sought to offer the best warmth-to-weight ratio and have therefore focused on reducing bulk without reducing insulation. The role of outer layer garments is to protect from the elements. They are now most often made of laminated textiles that block out wind and water without reducing breathability. Combined, these three layers are designed to work together to offer overall comfort and protection. Even during intense activity, the body stays dry and comfortable while protecting the wearer from inclement weather.

The classic protective garment system is well adapted to outdoor activities, from hiking to cycling to skiing. In situations of extreme cold or humidity, the three-layer system remains the best solution. However, it implies that rain is regarded as a constant companion of outdoor sports and relies heavily on the outer layer for protection.

This approach is currently changing. It is increasingly recognized that rainy weather deters people from going out. Although important, waterproofness is now not considered a feature necessary at all times. On average outings, a water resistant garment will be necessary 10% of the time whereas high breathability is fundamental in 90% of sports activities. Sportswear manufacturers now admit that rain protection has been overestimated, especially in summer collections where total waterproofness is rarely necessary and often reduces a garment's breathability. With the rise of soft shell garments offering lighter protection and enhanced wearer comfort, the focus is shifting from the outer to the inner, or second, layer. This is an example of how progress made at textile level influences the design of functional sports garments.

The equation that defined functional outerwear for several decades, waterproofness + breathability = comfort, is being reformulated in favor of breathability. This implies not only a new garment system integrating a soft shell layer but also a new marketing approach to performance sportswear. Waterproof textiles and waterproofing techniques are relatively easy to apply, and to explain to consumers. Breathability, however, is a function that is more difficult both to implement, since it requires highly sophisticated fiber, textile or garment constructions, and to explain to consumers in simple terms. The balance between water resistance and water vapor transfer remains a matter of subtle compromise that consumers do not always fully understand.

If waterproofness ebbs in importance, breathability becomes the main performance feature and the focus shifts to the second layer which is becoming the pivotal garment in outdoor collections. This new 'second' layer is designed to incorporate several functions: elasticity, wind protection and a degree of thermal insulation or water resistance, depending on its positioning. This is just one of many possible configurations of soft shell jackets, the recently coined concept that is revolutionizing outerwear. (See Table 3.3.)

The shift of emphasis from waterproofness to breathability first became an issue in waterproof and breathable membranes and as the market for performance outerwear grew. Having mastered waterproofness, membrane manufacturers concentrated their research and development efforts on improving the breathability of their products. The arrival of solid hydrophilic, as opposed to microporous hydrophobic, membranes and coatings made it possible to bypass the complex matter of trying to balance the porous nature of a microporous membrane with its necessary waterproofness.

*Table 3.3* The evolution of layering

| Before<br>Three-layer garment system | After<br>The switch to soft shells |
|---|---|
| Layer 1 → wicking (knit)<br>Layer 2 → warmth (fleece)<br>Layer 3 → waterproofness, windproofness and breathability (membrane) | Layer 1 → wicking (knit)<br>Layer 2 → elasticity, wind protection, breathability and water resistance (soft shell)<br>Layer 3 → waterproofness (hard shell) |
| Waterproofness + breathability = comfort | Freedom of movement + High breathability + Wind protection + Water resistance = Optimum comfort in action |
| Extreme conditions | Normal conditions |

### 3.3.2 A new category: the soft shell

The renewed focus on breathability over waterproofness implies reorganizing the layering system in such a way that the main item is no longer the outer layer, or hard shell, but the second layer, the soft shell.

The rise of soft shell textiles and jackets has been a subject of much debate in the outerwear industry, not the least of which being the choice of terms used to describe this new functional garment. Few people outside the outdoor industry understand the terms hard or soft shell when applied to garments. Yet no one has found a satisfactory alternative to explain the move from complete waterproofness (hard shell) to water resistance (soft shell). Semantic shortcomings aside, soft shells feature many functions and have been made possible through advances in textile technologies. Soft shells are the result of new developments in bonding multiple textiles together, including knits and fleece.

Since their invention in the mid-1980s, fleece knits suffered from their high air permeability. As warm as fleece can be, they are not capable of protecting the wearer from a gust of cold wind. Their thermal properties need to be supplemented by a windproof shell either as a separate item of clothing or by bonding the fleece to a membrane or a tightly woven or knit textile. Fleece manufacturers have sought to reduce the air permeability of their products to make them better suited to outdoor activities. Bonding the fleece to a woven face or to a wind-blocking membrane was the first step taken to provide adequate warmth and wind protection. But this is a delicate operation: the pile of the fleece knit makes it difficult to bond it to a smooth film. With the evolution of laminating techniques and glues, fleece manufacturers have developed durable composite stretch textiles to offer a new series of functions: breathability, thermal insulation, ease of movement, and, depending on the face fabric, abrasion and/or water resistance.

Membrane manufacturers quickly picked up on the trend and began to offer their own multifunctional multilayered textiles. Membrane-laminated garments could then offer thermal insulation as well as waterproofness and breathability. This led to a new range of laminates emphasizing wind protection over waterproofness: Gore-Tex WindStopper, Sympatex Windmaster and various other Wind Defender type membranes were developed to address the needs of those looking for a fleece garment offering thermal insulation in windy climate conditions.

Soft shells, which are advanced composite textiles, are difficult to market not only because of the novel nature of their performances, but also because of their high cost. They are often sold at prices similar to, or higher than, hard shells. Admittedly, they offer enhanced features when compared with traditional laminated outerwear. Designed for intense activities, they combine the best of two worlds: ease of movement and protection. In many cases, soft shells are also water resistant to a degree. They generally resist water penetration for 30 to 40 minutes, time enough to find shelter, or to slip on a waterproof hard shell jacket. A shell jacket designed for lightweight and compact protection is easy to store in a backpack and pull on when conditions get rough. This is why Gore developed the Paclite range of membranes and why $2\frac{1}{2}$ layer laminates were initially released. The waterproof and breathable hard shell thus became a foul-weather accessory that most outdoor enthusiasts own but do not look forward to wearing. The most important item of a functional garment system has shifted to the light, fast and efficient soft shell. For some companies, the arrival of this new category means the outdoor market is moving to a four-layer system. In extreme situations the wearer will combine four garments: first layer, fleece, soft shell and hard shell for maximum warmth and protection.

Two types of manufacturers have thus promoted the soft shell product: fleece suppliers and membrane producers. The result of this double route taken to design soft shells has led to two distinct schools of thought: one promoting a non-membrane approach to soft shells, the other basing its performance edge on the presence of a breathable, wind- and waterproof film. Fleece and fabric manufacturers have, by and large, promoted the non-membrane approach to soft shells. They point out that a membrane inevitably reduces breathability and therefore comfort. Fleece-based soft shells thus tend to focus on thermal insulation, elasticity and abrasion resistance. With a water-repellent surface finish, they are promoted as ideal outdoor textiles.

The main supporters of soft shells incorporating a membrane are most often membrane suppliers themselves. They tend to emphasize the inbuilt high protection from wind and water obtained through the use of a film: when it rains, even if the face fabric gets wet, water will not penetrate the garment.

The shift from protection to ease of movement has not only changed the marketing angle of shell garments, it has also introduced a new leaner and cleaner silhouette. Since they are not designed to protect from the elements, soft shell jackets do not require multiple drawstrings, elasticized hems or double storm flaps. Designers of performance outerwear have thus begun to focus on a closer-fitting silhouette made to enhance thermal insulation and to reduce bulk to improve ease of movement and comfort. This new approach has influenced hard shell jacket design which is also evolving to adapt to the new standard and ultimately promote the leaner, fitted look.

### 3.3.3 Air: a key raw material

What is the most important component in the design of the perfect sports garment? More often than not the answer is: air. From first layer to shell jacket, the natural element is regarded as a premium high-tech ingredient of performance and comfort. Air is synonymous not only with lightness, a major factor in comfort, but also with temperature regulation, since a layer of air between garment and skin helps reduce temperature variations. Research in air management has led to a new generation of first, second and outer layer concepts. In all cases, these garments perform better and are lighter to wear. Even fleece fabrics are more compact, furthering closer-fitting styling and improved design.

After having focused on wicking and quick drying, first-layer knits are adding air to their roster of features. Traditional sports knits such as piqué, honeycomb or ribbed raised textures trap a certain amount of air between the body and knit. By reducing the contact points between the skin and garment, air circulates freely and lets the body breathe. This so-called natural approach assumes that the human body possesses the most advanced thermoregulating system and should therefore be allowed to function naturally. Athletes cannot be asked to wear nothing ... but new textiles are increasingly designed to be as unintrusive as possible.

The alveolar or nodular structure of raised knits – honeycomb being the ideal form – is used with the raised texture worn next to the skin. This performance tactic has also been experimented with in fleece. By shaving away portions of pile to form a grid-like three-dimensional surface on the backside, fleece can trap a larger quantity of air next to the skin. The resulting garment is lighter, warmer and more efficient at drawing moisture away from the skin because the high air permeability of these textiles tends to improve their wicking capacity.

Mention should be made here of hollow fibers. Inspired by animal fur and developed in polyester in the 1970s,[3] hollow fibers are now available in polyamide.[4] Lighter than conventional fibers, by 20 to 25%, their improved thermoregulating properties also make them more comfortable to wear. Although they are in no way distinguishable from a traditional solid fiber, and possibly less efficient than other air-based textiles since the amount of air trapped inside the fiber is minimal, the contribution of hollow-core fibers to enhanced comfort should not be disregarded.

Three-dimensional knits, also called spacer fabrics, are also drawing the attention of sportswear manufacturers for their capacity to trap air and offer extremely lightweight high-performance thermoregulation. Initially developed for industrial uses for cushioning and filtering, these fabrics are now popular in both sports shoes and garments.

In outerwear, air is also being applied to novel self-adjustable and self-inflatable thermal systems. Membrane manufacturers W. L. Gore & Associates and Sympatex Technologies have developed elaborate concepts based on a network of textile tubing that the user can inflate on demand. Once inflated, the extra warmth provided by the garment is felt immediately. When temperature or activity levels rise, the air held inside the tubes can easily be released into the atmosphere: the wearer simply deflates the jacket until the next climate change. Gore's Airvantage and the prototype Vairis concept by Sympatex Technologies are very sophisticated yet very simple anti-cold linings that rely mostly on air.

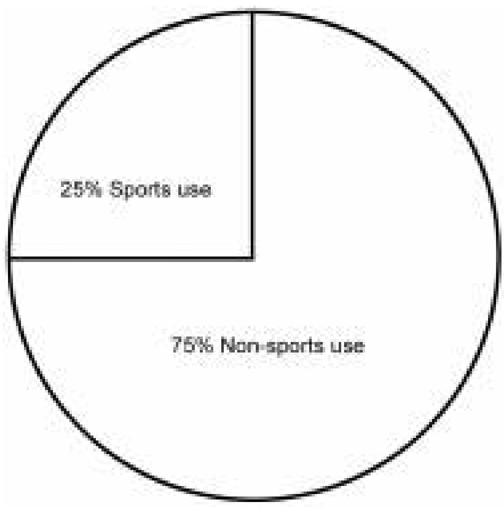
A crucial component of active sportswear, from first layer to outer shell, for warm and cold weather conditions, air is increasingly regarded as the ultimate ingredient for performance and well-being.

## 3.4 External influences

A more dramatic source of new styling directions in active sportswear comes from outside influences. The fading frontiers between sport and city wear and the large number of luxury and high-end ready-to-wear brands developing sports-oriented ranges are a growing source of novel design orientations for performance clothing.

The evolution of garment design knows no frontiers: it is influenced both by performance sportswear and ready-to-wear. The power of high-fashion brands in the larger sphere of sportswear should not be underestimated. Sports-inspired garments are now standard everyday wear, especially among younger generations who define what consumers will be wearing in the future. Figure 3.1 illustrates how the sportswear market is divided between sport and non-sports use.

The interactions between these two spheres of influence, sports and fashion, are a major source of new trends for both industries. For fashion brands, sports styling is an important asset to attract new generations of consumers as well as an essential market to maintain a (possibly) older consumer base that is looking to remain youthful. As for sports companies, a major portion of their business is selling after-sport garments to their core clientele. They also are seeking to attract a broader clientele looking for a sporty silhouette but not necessarily engaged in a specific sports activity.




*3.1* The sportswear market.

### 3.4.1 Interactions between fashion and sportswear

Polo Sport, Armani Sport, Prada Sport, Chanel Sport, Hugo Boss Sport: this short list of high-fashion sports labels gives a good picture of how future sports garments trends are going to evolve. Adidas and Puma are no longer competing only against Nike and Reebok. The new players coming from the fashion arena are potentially powerful rivals. Their main focus is on style and design, true, but they are also often expert in using high-performance fibers and fabrics. This trend constitutes a magnificent opportunity to see sports garments move into new design spheres.

When ready-to-wear manufacturers develop sports garments, their design approach takes into account an equal measure of style and performance. As first-layer garments and soft shells have shown, closer-fitting clothing often performs better. Fit thus gains importance in general. Fit and silhouette are often the defining elements of a high-end garment: fabrics and cuts are carefully chosen to enhance the silhouette. In sportswear, however, fabrics and cuts are selected for their performance features. Function is the principal goal of sports garment design. The end silhouette and the balance of proportions are considered of lesser importance. This is where high fashion labels gain their aesthetic edge. Table 3.4 lists the design priorities of fashion and sportswear manufacturers.

Focusing on the overall silhouette implies leaner, cleaner designs. Ready-to-wear brands rely less on logo visibility and placement than sportswear labels. Attention to detail is also a defining feature of high street fashion. High-fashion sports labels are driving the trend to pared and streamlined styles; a trend also promoted by alternative sportswear companies in surfing, skateboarding and streetwear in general. They carry considerable power and prestige among younger consumers as well and the youth market is a driving force in the fading frontiers between sport and citywear.

Sportswear in general is moving towards cleaner looks combining traditional natural fibers with the performance of synthetics. Consumers understand now that synthetics and traditional fibers can be effectively combined to respond to new, versatile or nomadic lifestyle needs: going from work to weekend or

*Table 3.4* Design priorities in fashion and sportswear

| Fashion | Sportswear |
|---|---|
| Style | Performance |
| Three-dimensional design | Two-dimensional design |
| Detailing for aesthetic purposes | Detailing to further protection or performance |
| Special attention to linings | Less attention to linings |
| Everyday use | Sport-specific use |

traveling and hiking with the same suitcase or backpack. Consumer trends emphasize multiple uses, and sports garments must also address these needs. Tomorrow's consumers will be more discerning; function alone will not guarantee durable market growth. The external influence of fashion should therefore be considered a major source of new market opportunities.

### 3.4.2 Wearable technology

Of all the materials that surround us, textiles are those with which we entertain the closest relationship. Supple, soft and comfortable, fabrics fulfill a basic yet double need: the comfort of a second skin and the reassurance of a protective envelope. Textile engineering has made this dual quest possible and offers myriad solutions to our everyday and specific sports needs. At the same time, the miniaturization of electronic components such as those found in mobile phones or smart cards, have become essential features of contemporary lifestyles. Hence, it is not surprising that these two realms would seek to pair up. Although the integration of electric components in textiles raises a number of challenges, electro-textiles, which first appeared in 2000, have been upgraded and updated recently in extreme sports garments as well as in advanced streetwear.

This new category of 'wired wear', which in fact is mostly 'unwired' (or wire-free), involves technologies that garment manufacturers cannot develop in-house. The most advanced concepts have, without exception, been co-developed with electronics companies, including Nokia, Motorola, Philips or Infineon. In Finland, home of Nokia, a consortium of researchers and manufacturers, including the Reima sports garment brand, began investigating communicating garments in the late 1990s. Reima presented its first prototype in 2000, the Cyberia survival suit for arctic environments. Incorporating several types of sensors (electro-frequence-meter, hydrometer and thermometer) connected to electrodes embroidered into the fabric, the garment was designed to monitor the user's physical condition and indicate its position by GPS (Global positioning system) in case of an accident.

With the ICD+ range launched in 2001, Levi's and Philips created the first commercial smart garment range. Designed by Massimo Osti, the four ICD+ jackets were equipped with electrical wiring connecting an MP3 player, a cell phone, earphones and a microphone to a remote-control device. The electrical wiring was designed to withstand machine washing, though the devices themselves must be unplugged for laundering. The components for the most part were the result of Philips research, and their transposition to garments required specific development. These electronically equipped garments can be considered mere gadgets or essential depending on one's degree of technology-literacy. It is noteworthy, for example, that Levi's ICD+ internet site included no less than ten pages explaining how to assemble and dismantle the garment's numerous devices.

Designed to respond to the needs of new lifestyles, these garments seem better tailored for work environments. Levi's, for example, wished to target couriers who handle simultaneously their motorbikes, mobile phones and deliveries. The integration of communication tools into their jackets could be considered a useful application. However, new wireless technologies (Bluetooth, infrared, wi-fi) have since made it unnecessary to incorporate electronics into the garment itself.

As a source of novelty, electronics rates high among major sports brands. Nike has developed a program with Motorola to create a smart jacket equipped with walky-talky functions. Infineon's know-how in flexible microchips and wiring sparked the interest of O'Neill to develop a jacket incorporating an MP3 player and telephone controlled by a textile keypad located on the sleeve.

From a design perspective, these additions to garments are comparable to high-tech trimmings. A microphone represented by embroidered control buttons can also be considered a form of graphic yet functional ornamentation. Research done in the late 1990s at the height of the internet bubble quickly lost steam but seems to be undergoing a renaissance in the action sports community. When targeting younger generations used to manipulating new technologies, sports brands cannot seem to resist the urge to offer communicating facilities as a showcase for their know-how.

How far this trend goes is largely a matter of how society evolves. Mobile phones are essential accessories of contemporary lifestyles. Consequently, integrating them into garments and textiles can make sense.

## 3.5 Future trends

Before closing this chapter on new design orientations in sportswear, two points often underestimated and generally underdeveloped merit special attention. In the quest for lightness, which is probably the single most important trend driving innovation in textile and garment design, there is always room for improvement. Lightness can imply less detailing and fewer accessories, but not necessarily fewer features. This approach can be called a form of stealth design, a term first used by the French jeanswear design duo Marithé and François Girbaud in the late 1990s.

Another area in which progress is called for is in the field of sizing and fitting. Sportswear companies have largely undervalued the importance of fit. With increased competition coming from high-street labels, the decision to purchase one brand's garment over another may depend largely on fit. In the past, sports enthusiasts may not have paid much attention to these details because they were looking for specific performance features. But once the product offering in a given category grows, styling and aesthetics become key issues in the buying process.

### 3.5.1 Streamlining or stealth design

Using lighter weight fibers, hollow or microfine fibers and textiles, as evidenced in recent fleece developments and high-tenacity Cordura fabrics for example,[5] or even switching to thinner seam-sealing tapes, are some of the many directions garment manufacturing has taken to reduce bulk and weight. Now is the time to look at reducing excess fabric by focusing on a closer-fitting silhouette. The introduction of watertight zippers has made it possible to forgo wind and rain flaps, at least in medium-level performance outerwear. A waterproof jacket designed to withstand heavy rain will always need storm flaps, but not all garments need to hold up to extreme climate conditions. Pockets are now often lined with mesh to offer the double function of storage and ventilation. Innovation in design is a matter not only of adding to but also of removing or reducing.

Trimming options also have advanced recently. Heat-sealed pockets, straps, flaps, etc. can now dispense with added layers formerly required for hemming and sewing purposes. It is safe to anticipate that other items, including drawstrings, self-gripping or snap closures will evolve towards leaner and more pared styles in the future and that these innovations will further lighten the weight of garments.

### 3.5.2 Fit and size

Any observer of the fashion and sport industries should find striking how consumers assess fitting and sizing differently when buying a product from one of these two categories. When shopping for a business suit, the consumer will check its fit and style. He will look to see not only if the garment feels comfortable but also if it enhances his silhouette. Why then, when the same consumer is shopping for a mountaineering jacket, should the silhouette not also be flattering, besides offering the necessary protection and technical features expected from a functional piece of clothing? It is understandable that brands look to reduce their size offering to lower costs, but in the end, a garment that is not flattering will not be worn other than at times when it is absolutely necessary. What is the point of buying a new jacket if the old one is in perfect condition?

Tomorrow’s consumers will be increasingly used to mixing sport and city garments, which will be considered largely interchangeable. Functional detailing and features will no longer be sufficient sales arguments within the context of a broader product offering. This is where a garment’s cut and design become critical.

If sportswear companies rely solely on function they will cut themselves off from a larger consumer base. Sports brands should continue to cater to the needs of their core market, but expanding their customer base is also a key source of new business. From sport-specific garments to lifestyle sportswear, developing better design at all levels is surely essential for the future success of this industry.

## 3.6 Bibliography

The subject treated here involves drawing from today's sportswear trends key developments that will influence sports garment design in the future. The points covered are mostly the result of my work at *Sport Première*, interviews with athletes and sportswear manufacturers. This is not a subject often treated in book form. Magazines and design agencies are usually the main source of information.

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*TechStyle*, yearly guide to new textiles published by *Sport Première*.

## 3.7 Notes

1. Bramel, S. and Fauque, C., *Le génie du pli permanent, 100 ans de modernité textile*, Editions IFM–Le regard, Paris, 2001. Bramel, S. and Fauque, C., *Une Seconde Peau*, *une histoire des fibres du XXe siècle*, Editions Alternatives, Paris, 1999.
2. In 1998, Gore launched the first 2½ layer laminate, called Paclite.
3. In 1973, DuPont started marketing Dacron Hollofil, the first hollow-core synthetic fiber. It was a polyester fiber designed to replace down.
4. In 1998, Nylstar launched the first hollow-core polyamide yarn, marketed as Meryl Nexten.
5. Cordura fabrics as light as 100 g/m$^2$ are now available.

# 4

# Material requirements for the design of performance sportswear

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## 4.1 Introduction

The new and unique design discipline of performance sportswear which, in relation to fashion design, has been given little prior consideration, raises some quite novel issues. The creation of a conceptual, highly individual fashion statement involves a totally different approach from that of the practical and more systematic design process for functional clothing. Fashion design might be put in context by references to art, literature or music rather than providing an explanation of function in relation to the needs of the practitioner. An in-depth consideration of end-user requirements, before starting design development, may be better understood in the disciplines of graphic, product or industrial design. Performance sportswear design is growing in importance and crosses the boundaries between design, technology and marketing disciplines. It embraces creativity and aesthetic awareness combined with an extreme requirement for technical understanding and innovation.

In the last three decades of the twentieth century a dramatic increase in participation in competitive, extreme and leisure sporting activities, as well as an interest in health and fitness, has expanded the market for sport-specific clothing. Performance sportswear has become increasingly sophisticated in styling and detail, benefiting from the rapid developments in fibre and fabric technology and modern garment construction methods. These influences have been adopted in products from extreme sports to related areas of the market such as adventure travel, corporate wear and health.

### 4.1.1 The link between textile technology and the demands of the end-user

In this new design discipline the range of topics for research is dispersed throughout design and scientific textbooks, trade journals, manuals and the media. Designers new to this specialism often find the range of issues forbidding and difficult to prioritise. The design and selection of textiles for a clothing system for extreme circumstances may have implications for safety and survival. Authentic sportswear brands, created by sports practitioners, function effectively but have often lacked aesthetic awareness and style. Performance sportswear design requires an approach where the form and function meet the needs of the end-user.

In this technical-textile-driven market, designers require guidance in their enquiry into the breadth and significance of the issues. The design process aims to support innovative decision making in the sourcing and selection of appropriate materials for the development of clothing which functions, looks good and which also addresses the cultural demands of a particular sporting activity. The design tool is represented as an information tree which maps out and prioritises an integrated mix of requirements uncovered in the literature and verified through consultations with sports practitioners, experts in human physiology and textile technology.

## 4.2 Identifying the needs of the end-user: developments in sport-specific clothing from postwar to the present day

### 4.2.1 The layering system

Military preparedness has been a major influence in the development of performance sportswear. British troops sent to the Korean war 'arrived in nothing but woollen serge battledress and windproof suits to fend off the worst of the Korean winter.'[1] This uniform was considered obsolete compared with the 'layered' concept of 'combat uniform' trialled by the United States Army in 1943. The British introduced their seven-layer version of combat dress during the Korean war in 1950, including pile 'liners', for smock and trousers, a heavy wool jersey, a standard jersey pullover, a flannel shirt, woollen underwear and string vest. A layering concept for combat clothing is retained to the present day with this principle adopted and modified by the civilian outdoors trade.

### 4.2.2 From walking to mountaineering

Tony Lack portrays the initial postwar image 'of a keen minority of hikers' in 'shorts, clumpy boots and bulging rucksacks'. He attributes the rise in popularity of 'holiday walking', promoted by organisations such as the Holiday Fellowship, the Co-operative Holiday Association, Ramblers Association and the Youth Hostels Association, to increased leisure time and improvement in transport services. Lack describes 'the only true performance fabric', developed during the war for aircrew, as the specialist cotton woven construction 'Ventile'. He recalls the popularity of mountain sports boosted by the announcement of the first ascent of Everest, coinciding with Coronation Day in 1953. Growing participation in outdoor activities, such as camping and climbing, demanded more comfortable and lightweight products. At Pindisport, a specialist outdoor retailer in the 1960s and 1970s, prominent fabrics were closely woven proofed gabardine, cambric, proofed poplin and basic plastic for Pacamacs and overtrousers. The Coronation issue of Pindisport's camping catalogue showed 'the climber's anorak' in what was described as 'superfine mercerised vat-dyed Valan-proofed self-sealing fabric'. Mid layers included woollen knitwear, men's 'Bukta' and ladies 'Ladybird' cotton fleece 'windcheaters' and men's wool and cotton blend woven tartan shirts. Under these were textured cotton jersey shirts and string vests. Accessories, such as ski mitts, often continued to be government surplus.

In 1956, Pindisport promoted jackets for skiing and climbing in Grenfell Cloth, mostly 'self-lined' throughout, but one lined with 'woollen fleece'. The 'Story of Grenfell Cloth', a fabric originally produced for Sir Wilfred Grenfell of Labrador, provides an early explanation of the design requirements for an outdoor garment for extreme conditions: 'It had to be light because travel in Labrador is done on dog sleighs, strong for the wearer's life might depend on it, windproof and snow proof. Above all, it must allow the body moisture to escape.' Pindisport promoted the product by listing 'Famous Grenfell Users', including Admiral Byrd of the Antarctic, British and American Ryder Cup teams, Everest expedition teams, Stirling Moss, the expedition to Kilimanjaro and the 1954 Daily Mail expedition to find the Abominable Snowman.

For the first ascent of Everest in 1953, British and foreign firms became involved in the development of garments 'of a familiar pattern' with the real emphasis put on innovation in material. Outer suits were of cotton–nylon windproof material and both smock and trousers were lined with nylon. The combined weight of an average-sized suit of this type was a little over 3 lb 12 oz (1.7 kg). The smock had a hood with a visor to provide protection against wind and snow. To wear inside the windproofs at high altitude, the climbers would have a two-piece suit in down, the jacket with a hood, like the outer blouse. This down clothing reduced the number of woollen garments needed, but each climber was provided with two featherweight jerseys and one heavy pullover.[2]

Such expeditions promoted a greater awareness of clothing requirements and textile properties. Blackshaw's mountaineering handbook listed essential requirements; protection against wind, cold and rain; adjustability to meet the extremely wide variety of conditions that may be encountered in a single day; lightness combined with durability.[3]

The handbook treats the issue of safety by advising climbers to wear 'brightly coloured' socks or hat to 'be seen from a distance' in case of accident. A windproof anorak, in fabrics such as Ventile, Gannex and Wyncol, to be 'worn over a lot of clothing', must have 'good long sleeves' and be long enough to sit on. Recommended details include a half zip at centre front for ventilation, a zipped map pocket, adjustable hood and draw cord at waist. A double thickness of material is advised for protection over the shoulder area. Quilted linings are considered heavy and slow to dry. The ‘new’ lightweight nylon or terylene ‘cagoules’ are recommended for keeping in the pocket when not in use. A plastic Macintosh is suggested as ‘a good alternative’.[4]

The concepts of trapping still air for insulation and the need to avoid the build-up of condensation inside waterproof layers are explained in the handbook in simple terms. Waterproof trousers are not recommended as they make the wearer too hot. Flannels are considered adequate, for summer walking, and breeches, with long woollen stockings for climbers for greater freedom of movement and to allow the climber to see footholds. Zips or covers for pockets are needed to enclose cash, compass, watch or camera filters. An extra waterproof patch on the seat is suggested. Materials such as moleskin or woollen Bedford cord are preferred to corduroy, which is heavy when wet. Underlayers mentioned include a long string vest to trap air, although it may chafe the skin if carrying a rucksack. Cotton and nylon underlayers are not recommended as they will get cold when wet. For cold weather, a woollen vest, woollen shirt, and a lightweight sweater and a medium-weight one, are considered more flexible than one heavy sweater. Down jackets are recommended in the Alps and for snow and ice climbing in Britain.[5] Long gaiters are useful for keeping out snow.

In the early 1960s, Pindisport was stocking insulated, down-filled, quilted jackets with an ICI terylene-filled and nylon outer ‘Ellesmere mountain jacket’. By 1968, polyurethane-proofed Bri Nylon cagoules and overtrousers were part of the range. Garment producers had problems in sourcing better-quality zips, Velcro fastenings, mesh panels and foam linings, in an attempt to refine the basic design features and combat the build-up in condensation within these non-breathable fabrics. Lack comments that ‘comfort under most conditions was not a feature of the time. Comfort is essentially negative – true comfort you just don’t notice – but equipment and clothing of that era [were] often heavy, bulky and condensation was a major problem.’[6]

In 1968, Pindisport opened a ‘mountain shop’ with Chris Bonington as technical advisor promoting ‘a full range of modern equipment, clothing and footwear for mountaineers, rock climbers and hill walkers’. For the first time, Helly Hansen waterproofs and nylon fibre pile ‘polar suits’ were featured and described clearly in terms of insulation and moisture management.[7] From 1970, ‘everything was beginning to move and develop and the pace was to accelerate markedly throughout the next decade.’ Lack believes that Bonington, ‘as a publicity-minded expedition leader . . . initiated the change in the public’s view of climbing and mountaineering, and therefore, indirectly, of walking.’ The screening of a spectacular television series of his successful 1970 Annapurna South Face Expedition, triggered so much development in equipment, clothing and changes in attitude, that it also started the boom in manufacturing, importing and retailing outdoor products that was to be such a marked feature of the next few years.[8]

### 4.2.3 Point-of-sale promotional material

Pindisport identified categories of end-user including 'the hill-walker', 'the rock-climber', 'the Alpinist' and 'the expeditioner'. Its *Technique and Equipment Guide 1973*, made specific reference to end-user requirements from a clothing perspective, garment performance and use of design features by expedition experts. The 1974 Equipment Guide gives a most comprehensive explanation of 'allweather clothing', including fabric information and weights, garment design features and cut, hood details, seam constructions, fibre information and garment aftercare. Subsequently, new range concepts were to come from companies such as Ultimate Equipment, Rohan and Buffalo.[9]

The 1978 *Expedition Handbook* explains how the 'primary purpose' of clothing is to maintain the body temperature at 36.9 ºC and 'to protect the body surface from damage'.[10] With still air as the 'lightest, cheapest and most readily available insulation', the concept of wearing a number of layers of clothing beneath a windproof outer shell is explained. The risk of damp reducing insulation, either from perspiration or the penetration of rain or snow, is stressed. Generic fibre information is mixed with references to branded products. Helly Hansen fibre pile garments are recommended as lightweight and for the trapping of air. Ventile, proofed sailcloth, gabardine or poplin are all considered satisfactory for the windproof anorak or hooded jacket, which should 'breathe'. A light, 2 oz nylon anorak or cagoule is proposed for the truly waterproof layer. Polyvinylchloride (PVC) coated front-opening jackets and overtrousers are said to have the advantage of easy ventilation without removing the whole garment.[11]

In 1982 Joe Tasker stated how recent innovations in fibres and finishes were the driving force in clothing and equipment that enabled small teams 'to operate as a mobile, self-contained unit on the highest mountains in the world' and to survive conditions which would have halted previous expeditions. These included shell boots and the revolutionary Gore-Tex-covered down or synthetic insulations, such as Thinsulate.[12]

In the mid-1980s, Geoff Tabin, in his ascent of Mount Vinson, Antarctica, described his 'two sets of heavyweight polypropylene underwear, bib overalls, thick pile jacket, a one-piece insulated windproof suit, goggles, neoprene face mask, three layers on head and hands, vapour-barrier socks, plastic boots with avolite inners and neoprene overboots', and he still felt cold.[13] Wally Herbert warns expeditioners against wearing high-altitude cold-climate mountaineering clothing in the polar regions. In Greenland, within 100 yards he was 'wringing wet with sweat, and, within a mile . . . on the brink of hypothermia, because all the sweat had frozen'. With no way of changing his clothing and nearly thirty miles to travel, he came close to dying of severe wet cold.[14] He stresses the need for investment in retail staff training, in specialist outlets, but also warns against the pressures of 'marketing techniques, advertising programmes, public relations exercises and discounting wars.'[15]

## 4.2.4 Synthetic fibres and fabrics

There was ‘enormous optimism in the early post war period’[16] for man-made synthetics as they became commercially available. Nylon, first marketed in the 1940s, was hugely successful made into ultra-sheer stockings. The Pioneering Research Division of DuPont de Nemours in the US, set up in 1935, developed new polymers that were to include Orlon acrylic fibre (mid-1940s) and Dacron polyester. These fibres ‘promised wonderful new qualities of durability, easy care, delicacy and fashion styling’.[17] One of the major applications for the new man-made polymers was swimwear, as they provided ‘scope for developing garments which looked attractive at the same time as satisfying functional requirements’.[18] Speedo recognised the importance of consulting sports practitioners in the design development process and, in 1957, the Australian freestyle star Lorraine Crapp (Thurlow), with fellow world record holder Dawn Fraser, became involved in experimenting with ‘the new wonder fabric, nylon’. This fibre, favoured for strength, elasticity and ease of dyeing, was found to be especially suitable as a swimwear fabric because of its water repellency and quick drying properties.

Fibre and fabric innovation had gained momentum with the introduction of the elastomeric fibre, generically known as spandex, in 1958, with DuPont’s trade name ‘Lycra’, historically adopted by the foundations industry to replace rubber and provided power, support, control and compression. From the beginning of the 1960s, Lycra was available in circular knit, power net (two-way stretch) and leno (one-way stretch). Lycra revolutionised swimwear in adhering to the contours of the body, being light in weight and through its suitability for a variety of printing methods in very bright colours. Poli states that ‘the assets of the new material were not appreciated immediately by all: it was dismissed by many as too daring, as it hid nothing of the female body.’[19]

Competitive swimmers began to demand comfortable costumes that provided the lowest possible resistance in water. In 1962, the Amateur Swimming Association, ASA, authorised research into problems of drag in swimming costumes. The selection and appropriate positioning of fabrics on the swimmer’s body became relevant owing to the need to enhance speed, with Lycra launched as a competitive swimwear fabric at the 1972 Olympic Games. Swimmers were now fully aware that design innovation could improve results, and research and development has continued ever since as fibres have become lighter in weight and stronger. By 1994, Teflon-treated fabrics further enhanced water repellency with claims that the ‘low drag’ quality could give crucial differences in timing of a fraction of a second.

Polyester textured yarns, branded ‘Crimplene’, were launched in 1959. Crimplene’s ‘performance, aesthetic properties, quick drying and resistance to crease and wear all contributed to its success’. Austin states that the ‘Crimplene boom’ prompted the technological developments of circular knitted fabric machinery. Crimplene came to an end in fashion by the mid-1970s when consumers turned away from synthetic fibres. One of the negative properties of polyester, from the fashion designer's perspective, is seen to be its lack of moisture absorbency. This hydrophobic property has since become one of the valuable attributes of the fibre for moisture management in sportswear applications.

In 1976, W. L. Gore established the concept of the waterproof, breathable membrane. The Gore-Tex technology was to revolutionise the outdoor and related sectors of the performance sportswear market. This and Teflon (PTFE) were branded innovations that filtered down from medical end-use and from the National Aeronautics and Space Administration (NASA) in the US.[20] In 1969, Buzz Aldrin's Extravehicular Mobility Unit, the spacesuit and 'back pack' together weighed 183 lb, which, intolerable on earth, represented only 28 lb on the moon.[21] The Apollo 11 suit incorporated layers of sophisticated textiles all with their respective functions. The innermost layer regulated temperature by means of a network of thin-walled plastic tubing.[22] The three-layer pressure garment began with a 'comfort layer of lightweight nylon with fabric ventilation ducts' followed by 'a Neoprene-coated bladder, surrounded by a Nylon restraint'. Five layers of aluminised Mylar incorporated spacer layers of Dacron as protection against heat. Surrounding these were two thermal insulation layers of Kapton and beta marquisette. An additional fire-retardant, abrasion-resistant covering of Teflon beta cloth was finally protected by the outer shell of white Teflon cloth.[23] The spacewalk demanded bellows-like flexible joints for movement and, for dexterity, gloves were designed with 'moulded silicone rubber fingertips.'[24] Design attributes from such high-specification garments, and their textiles, have been adapted for commercial use. In particular, the flexible joints of the spacesuit inspired the development of the modern ski boot.[25] Gore-Tex and Teflon have since become household brands.

## 4.2.5 Commercialisation of sport

In various forms, technology has enhanced opportunities for mass participation in sport, leisure activities and in spectator sport. Above all, colour television, introduced to British viewers in 1968, has had the greatest impact. Baker states:

> For sports, television is the great popularizer, benefactor and dictator. It encourages the growth of organized sports at all levels; it ensures huge profits for professional owners, promoters, and athletes: it has subtly changed the character of both amateur and professional sports.[26]

Television gave impetus to the provision of more visually attractive garments evident for both team strip and spectator replica kit. For certain sports, the rules of the game dictate colour and have implications for the size and placement of logos. One of the most spectacular moves in competitive swimming has been the removal of the laws restricting the use of colour. The introduction of nylon and new dyestuffs prompted the use of colours other than navy, red and royal blue being the most popular. Colour-fast prints were adopted by Speedo and the Australian team for the 1964 Tokyo Olympics and, from 1970, ASA permitted much more colourful costumes. The introduction of colour into cricket has also been prompted by commercial considerations. In the 1970s, Kerry Packer, in Australia, introduced one-day cricket and, as for other high-profile televised sports, bright colours were to make more of an impact. Major players such as Adidas, Puma, Reebok and Umbro have created easily identifiable graphic images essential in modern professional team sport, 'where fans pay to see the heroes of their tribe clothed in a distinct set of colours and arranged in a set pattern.'[27] The Manchester City football kit of 1904 looked very plain compared with the sponsor-emblazoned kit of today.[28]

### 4.2.6 Technical sportswear for women

The women's sports market developed as the fitness boom took hold of the US in the late 1970s, 'as sweat suits became chic and bottled water the coolant for the cool'. In 1974, Billie Jean King boldly launched the magazine *WomenSports*, wishing to feature women athletes other than because 'they had nice legs', and to offer 'some way to let young women know that . . . their desire to compete and excel wasn't abnormal'. In the outdoor market, despite the prominence of women mountaineers, such as Alison Hargreaves, it was the end of 1990s before there was any serious provision of specialist technical clothing for women. It has been similar for other disciplines as, until the 1990s, 'very little sports gear was made specifically for the woman athlete, and almost no advertising targeted her'.[29] Around 1992, the Swiss company Wild Roses was founded by Dodi Kunz, catering entirely for women, while, in the UK, Berghaus introduced female cuts.[30] An increase in lightweight equipment contributed to freedom for women as greater speeds and higher achievements in athleticism heightened the visibility of women's sports, making them more appealing to spectators.[31]

### 4.2.7 Trend, style, fashion

During the 1970s, the outdoor clothing market had advanced technically but it still had little aesthetic appeal. As Lack points out, a parallel market, skiing, was leading the way in clothing and fabric development. Not only was skiing a world championship activity but it was also a well-publicised Olympic sport, and the ski world thrived on 'new looks'. Fashion became an integral part of it, though it was anathema to most other outdoor people. Ski clothing manufacturers looked for fresh colours, new styles and different fabrics. The look became more important than the function, very much the reverse of the mountaineer's or hill walker's view.[32]

Since the 1950s, one of the leading technical skiwear brands has been the Japanese company Descente. The stretch woven ski pant was introduced in 1954 and 'retail sales of the pant were so successful that the name became the identity for the entire company'. Descente Ltd has been a leading name in the development of Lycra and spandex downhill ski suits, becoming the official suppliers to leading athletes. In 1979, at the Kitzbuhel men's downhill event, the Descente suit was nicknamed the 'magic suit', taking first, second and third positions, and, in 1980, the speed skater, Eric Heiden, won five gold medals at the Lake Placid Winter Olympic Games wearing a Descente speed suit. Descente continued to lead in innovation and by 1988 introduced Solar-Alpha for slalom suits, a fabric that claimed to absorb the visible rays of the sun and transform optical energy into heat energy. In addition it is said to reflect the infrared rays generated from the human body, effectively trapping the warmth next to the body.[33] The Japanese have led innovation in microfibres, wetsuit neoprenes and swimwear fabric technology.

The Italians have led the way in Europe for aesthetically innovative interpretations of highly technical fabrics in terms of finishes, textures and colours. The end of the 1970s saw synthetic stretch fabric constructions being produced by mills such as Figli di Michelangelo Calami for ski pants and tennis shorts. In 1987, Calami produced its first pile fleece fabrics and today includes in its range thermal knit fabrics for sports underwear, 'sandwich' fabrics for protection, and flame-resistant materials for corporate clothing.[34] Knitted polyester fleece fabric developments have played a major role in the advancement of lightweight, wicking and insulating, sportswear fabrics.

Vittorio Giomo, who currently represents sportswear designers in international colour meetings, maintains that it is only recently that 'trend colour forecasting has made its official entry into activewear'.[35] The high-performance sportswear products of the 1970s, apart from skiwear, were not directed by fashion forecasting. Relatively small companies continue to be restricted by the choice of available fabrics and colour selection owing to the high costs of creating new developments with minimum production runs for special colours and finishes. Some 'practitioner designers', focused on performance, have attached little aesthetic importance to colour, and certain end-users retain traditional colours for sports such as sailing, cricket and golf. The approach of Yvon Chouinard, founder of Patagonia, has always been to promote sophisticated individual colour combinations. His clientele has been able to identify with natural tones to blend in with the landscape, or characterful brights for safety. Patagonia has worked closely with Ciba to arrive at a colour palette for its organic cotton range, which provides designers with guidance in making choices in dyestuffs which have less environmental impact.

## 4.2.8 Fibre branding

As Lack has observed, in the 1970s 'everything was beginning to move and develop and the pace was to accelerate throughout the next decade'. Synthetic apparel fibres have become increasingly refined since the early 1980s providing scope for innovation in fabric constructions, blends and finishes for technical clothing systems. By the 1980s, branded waterproof, 'breathable' coatings, laminates and finishes were well proven, such as Cyclone, Sympatex, Gore-Tex and Teflon. Synthetic insulations such as Quallofil, Hollofil and Superloft were in general use, with Thinsulate and Thermoline for a slimmer look. Fibrepile, well established in the 1970s, became more aesthetically interesting in terms of colour and pattern. Generic fibres were being relaunched under new brand names such as ICI's Tactel and Rhône-Poulenc's Meryl. Subsequent modifications to polyamide, polyester, polypropylene and spandex have been launched under a range of heavily marketed brand names. Polyester fleece has revolutionised the mid insulation layer and gradually replaced knitwear for active sport and, more recently, in fashion leisurewear. Polyester base layers have been given wicking agents such as Capeline. Post-millennium fibre innovation continues with some concern for sustainability. Teijin in Japan produces recycled polyester and Cargill Dow is developing polylactide polymers (PLA) from corn.[36]

### 4.2.9 Garment development

The development of breathable fabrics permits closer fit. For extreme sports, such as snowboarding, speed bike racing, and skydiving, competition kit is custom made with measurements taken for individual sports practitioners. Georges Pessey, of Jonathan and Fletcher, states that some garments 'may have up to 200 different pieces and call for 25 different materials, zippers, pullers, snaps and other accessories', and that 'for each activity we have very special patterns and sizes'. His staff 'have to have the ability to adapt themselves and their work to each brand they work on and to the different areas the company now specialises in'.[37] His principal garment engineer confirms that, to become technically oriented, the sportswear designer is obliged to learn the specialist measurements, cutting and construction while in the industry. No textbooks exist to explain the complicated development of articulated garment shapes and visible and hidden technical details.

The British outdoor trade and ski trade, which grew out of the outdoor trade, are quite distinct from the sportswear brands emanating from shoes and football shirts.[38] Authentic sports brands emerge through the spirit of invention, customisation and relentless testing and adaptation by passionate practitioners. In Britain, the long distance runner, Ron Hill developed his own running clothing. His unique background, working in Courtaulds' dyeing research laboratory, gave him the advantage of being a practitioner with a knowledge of textile fibres and their properties. In running over seven miles to and from work, over a period of eleven years, as well as competing in international events, he was able to assess the shortcomings of existing clothing. Prior to setting up his own label in 1970, Ron Hill had experimented with customised shorts and vests. He knew that cotton shorts, provided for runners in the 1964 Olympics, became abraded within three weeks. He replaced this with ‘regular woven nylon’ and invented the wrapover cut at the side of running shorts to allow for freedom of movement. For long distance contests in hot climates, initially for the 1968 Olympics in Mexico, he adopted a string vest from the Army and Navy stores. He won the marathon in Athens in 1969 in the same vest as well as the 1970 marathon in Edinburgh. After selling garments from the back of his car at athletics events he established his own mail order business in 1970.[39]

The wetsuit, which has enabled the practice of watersports regardless of water temperature, was developed as early as 1952 by the hardcore surfer Jack O’Neill in northern California.[40] He replaced wool sweaters soaked in oil, with a flexible plastic foam which he described as ‘one of the many technological developments to emerge from World War II’. He sandwiched the foam between sheets of plastic prior to discovering the foam carpeting material neoprene in the aisle of a DC-3 passenger plane. His relatively lightweight, flexible wetsuits encouraged the growth of surfing, as riders were able to spend longer in the water perfecting new techniques. By the 1960s, O’Neill was laminating stretch nylon jersey to the surface of the closed-cell foam and using zigzag stitch in the development of new styles.[41] By the 1980s, a diverse range of watersports had benefited from adaptations of wetsuit technology, as the consumer demanded better adjustment for movement, thermal insulation, weight reduction and protection for high stress areas. In 1998, O’Neill commissioned Vent Design to further refine ‘a protective layer of fabric, which would be thin yet rugged’.[42] The Animal wetsuit incorporated an ‘accordion-like pleating system’ providing ‘bellows-like sections that can be used in areas where maximum flexibility is needed’. The suit, made from ‘moulded neoprene rubber, thermoplastic elastomer, nylon jersey with a Delrin zipper’ was to be registered as the O’Neill Expansion System.[43] More recently, biomimicry has inspired Speedo’s Fast Skin swimwear for the Sydney Olympics in 2000.

## 4.3 The design development process: the application of technical textiles in performance sportswear

### 4.3.1 Design research: addressing the needs of the end-user

The design research process informs the sourcing and application of technical textiles in the development of apparel which supports, and ideally enhances, the performance of sport. To practise successfully, those involved in product research and development must identify, understand and respond to a broad range of both technical and creative issues. This exciting design subject crosses the boundaries of specialist knowledge both within and outside the scope of art and design. It demands an awareness of aesthetics, general creative design skills and an appropriate knowledge of garment and textile technology. A basic knowledge of human anatomy and physiology is fundamental as well as in-depth information on the sporting activity in question. Designers need a thorough understanding of the needs of the sports practitioner from a cultural perspective and recognition that 'fit for purpose' requires an appropriate balance between the function of the garment and its appearance.

Current sports practitioners demonstrate a definite interest in the appearance and fabrication of the clothing with individual preferences for the styling of different brands and opinions on colour choice. The balance of technical attributes versus aesthetics is normally governed by the anticipated end-use. A snowboarder only rides in clothing that looks 'cool', but experiences discomfort and frustration if it does not perform. The kit for triathletics is dictated by the governing body, team or sponsor both in terms of colour and technical specification. Performance sportswear design, concerned with end-user requirements, is closer in philosophy to industrial or product design than to fashion design as the 'professional service of creating and developing concepts and specifications that optimise the function, value and appearance of products and systems for the mutual benefit of both user and manufacturer'.[44]

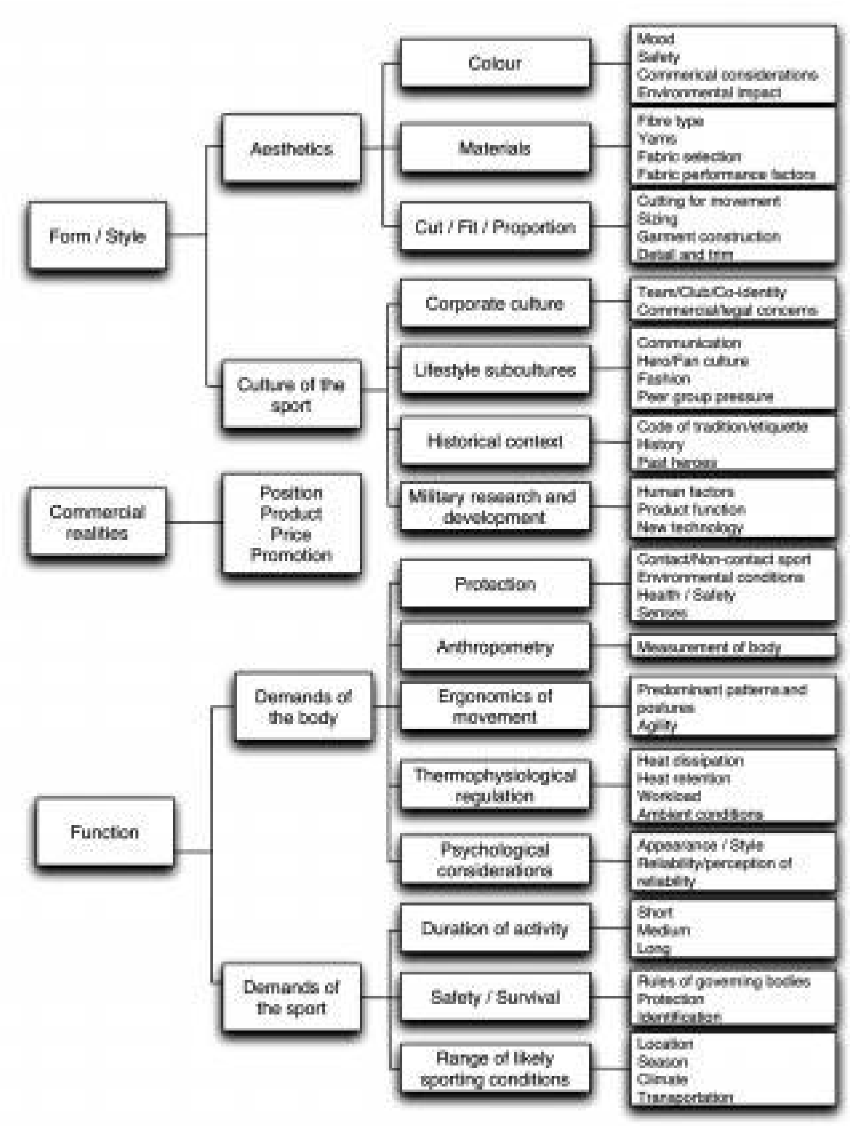
The regularity of issues emerging from consultation with current sports practitioners has led to the development of an information tree to guide the design research process for performance sportswear designers (see Fig. 4.1).

## 4.3.2 Functional needs of the end-user

*The needs of the body*

In the original Olympic games, male athletes performed naked. The skin is still the best fabric available, with regard to human physiological concerns such as breathability, thermal regulation, movement, fit, agility, sensitivity and grip. For modesty as well as climatic and environmental reasons, clothing has been adopted and modified over the centuries in an attempt to achieve the neutral state of 'comfort'. Designers must have knowledge of textile properties and constructions in tandem with a basic understanding of human physiology and issues to do with survival. Discomfort only becomes apparent when the body feels too hot or too cold, where clothing impedes or restricts movement or visibility and lacks the desired fit, especially in the case of performance clothing for female athletes. Clothing can be abrasive and chaffing, can permit damp or wet to penetrate, be noisy, smell bad or look unattractive and generally fail to have the 'feelgood' factor.

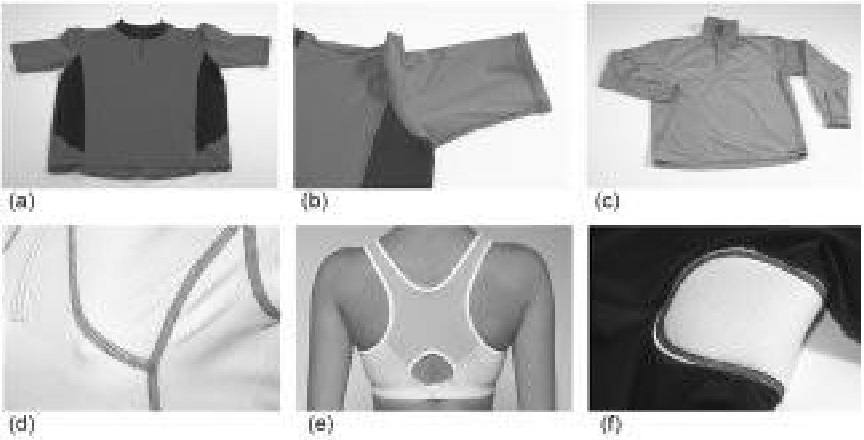
To provide a comfortable microclimate for a specific end-use, designers must observe and obtain verbal feedback from the practitioner regarding issues such as workload, moisture management, thermal regulation and protection against ultraviolet light in a potentially hostile environment. Consideration must be




*4.1* Information tree to guide the design research process for performance sportswear designers.

given to warm-up and cool-down before and after exercise. Potentially confusing scientific data and terminology from testing methods, carried out both in laboratories and in the field, must be understood by the designer.

The sports 'layering system' has evolved from military combat dress to enable the selection of appropriate combinations of technical textiles in clothing




*4.2* Base layer. (a) Arena wicking weft knit polyester 'T' with enhanced ventilation structure in side panels. (b) Arena T-shirt showing coverstitch seam detail for armhole, cut to enhance arm lift. (c) Paramo reversible warp knit shirt with brushed surface worn to inside to trap still air or worn outwards for cooler effect. (d) Wicking tennis top with complementary knit constructions to enhance breathability/support/stretch for movement. (e) Sports bra cut with wide supporting straps, singlet style back with mesh insert for breathability. (f) Antimicrobial cycle pad in Arena shorts. (Source: David Bryson.)

to protect the body for different sports in contrasting environmental and climatic conditions. The system is normally made up of base layer (Fig. 4.2), mid insulation layer (Fig. 4.3) and outer protective 'shell' (Fig. 4.4). The term 'second skin' is often used for garments worn closest to the body. Knitted constructions are selected for movement and protection and from suitable fibres to promote moisture management. It is not normally desirable to have damp clothing next to the skin, especially when stationary in extremely cold conditions, and so fibres such as polyester and polypropylene are chosen for their wicking properties. The insulation layer varies in thickness in its ability to trap still air in down, synthetic waddings, fleeces, fibrepile or other three-dimensional knitted and non-woven assemblies. Fibres may be shaped and/or hollow, and often made from polyester to prevent absorption of moisture. The outer shell, or protective layer, is selected to provide the most appropriate balance of windproof and 'waterproofness' versus 'breathability' for the specified range of activities. The wind chill factor can lower the ambient temperature dramatically and threaten the clothing microclimate. Outer fabrics are normally of lightweight nylon or polyester woven constructions with coatings or laminates in two- or three-layer assemblies. Two-layer fabrics have an exposed coating or laminate on the inside, normally protected by a loose mesh lining, and three-layer fabrics have a sandwich construction with a fine single jersey backing to protect the laminate. The outer shell design must


*4.3* Mid insulation layer. (a) Fleece jacket with asymmetric neck detail to avoid chaffing and underarm gussets for enhanced arm lift. (b) Patagonia polyester fleece collar detail with taped back neck and woven nylon binding for simple lightweight finish. (c) Reebok fleece gilet with reflective piping for both style lines and safety. (d) Crag Hoppers heavyweight fleece zip-through jacket. (e) Crag Hoppers fleece showing underarm zips for ventilation. (f) Crag Hoppers fleece showing inner mesh security pocket to cut down bulk. (Source: David Bryson.)

incorporate appropriate ventilation, as few textile assemblies cope with the moisture produced from extreme workload.

The technology associated with the design, cutting and manufacture of performance clothing is highly complex. Little guidance is available in textbooks to assist the designer in the pattern development of garments for extreme posture and body movement with functional detail such as arm lift, articulated elbow and knee constructions. Standard garment size charts, diagrams and corresponding tailors' dummies cater for relatively restricted movement, and traditional cutting is depicted in erect 'fashion' poses. The cut and manufacture of sophisticated hoods concealed in collars, intricate closures and many other features relevant to movement and body protection are developed through experience and experimentation. Specialist studies of body measurement, for performance wear, are carried out by the military and by commercial concerns, but this data is not readily accessible in the public domain. Sizing and predominant build for one sport, constituting 'small, medium and large', will be very different from those in another sport. Independent sizing for women has often been neglected, with the lack of suitable clothing, in the right size 'preventing women from going out on the hill'. A male rescue team member was unable to take advantage of a uniform, as it did not exist in his size. The development of garment blocks for performance sportswear has been through trial and error or from adaptations of existing garments.


*4.4* Outer layer/protective shell. (a) Nylon smock with double zip opening to access climbing harness. (b) Hood with adjustable cord stops and reinforced shoulder detail. (c) Berghaus Gore-Tex Paclite with inside mesh security/map pocket. (d) Berghaus Gore-Tex Paclite showing hood detail with stiffened peak, inner cord channel and Velcro fastening. (e) Lightweight woven jacket with contrast stretch inserts to enhance movement. (f) Sprayway ski pant with inner leg gusset and side zip for access to boot. (g) Karrimor Gore-Tex jacket showing lower back hem for predominant posture. (h) Scooter jacket with shoulder and sleeve pockets to insert body armour. (i) Sprayway jacket with double storm flaps to protect front zip opening. (j) Drysuit with rubber feet, cuffs and neck detail. (k) Drysuit showing asymmetric waterproof zip with Velcro-fastened storm flap. (l) Sprayway jacket showing hem detail of mesh lining and adjustable shock cord. (Source: David Bryson.)

The 'layering system' is becoming more tailored and refined with advances in textile technology and garment construction. Stretch yarns in knitted and woven constructions, seamfree technology, moulded components and light-weight body armour and abrasion-resistant materials take advantage of modern fibre properties to provide ease of movement, appropriate cut and fit, and personal protection as required for specific end-use. Snowboarders now adopt body armour akin to personal protection for motocross and the wearing of helmets has become commonplace. Textile assemblies vary considerably for different activities or sequences of events. Research and development in materials and clothing for military end-use filters down and becomes modified to the requirements of the commercial ranges. Sports apparel, driven by innovation in fibres, fabrics and garment manufacturing techniques, enables the athlete to 'feel good' which, in turn, promotes better performance.

### *The demands of the sport*

Designers must study the chosen sport, or range of activities, and identify the main events, media coverage and training manuals or videos as well as primary research in observing and obtaining feedback from serious practitioners to identify with end-user needs. Is the activity over very quickly or of medium or long duration? Is the warm-up kit worn for longer than the competition? It could be a sprint in a stadium, triathletics, a day trekking or a polar expedition. Contrasts between training, team, competition uniform and post-activity clothing are clearly defined.

An appreciation of the impact of the environment in which the sporting activity takes place is required. Is the sport seasonal, to be practised indoors in a controlled environment or outdoors on a pitch or rough terrain. Is it a contact or non-contact sport? Is there an extreme climate or a range of temperatures and degrees of humidity? It is easier to design for very cold, dry conditions or hot humid conditions than for both. Does the practitioner have a car to get to the venue or is there heavy 'gear' to transport for long distances. The usual requirement for an outer shell garment is to be super lightweight with minimum bulk for easy storage. Details include an adequate map pocket, zip guards, slim fit to avoid billowing at speed, front hem of jacket to be hollowed out and back to be lowered, Velcro cuff adjustment, neck adjustment, optional foldaway hood and pit zips for ventilation.

The 'rules of the game' may include a dress code or restrictions to do with safety or fair competition, which impinge on apparel design. There may be safety and/or commercial considerations to do with identification. The kit for triathletics, dictated by the governing body, specifies the thickness for neoprene for wetsuits and limits the environmental conditions where protection may be worn. The extreme design requirements of military clothing, or for more efficient labour-intensive work in hostile conditions, also provide an important point of reference in the development of performance sportswear for extreme protection.

### 4.3.3 Form and style considerations

*The demands of the culture*

Successful performance sportswear design is the result of designers becoming thoroughly conversant with the culture of the sporting activity. The development of sport-specific technical clothing is often based on feedback from sports experts dissatisfied with ranges available. Leading practitioners have liaised with manufacturers in the design development of new products where cut, detail and fabrication respond directly to their own perception of what is required for their particular sporting activity. Many practitioners initiated their own range development, including Douglas Gill and Musto for sailing, Jean-Claude Killy for skiing, Ron Hill in athletics and, more recently, the Williams sisters have been promoting their unique brands of style in tennis.

Team sports, whether for international competition or regional clubs, have a need for team uniforms as a means of identification. The impact of the media, and especially colour television, influences the use of colour and graphics for corporate uniforms, while sponsorship logos are prominent within given restrictions. Charismatic sporting heroes are endorsed as leaders of style to promote the image of major clothing brands for both team and individual sports in order to create product that is attractive to the peer and fan culture of the sport. Garment and textile producers' benefit from media attention generated in the developments in team kit and from the sizeable market in supporters' replica kit.

The subtleties of the lifestyle trends behind the sport affect the style and mood of sports clothing. 'What's cool' for snowboarding will be quite different from what is in demand in extreme expedition wear. The designer must be aware of major sporting events, read the specialist press and visit international sports trade fairs where leading fibre and fabric producers promote new developments (see Table 4.1). Many sports practitioners, at the peak of their performance, have grown up at a time of increasing awareness of design in all areas of clothing and lifestyle products. Trend forecasting with regard to colour, styling and mood is now available for sports fabrics and apparel.

The designer must acquire an appropriate knowledge of the history and tradition of the chosen sport and the 'rules of the game', especially those which specify codes of dress. Relevant information on sporting traditions may be found from a variety of sources such as the records of expeditions, the personal accounts of practitioners, past sportswear clothing catalogues, museums, sporting archives, photographs, film and memorabilia. Traditional sports are evolving as modern practitioners are becoming more aware of how fashion and technical textiles can enhance more stylish cut, fit and proportion.

*Table 4.1* Major international sports trade fairs where leading fibre and fabric producers and garment manufacturers promote new developments for the sportswear market

| Event | Dates | Venue | Organisers | Focus | Trade fair or conference |
|---|---|---|---|---|---|
| Outdoor Retailer | January and August | USA Salt Lake City | www.outdoorretailer.com | Outdoor sporting goods, clothing and textiles | Trade fair |
| ISPO | February and July | Germany Messe Munich | www.ispo.com | Sporting goods, clothing and textiles | Trade fair |
| Soltex | February | UK Manchester GMEX | Rare Management www.soltex.co.uk | Snowsports goods, clothing and textiles | Trade fair |
| Premiere Vision | March and September | France Paris Parc des Exposition | Premiere Vision www.premierevision.fr | Textile fair incorporating sportswear fabrics | Trade fair |
| Tex World | March and September | France Paris CNIT la Défense | http://interstoff.messefrank furt.com/texworld/en/home.html | Textile fair incporating sportswear fabrics | Trade fair |
| Survival Conference | March | UK Leeds | http://www.leeds.ac.uk/ textiles/CTT/news.html | Technical textile-related papers | Conference |
| Techtextile | June (biannual) | Germany Messe Frankfurt | http://techtextil.messefrank furt.com/frankfurt/de/home .html | Technical textiles | Trade fair |
| Avantex | June (biannual) | Germany Messe Frankfurt | http://avantex.messefrank furt.com/global/en/home.html | Technical textiles | Conference with exhibits |
| Go Outdoors | September | UK Harrogate | www.go-outdoors.org.uk | Outdoor fair with textiles | Trade fair |
| Pertex Clothing for Extremes | September | UK Penrith Rheged Centre | http://www.pertex.com/ newsstory.asp?id=38 | Historical perspective on outdoor clothing and textiles | Conference |
| ISWC | October | USA, Japan, etc. | www.cc.gatech.edu/ccg/ iswc04/organizers.html | International Symposium on Wearable Computers | Conference, workshops and posters |

In contrast to the culture of mainstream fashion, serious sports practitioners, and those in sports retail, are knowledgeable in their understanding of generic textile terminology and the claims of the brands regarding fibres, fabric constructions, coatings, laminates and finishes. Designers must communicate with sales teams, retailers and practitioners to achieve aesthetically strong design statements, which also promote maximum performance characteristics in the product. Point-of-sale material must be produced in a language which is accurate and appropriate to the culture of the sport.

*The demands of style and fashion*

Technical innovation in design, driven by sports practitioners, has led to greater comfort and safety in performance clothing but in some cases at the expense of appearance. The aesthetics of functional garments, in terms of colour, trim, style and fashion appeal, has not always been of major importance. Some serious practitioners have maintained, in conversation with the author, that it is even frivolous to think of aesthetic qualities such as colour in the design of performance wear. Designers must have a healthy respect for the knowledge and advice gained from practitioners and combine technical feedback, and an appreciation of the sport's culture, with aesthetic judgement in the creation of innovative product.

Despite the rapid growth of the sportswear market over the past thirty years, few designers have been trained to work in this specialism. Prior to the 1990s there was no specialist training in performance sportswear design within the art and design community. Fashion design had to fight for academic recognition while, in the later decades of the nineteenth century, art college training focused primarily on fine art. Despite certain persistent young women being accepted to study embroidery, fashion design was not an available option. Tailoring and dressmaking, located in the realm of local authority part-time vocational classes for factory workers, remained in low esteem within the art college system until the middle of the twentieth century. As a reaction to the stigma of an association with women's dressmaking, fashion has aspired to a conceptual, more fine art oriented approach to design.[45] Designer fashion has focused on mood, image and creative individuality, often at the expense of technical expertise, cut and finish.

Little comprehensive technical information exists on the range of specialist garment construction methods for the application of technical textiles. The manufacture of a broad range of garment types is complex, encompassing many different manufacturing technologies. The utilisation of materials, with stretch content, the seaming and sealing of waterproof fabrics for protective shell garments, the moulding and laminating of garment areas, the incorporation of insulation and protective components, and the application of technical hoods, pockets, storm flaps and other intricate details all require specialist techniques. The choice of appropriate construction methods is often a major feature of the design. In contrast to fashion design, where it is rare for the designer to have hands-on involvement in prototype garment manufacture, the sportswear designer must have an awareness of the capabilities or restrictions of both traditional and state-of-the-art manufacturing methods and provide detailed technical design specifications, describing such procedures.

Textile technology textbooks, journals and papers have a wealth of information but the relevant issues may be dispersed and often in a language not easily understood by designers. Recent acceleration in fibre developments and new textile constructions, assemblies and finishes has been dramatic. Improvements in handling, comfort and aesthetic appeal of synthetics have made a major contribution to modern expectations concerning the weight, protection, function and appearance of performance clothing systems. Understanding the characteristics of generic fibres, microfibres, bi-component yarns, elastomerics and the range of knitted, woven, multi-layer and non-woven constructions, breathable membranes, coatings, insulations and water-resistant finishes is essential. These products are now being augmented by 'smart' and 'intelligent' textile innovations. To benefit from the range of textile products available, designers need an understanding of their properties and applications and should be able to distinguish one commercial branding and marketing claim from another.

## 4.4 Emerging trends

### 4.4.1 Commercial reality

As sport permeates diverse aspects of our global culture, 'sport is no longer mere sport: it is business, politics, art, film, TV, advertising, fashion, design'.[46] Huge income is generated for football clubs as they alter officially branded clothing on a regular basis to exploit the commercial potential of replica kit. 'The unique relationship between team and fan makes for the kind of brand loyalty marketers dream of.'[47] Branding and the sponsorship of athletes is a global business with sports personalities better known than politicians. Products, endorsed by personalities such as Tiger Woods and the Williams sisters, have 'a multimedia mass of graphics-in-motion that operates consciously and unconsciously.'[48] Andrew states that, today 'amateurism is dead and money has become the lifeblood of sport . . . Professional sport by definition is sport played for money, and the money – from spectators, sponsors or TV companies – will not come without the stars.' The salaries of athletes depend on the size of their audiences.[49] As Tiger Woods plays golf in the Masters tournament, an audience of 10 million in America, and 370 million more around the world, sees not just Mr Woods' smiling face but also the Nike 'swoosh' – the company's distinctive symbol – on his cap and shirt. Brand-imaging and advertising by stealth? Of course.[50]

This commercial culture has direct impact on the sourcing and selection of fibres, fabrics and finishes. In co-branding between apparel and fibre brands,


*4.5* Branding logos on sportswear garments. (a) Rab down jacket. (b) Gul neoprene wetsuit. (c) Lowe Alpine wicking polyester 'T'. (d) Arena fitness wear. (e) Reebok tennis culotte. (f) Speedo competition swimwear. (Source: David Bryson.)

athletes promote the textile chain from fibres through to fabrics, insulations, membranes and finishes. Point-of-sale materials such as swing tickets, posters, videos and, more recently, compact discs reinforce the 'story', as do logo flashes on the garments themselves (see Fig. 4.5). The end-user is aware of the branding rather than the generic fibre content. Invista's marketing, originally DuPont, has adopted 'umbrella' categories where 'Aquator' refers to waterproofness, 'Lycra' to any stretch fabric, and 'Coolmax', originally a shaped polyester fibre, now means 'wicking' fabric. The sportswear designer is faced with a confusing selection of brand claims, with selection often determined by commercial deals.

Since the 1990s, extreme sports have been promoted in the media from commercials for soft drinks and sneakers to programme series representing the most daring and demanding feats in both individual and multi-disciplinary combinations of sports. Back-country skiing, snowboarding, skydiving, rock and ice climbing, marathon running, bungee jumping, kite surfing and adventure racing are among the high-risk pursuits which, in turn, rely on technical textile advances. These feats of endurance test virtually every aspect of the functional reliability of clothing design and the interrelationship with equipment and accessories. As technological advances enable practitioners to push themselves to new extremes, safety in sport is a major issue.

## 4.4.2 Smart clothes and wearable technology

Aspects of wearable computing filtering down from military end-use will soon address the demands of extreme sports. Smart textiles are being developed to incorporate conductive fibres and inks with sensors and switches to monitor aspects of health and wellness, positioning, predominant posture, speed as well as all that is concerned with mobile phone communications. A computer can already be the size of a belt buckle or packet of chewing gum, with soft keyboards or laser projection of data. Commercial innovations in smart clothing and wearable technology have already emerged in sportswear ranges to include phase-change fibres (Outlast), antimicrobial silver fibre (X-Static), intelligent devices such as heating in fleece (Malden Mills), heart monitoring in sports bras (Philips), avalanche detection (Recco), MP3 players in snowboard jackets (Philips/Levi and Burton), and global positioning devices in protective outerwear (Reima).

### 4.4.3 Biomimicry

As nature is tried and tested, biomimicry is now informing textile development and apparel design in terms of material constructions and their appropriate placement on the body, with specialist properties and finishes to enhance performance. Shark skin has been mimicked for competitive swimwear by Speedo, insect 'shells' for helmets, and 'mimicking the material used by spiders to create webs could provide a way to manufacture fibre without using high heat, high pressure, or toxic chemicals. The spider's fibre is stronger and more resilient than anything on the market today.'[51]

### 4.4.4 Environmental issues

As we begin the twenty-first century, sustainability and ethics in design should be a major concern for the product development team from fibre production through to the disposal of garments at the end of their use. Biodegradable polyesters can now be produced from cornstarch, with the easy-care properties of real polyester yet based on annually renewable resources rather than fossil fuel, with potential applications such as fabrics for clothing, packaging and carpets. Jim Lunt of Cargill Dow Polymers LLC presented Nature Works fibre, since renamed Ingeo, to the sports trade at the DuPont and WSA's joint conference in Evian in 2002. Lunt believes that crop-based biodegradable PLA will bridge the gap between natural polymers and the synthetics, offering a unique combination of properties combining the best attributes of natural and synthetic fibres. In addition, PLA products are fully compostable in commercial composting facilities. Cargill Dow plans to further develop technologies which, instead of using corn, use only the waste, such as corn stalks or straw, to create even more eco-friendly materials for the future.[52]

A company with a serious environmental commitment is Patagonia, California, established by the climber Yvon Chouinard in 1973. His company's ethics are admirable, with the provision of child care for workers, flexible working hours to promote the practice of sport and an Earth Tax, representing

1% of sales revenue, allocated to the protection and restoration of the environment.[53]

At Patagonia, relentless research has gone into the life cycle of the product, balancing functional attributes and longevity of design, with the environmental impact of fabric processes and aftercare. Patagonia was the first American company to specify recycled polyethylene terephthalate (PET) fleece and more recently has adopted exclusively organic cotton for appropriate items. A colour palette, for organic cotton, devised with Ciba, guides designers in selecting dye colours that are the least toxic. The aim of the design team is to achieve minimal environmental impact without compromising technical performance. Chouinard's aim has been for sustainability in design based on the philosophy of simplicity and quality. This follows the theory that there is nothing that is extraneous in good design; everything matters and every part serves a purpose.

## 4.5 Further information and advice

This survey demonstrates how comparatively recent the development of high-performance sportswear has been. It has revealed the impact of modern technology on sport in relation to medical science, innovation in fibres and materials, industrial processes and global communications. It has emphasised the need for sports clothing to combat the hazards of the sporting environment and, ideally, enhance performance as practitioners have taken greater risks. A practical concern, from the middle of the nineteenth century, 'protection' has expanded to embrace abrasion resistance, insulation, tear strength, waterproofness, windproofness and, most recently, antibacterial and anti-UV properties. It has highlighted concerns with regard to comfort and functionality but shown that these do not entirely satisfy the needs of the practitioner. Appearance and 'mood', influenced by fashion and the culture of the end-user, are important elements in the mix.

A clear and comprehensive design brief is essential prior to embarking on research and development. The sportswear designer of this century may be one of a team to include textile technologists, garment engineers, electronics experts, biologists, digital media experts and computer scientists. As the increasing commercial power of the corporate brands has led to concerns about a loss of understanding of the real needs of the practitioner, with individuals having loyalty to the smaller practitioner-led brands which survive, the end-user may be able to engage with the design process from entering a sizing booth to specifying individually customised product with the addition of personalised wearable technology. Sustainability will be a major concern as renewable fibres and recyclable materials are developed alongside durable and, hopefully, non-toxic components. Designers should be informed and empowered to participate in decision making about emerging technologies.

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# 5
# Functional sport footwear

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## 5.1 Introduction

Functional features of sport footwear are comfort, performance, protection, support and shock absorption. The primary function of all shoe types is protection. Shoes provide the feet with a firm hold, protect them from injury and improve sporting performance.[1] Optimal functionality is achieved through correct design of the upper and lower parts of the shoe, correct last shape with technically chosen materials and components, correct shoe construction and the appropriate shoemaking technique.

The prime functions of the foot are to serve as a base for supporting the body and as a lever for locomotion. Our feet are, however, unique, and they have special requirements. One style will not fit all and therefore it is difficult to make a general prescription for appropriate sport footwear. Sport shoe manufacturers are developing customised footwear. Specially designed insoles (footbeds) are one example of mass tailoring. High-level end users prefer a customised last which gives optimal fitting for the individual athlete.

The sport footwear industry is producing competitive, profitable and fashionable shoes. Their styles not only influence high street fashion but are also appearing in the most innovative fashion designs. As *Sports Edge* magazine has declared, fashion and function have become one family.[2]

Below is a list of different types of sport shoes, and it shows how prevalent footwear is in this field. Various sports are divided into seven categories; athletic sport, court sports, field sports, winter sports, track and field sports, outdoor activities and special sports. Athletic sport means running, training, hiking walking, jogging and exercise walking. Court sports include indoor and outdoor sports such as racket sports and team court sports (volleyball and basketball). Field sport includes football, rugby, softball, soccer and baseball. Winter sports includes skating sports such as ice hockey and figure skating, and bobsleigh, cross-country skiing and ski-jumping. Track and field sport includes shoes for individual athletes who compete on the field or track (sprint, javelin, high jump, etc.). Outdoor sport includes hunting, fishing, climbing, parachuting, boating and other recreational activities.[3] Finally, there is speciality sport such as golf, aerobics, cycling, dancing, etc. All the sports mentioned above, and many others, have their own type of sport footwear which has special demands.

This chapter looks at the functionality of sport footwear in general. Its purpose is to explain what is generally meant by functional footwear design, functional shoe fitting, and functional materials and components in sport footwear. Construction and materials maximise or minimise the performance. Functional shoe fitting is about comfort, shock absorbency and biomechanical features of the shoe. It is also about stability, support and protection. Important fitting areas are joint area, heel area, toe and arch area. Last shape is an important feature of good functional footwear. An optimal fastening system provides good fitting during performance. The most common sizing systems are also discussed. The last part of the chapter covers functional materials and components.

## 5.2 Functional design of sport footwear

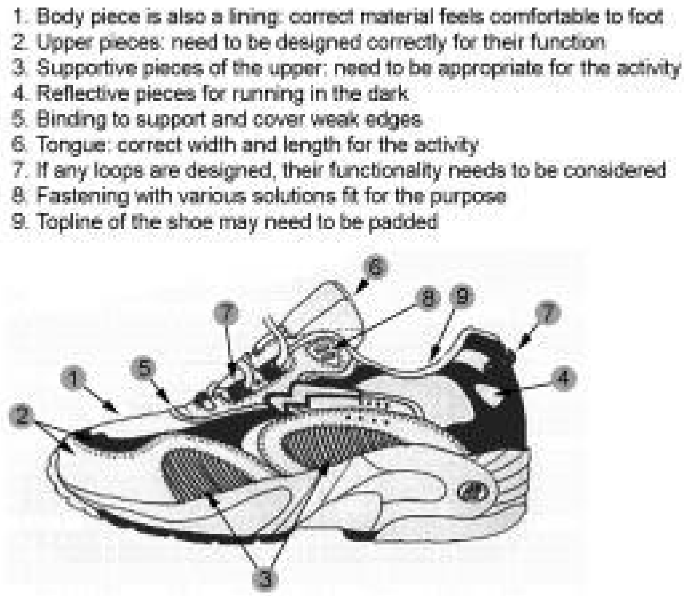
A functional footwear design means understanding of the shoe end user, the sport/performance, shoe construction and manufacturing techniques. It also means knowing how to develop the footwear to meet the demands of the above-mentioned areas. In addition to these, knowledge of anatomy and the biomechanics of the foot is important. *Sports Edge* magazine quotes Dr Berthold Krabbe, manager of Adidas's biomechanical department: 'Only those who understand the foot can make good shoes.'[1] Functional footwear design also means knowing about technical materials and components. Testing the design in the laboratory and in the natural environment makes it easier to develop and gain more knowledge about functional designs that are fit for their purpose. In order to fulfil all the requirements, professionals from various areas need to work as a team. A designer is often called an integrator who collects information from various professionals and puts the developments into practice by designing an optimally functional shoe. Naturally, marketing and price issues are always part of functional footwear design, just as they are in the development and production of any product.

Athletes say that shoes are functional when they do not feel the performance.[4] At the same time, shoes give the necessary support for the foot's action. Athletes use the word 'feel'. The feel of the shoe is important to them. According to the same study,[4] the following apects of functionality are important. For long distance runners, shoes need to be supportive and they need to be light. They need to have good shock absorption to enable their feet and body to cope with impact forces in the take-off phase. Shoes also need to feel flexible and comfortable in running. For outdoor activities, shoes need to be supportive. Terrain should not be felt under the sole, therefore shoes need to be strong, thick and rigid. An orienteer commented that shoes are good when you do not feel them at all except through the soles. They want to feel the terrain. Shoes should not become heavy in water and in wet terrain. They should be light on the feet. Shoes need to feel tight on feet. Feeling is also important to a heptathlete. According to the study, in sprint events, shoes should feel a bit uncomfortable but give maximum performance.

In technical design, functional footwear materials and construction go hand in hand. Correct design at the joint area gives flexibility. Lightness of the shoe is achieved via the choice of upper materials and by using less cushioning. In running, for better rolling motion a curve last is used. For water resistance, correct seam allowances, correct closing techniques and correct materials need to be used. If a high level of flex resistance is needed, then materials that work in various climates and environments must be selected. Materials are also important for preventing pilling from abrasion. This is especially important on linings. Also with regard to the choice of lining material, you need to think how moisture will be absorbed from the upper lining, insock and insole. Comfort of the shoe upper is gained with a padded tongue and mesh upper materials. Stability of the shoe can be achieved with cushioning, medial support and with a semi-curved or curved last: it supports foot movement.[5] Also, backpart design and correct inserts give necessary stability. Durability in the upper is achieved with toe bumpers and stitching, and in the sole with materials and traction design.

Controlling a motion is achieved with a heavy, more rigid, and durable shoe, and by limiting overpronation. Movement control is also achieved via the design of the midsole and waist area, that is, arch support. Traction of the bottom of the shoe is achieved with an increase in outsole traction and with midsole stability. Correct shock absorption in shoes is controlled by the outsole and midsole. Tightness is achieved with the correct fastening system and by tightness between instep and joint.[6] A tight ankle, tight instep, rigid toe and rigid backpart give support to the footwear.

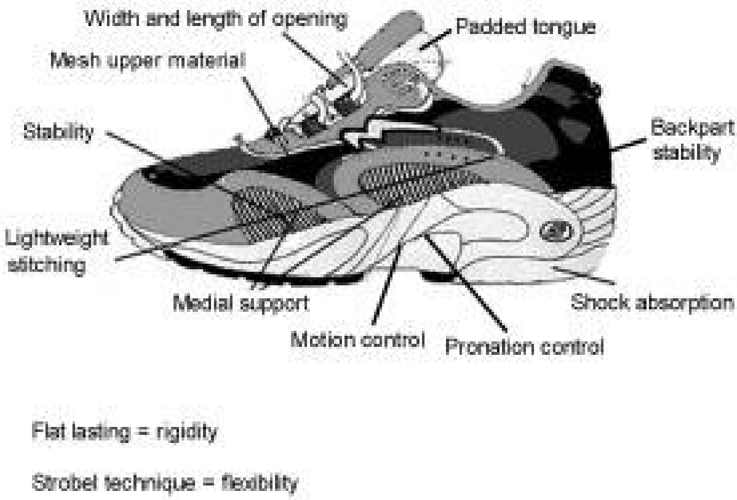
When designing functional footwear you need to know if the sole needs to be heavy or light, rigid or flexible, thick or thin, supportive or loose. You need to know the behaviour of the shoe in wet and in dry conditions, in snow and on grass, in concrete and in swamp. Climatic conditions are some examples of various conditions where sports are taking place. It is also essential to know how shoes feel while in motion when considering the production of a sport shoe. You need to know how the shoe feels when running, jumping, sliding, stopping, when it is stretched, put under pressure, formed into various shapes, folded and so on. In functional footwear design, you also need to know how to minimise or maximise movements. For instance, in minimising sliding of the sole you have to use soft or sticky soles and strong traction, but for maximising the sliding, you have to use leather or PVC (polyvinylchloride). For minimising upper stretching, heavy and stiff materials are used. For maximising stretching, soft and knitted materials can also be used.[4]




*5.1* Functional footwear design must follow certain rules. This figure shows nine important points for a running shoe.

From a technical point of view, the upper construction has some rules to follow. Figure 5.1 shows points that should be considered when designing running shoes.[7] Important points are the length and width of the opening for laces. The design should be sufficiently low that it facilitates the fastening system, making possible the correct tightening of laces and other fastenings. Eyelets or holes need to be placed so that they have enough support from the materials for the lacing up function. They also need to be secure and supportive when running. The backpart of the running shoe must be of the correct height and it should give adequate support to the ankle in motion. The topline of the running shoe should be at the correct height to support the ankle when force is exerted through movement. The joint area must be kept away from thick seams and other details to avoid excessive weight.[6]

Looking at some sports more closely, we can see some important requirements. Some long distance running shoe requirements are shown in Fig. 5.2. Walking shoes need to have a comfortable soft upper and good shock absorption. The tread in the sole needs to be smooth. Sole design needs to support the natural roll of the foot during the walking motion. Jogging shoes need to have cushioning and control and stability in the heel area. Lightness and good sole traction and flexibility are important factors too. In many winter sports an important factor is to protect the ankle; thermal conditions must be considered too. Most shoes in court sports require the body to move forward,




*5.2* Requirements of a good running shoe.

backwards and side to side. The support from the sides and sole are very important.

## 5.3 Functional fit of sport footwear

What is a good fitting of the shoe? Peet explains that a good fitting 'allows the foot to function normally for the application it is designed to meet'.[8] He goes on to say that the shoe needs to have a shape and dimensions which maintain good health and it needs to be constructed and manufactured from materials which ensure its properties in wear. Good fitting also means comfort in most cases (note that with sprint footwear, performance is more important than comfort). Optimal underfoot shape also gives a good fitting, if it is checked carefully. Insole and insocks need to be checked as carefully as styling to ensure they fit the user. Generally, sport footwear does not fit as firmly as fashion shoes.[8] Some exceptions are rock climbing shoes and sprint shoes.

Factors affecting shoe fit are physical and psychological.[9] Physical fit starts from the shape and size of the foot and a shoe. Health factors and the foot in motion and at rest affect the foot shape. The shape of the last and production variations affect the shape of the shoe. Normal foot or variation affect the size of the foot. Again style requirements, fit requirements and rules of last manufacturers affect the shape of the last.

The foot's shape, proportions and size differ depending on function and in weightbearing. The therrmal condition of the foot affects the foot shape. Functional footwear is designed and produced to fit the purpose. The foot needs to fit the shoe in length and width in the joint area. It also needs to fit from heel to joint area, from arch length and from heel width. There are very few static phases in sport (where proportion and shape remain the same). The foot bears weight and it uses muscles. Because of that, the shape of the foot changes from the static phase. Weightbearing can be seen under motion such as walking or running. According to Rossi and Tennant, a shoe is a static object and the foot a functioning object. Therefore shoe and foot need to cooperate as well as possible.[9]

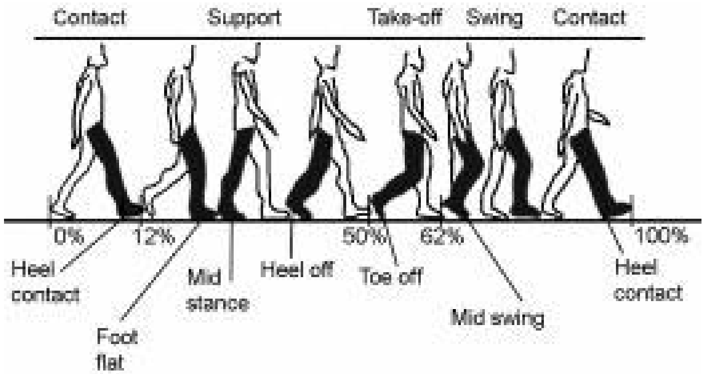
### 5.3.1 Biomechanics of the foot

The foot can be divided into three parts: rearfoot, midfoot and toes.[9] Each section has its own special function. The back of the heel bears the bodyweight in standing and also absorbs shock in walking. The midfoot can be called the spring section of the foot and has a shock absorption role. Weight and stresses are transported to the forefoot. This prepares for the step take-off. The toes keep the balance of the foot. Walking is a linear movement. We land on our heel when walking and running.[9]

The foot is subjected to a mechanical dynamic load. In weightbearing, the foot becomes longer and it is stretched forward and rearward at the heel area. There is more spread at the waist and joint area and the foot becomes wider from the joint.[9] Walking puts up to 1.5 times our bodyweight on our foot, and running two times our bodyweight. The bodyweight of the athlete, running speed, and shoe and surface properties also affect the impact force. A heel hitting the ground transfers two or three times the person's bodyweight to the foot. For a basketball player the factor could be eight times bodyweight.[1] During a marathon race, the runner experiences approximately 25,000 impacts with the ground.[10] Because of impact from bodyweight motion, some sport performances need good support on the heel. The heel counter stabilises the heel area. However, too rigid a shoe does not provide any greater protection against impact and may affect the gait cycle.

Movements of the foot in running and walking constitute a gait cycle (see Fig. 5.3).[11] The gait cycle varies among athletes. It includes an impact phase, a pronation (rolling in) phase and a supination (rolling out phase). After heel-strike follows an unrolling movement of the foot and then take-off from the ground through the forefoot.[11] This phase is important when choosing the right sole material. It is important that as little energy as possible is absorbed in the sole of the shoe. This way it gives the athlete better 'spring' away from the ground. Therefore some professionals recommend special materials for the forepart of the sole to improve the performance at the take-off phase.[1]

Because of the linear movement, walking requires flexibility of the forefoot to enable proper rolling of the shoe. Aerobics include lateral movements and need cushioning on the forefoot.[12] Running usually occurs in a straight line.




*5.3* Gait cycle on walking is separated into phases of contact, support, take-off and swing. Shaded right leg shows movements of foot.

Running is linear movement, but demands less push from the forefoot and less flexibility in the front of the shoe. Lateral stability is not so important. Shoes have slight heel elevation to help to minimise the stress to the Achilles tendon.[13]

The weight of the sport shoe is important in any sport. If the shoe is light, weight savings may reduce oxygen demand when running by 1%.[10]

### 5.3.2 Fitting areas of the shoe: flexing point, heel, toe and arch, heel-to-joint and shock absorbency

The flexing point of a shoe is important in most performances. Walking, for instance, has a take-off phase, and that is the phase where flexing appears. It is advisable to prevent thick overlaid materials or seams at the area. Pattern pieces and how to construct them on the upper of the shoe has huge influence on shoe fit. Upper design allows the foot to go into the shoe and also keeps the shoe securely on the foot.[9] The toe area is designed to allow the toes to spread during the take-off phase. Some actions, however, require very tight fit in the toe area. Rock climbing and sprint are examples. The fit of the heel influences the whole sport shoe. Heel profile (straight or curved) and its length and rigidity give needed support. In some sport performances, a straighter and higher heel height gives support; in others, low heel height allows the heel area and ankle to move freely. In running, a chunky feel forces shin muscles to work hard and may cause breakage in motion.[9] In sport shoes which are mostly low-heeled, the joint area needs to be given room for motion. When we have a little heel, bodyweight shifts more to the joint area than when walking in bare feet. The fit of the arch area is also important. Many sport shoes have a midsole, often made from EVA (ethylvinylacetate). It gives needed firm support under the arch and on the outside of the sole, and cushions the impact. It also helps in pronation or inward rolling of the foot. It absorbs much of the shock and centres the heel. Three different degrees of firmness of EVA can be used to give comfort, stability and balance to the foot in motion. If firm cushioning is placed on the heel, the shock centres the heel. When firm cushioning is placed in the middle (arch) area, it redirects the foot towards the lateral side (outside). Firm cushioning placed around the joint area shifts the centre of gravity to the lateral side and the foot is stabilised. Very soft EVA can be placed under the fifth metatarsal peak pressure zone for cushioning.

Shoes also need to fit from the heel to the widest part of the foot. This means that the joint of the foot and the arch base of the shoe will meet at the same point.[9] If these do not meet, discomfort and strain to the foot arch result. Our feet normally expand by 5% during the day. Movements such as walking, running or playing tennis expand the foot about 1½ shoe sizes.[9] Because of this and other factors, the width of the joint needs to meet all demands. In sport shoes it is important to know for how long the shoe will be on the foot in motion and the thermal conditions. The last must be designed, and the correct materials and components chosen, accordingly. According to Rossi and Tennant: 'The shoe is designed to flex on a precise angle across the joint, widest area. This flex joint area is important to the proper tread of the shoe and also to the comfort of the foot's flex action inside the shoe.'[9]

Toe spring helps in the rolling motion of the shoe in the take-off phase. Depending on the performance, toe spring requirements differ. On a sprint shoe there is strong spring because toes produce most of the thrust in running. For shotput, shoes have hardly any toe spring.

### 5.3.3 Shape of the last

The last is used in the shoe making process. The upper of the shoe is 'lasted', that is pulled over, the wooden, plastic or metal last, to form a shoe. The purpose of the last is to give shape and fitting to a shoe.[14] The shape of the last follows in many areas the shape of the foot. Also some parts of the last are standardised for manufacturing purposes. The last has a heel and toe spring for functional purposes. The toe spring enables foot rolling movement in motions such as walking or running. A high toe spring is used, for instance, in sprint shoes for better running motion because the action is performed mostly in the tip of the toes. There are some differences between foot and last. The last shape from the heel or backpart area is tighter than the foot heel shape. There is more heel curve on a last compared with feet to give a better grip on movements. The width of the bottom part of the heel also varies. Variations enable either tight fitting or loose fitting and allow good grip in movements. Also, the instep area in the last is tighter than in a foot. A tighter instep area enables a better/tighter grip from the front of the shoe. In addition, the bottom shape of the sole in a last is smaller in area than the foot. This again enables a better and supportive grip of the shoe. Other areas in the last are toe area, joint girth, bottom curvature and feather edge. Joint girth varies a lot because this is the widest part of the forefoot.

The shape of the last bottom, the sole, varies. The human foot is naturally curved inside. It follows the natural walking motion. The last can also be curved inside for better fitting and comfort. Generally speaking, sport shoe lasts are often slightly curved inside. A straight last is more often used when more support on the medial side is needed. The arch of the foot fits differently to a curved and a straight last. A high arch may feel more comfortable in a curved last whereas a flat arch may feel more comfortable with a straight last.[9]

The shape of the toe also varies. The toe is very important in fashion footwear. On a sport shoe, the last shape of the toe is designed according to the needs of the sport. Outdoor footwear needs more space in the toe in height and width than a shoe for sprint running. This is because of comfort. In sprint footwear, maximum performance takes precedence over comfort.

An athlete may order a customised last. Individual measurements from the athlete's foot are made, to be used as the basis for the last. Joint girth, instep and the shape of the forefoot area are also taken into consideration, as well as the width of the athlete's own sole.

### 5.3.4 Fastening systems

A functional fastening system is an important factor in good sport shoe fitting. The length, width and the place of the fastening maximise or minimise the performance and comfort. Laces are found to be a very useful fastening system because an athlete can modify tightness or looseness of the shoe with them. A zipper can be used for closing the footwear. It can be seen also as a covering piece for the laces. Velcro is sometimes used for ankle and calf area fastening. Elastic can be used on the instep area to tighten the fit on the cone area. The importance of place and size of the fastening technique must not be overlooked in functional footwear styles.

### 5.3.5 Shoe size systems

With the last, the size of the shoe is also specified. There are different size systems used in shoes. They are all based on the length of the foot and shoe. In Europe, in fashion shoes, the most common sizing systems are the English and Continental systems. In sport shoes, three or four different size systems are used. They are English, American and Paris Point (Continental) and Japanese sizes. In eastern Europe and Japan, a centimetric size system is used, and in South Africa and in eastern Europe a Mondopoint (millimetric) size system is used. Brazil uses the Continental system. In sport shoes, size systems are marked as follows: English is UK, American is US, Paris Point is EUR/EU or PP, and Japanese is marked JP/JN or CM. Outdoor footwear manufactured in European sizes may be marked only with Continental sizes, e.g. 43. Size marking on sport footwear manufactured in the Far East is basically marked according to the countries where it will be sold.

English and American sizes are based on inch measurements. The various size systems are summarised in Table 5.1.[14] The English/UK scale starts from 4 inches and American/USA scale starts from $3\frac{11}{12}$ inches. This makes US sizes one size larger than UK sizes: USA 9 is UK 8. Both size systems also have half sizes. One size difference is 8.47 mm on both, and a half size difference is 4.23 mm. Continental/Paris Point starts from zero and the difference per size is 6.67 mm. The size system uses whole sizes, such as 42. The Japanese system uses the length of the average foot, measured in centimetres. One size difference is 1 cm and half size 0.5 cm (i.e. size 26 equals 26 cm). A comparison of four most often used sizes for sport shoes is: USA 9, UK 7, ParisP 42 and Japanese 26. Mondopoint is similar to the Japanese size system. It is based on length of the shoe (in millimetres) and also on width of the shoe from the ball (in millimetres).

*Table 5.1* The most common size systems used in functional sport footwear

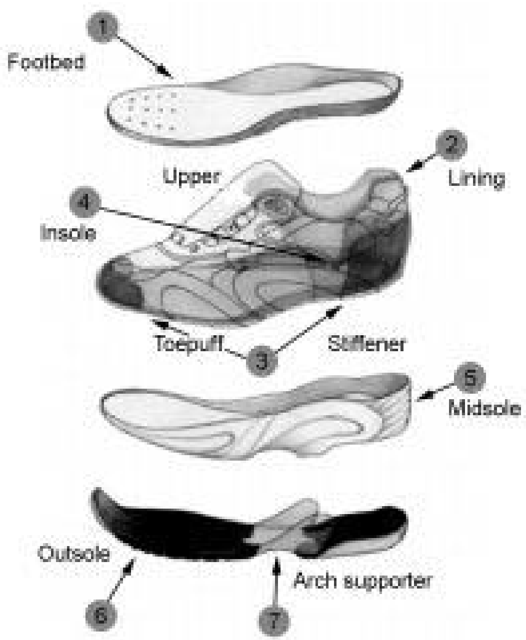
| USA American[1] | France Paris Point[2] | UK English[3] | Japan centimetres[4] | cm | inch |
|---|---|---|---|---|---|
| $3\frac{1}{2}$ | 35 | $2\frac{1}{2}$ | 21.5 | 22.8 | 9 |
| 4 | $35\frac{1}{2}$ | 3 | 22 | 23.1 | $9\frac{1}{8}$ |
| $4\frac{1}{2}$ | 36 | $3\frac{1}{2}$ | 22.5 | 23.5 | $9\frac{1}{4}$ |
| 5 | 37 | 4 | 23 | 23.8 | $9\frac{3}{8}$ |
| $5\frac{1}{2}$ | $37\frac{1}{2}$ | $4\frac{1}{2}$ | 23.5 | 24.1 | $9\frac{1}{2}$ |
| 6 | 38 | 5 | 24 | 24.5 | $9\frac{5}{8}$ |
| $6\frac{1}{2}$ | $38\frac{1}{2}$ | $5\frac{1}{2}$ | 24.5 | 24.8 | $9\frac{3}{4}$ |
| 7 | 39 | 6 | 25 | 25.1 | $9\frac{7}{8}$ |
| $7\frac{1}{2}$ | 40 | $6\frac{1}{2}$ | 25.5 | 25.4 | 10 |
| 8 | $40\frac{1}{2}$ | 7 | 26 | 25.7 | $10\frac{1}{8}$ |
| $8\frac{1}{2}$ | 41 | $7\frac{1}{2}$ | 26.5 | 26.0 | $10\frac{1}{4}$ |
| 9 | $42\frac{1}{2}$ | 8 | 27.5 | 26.7 | $10\frac{1}{2}$ |
| $10\frac{1}{2}$ | 44 | $9\frac{1}{2}$ | 28.5 | 27.3 | $10\frac{3}{4}$ |
| $11\frac{1}{2}$ | 45 | $10\frac{1}{2}$ | 29.5 | 27.9 | 11 |
| $12\frac{1}{2}$ | $46\frac{1}{2}$ | $11\frac{1}{2}$ | 30.5 | 28.6 | $11\frac{1}{4}$ |
| **Length grade** | | | | | |
| $\frac{1}{3}''$ or 8.47 mm per size and $1\frac{1}{16}''$ or 4.23 mm or half size | $\frac{2}{3}$ cm or 6.67 mm per whole size | $\frac{1}{3}''$ or 8.47 mm per size and $\frac{1}{6}''$ or 4.23 mm per half size | One size difference is 1 cm and half size is 0.5 cm | | |

[1] The scale used is identical to the UK scale except that it starts at $3\frac{11}{12}''$ instead of 4″. Therefore on US system the size will measure one size larger.
[2] Size system starts at 0 and advances by $\frac{2}{3}$ cm.
[3] A length scale that starts at 4″ is called 0, and proceeds at intervals of $\frac{1}{3}''$ (8.47 mm) until size 13 at $8\frac{1}{3}''$ called size 1 and proceeds in $\frac{1}{3}''$ as before.
[4] Length of average foot in centimetres.

## 5.4 Functional materials and components in sport footwear

Functional footwear has an upper section, lining section, and reinforced pieces between lining and upper (Fig. 5.4). Footwear often has an insole and almost every sport shoe has a loose insock or footbed. The sole of the shoe can be in unit form or it can be built up from midsole and outsole. Various types of pieces are used as a supportive part on the upper and on the sole. All the materials and components are directly involved in the fit, comfort and general performance of the shoe. Aesthetic contribution is made by the materials. It is not just the material in the footwear that affects fit. A sock plays an important role too. A sock made from natural fibre will transport dampness more effectively than most synthetics fibres, for example.

Materials and components have properties which ensure comfort, fit, protection, stability and support. Materials and components can also maximise prolonged wear and retention of the shoe shape. They also play a role in transferring heat and moisture from the foot and from the external environment.




*5.4* Functional footwear has an upper, lining section and reinforced (supportive) pieces such as stiffener and toepuff. It also has a footbed and an insole. The sole can be divided into a midsole and an outsole.

### 5.4.1 Properties of materials and components

The properties of upper materials vary according to the requirements of the sport. General properties are softness/stretchiness, flexibility/stiffness or comfort. Upper materials need to mould to the shape of the foot. The lining materials need to meet the highest standards. A function of the lining is to serve as a buffer zone between the shoe and the foot. The lining absorbs perspiration and soiling from the inside of the shoe and the feet, and it helps to prevent staining of the upper material. It needs to be breathable and to absorb and transport dampness from the foot. Abrasion and pilling in counter and quarter lining and in collar lining are under continuous testing in laboratories. Material companies are developing frictional properties of lining materials to meet the requirements of many sports. Commonly used materials for lining are woven nylon, terry loop and knitted fabric.[15] Thermal insulation properties are important for some sports too. In a cold climate, the lining needs thermal microfibres, which are used as insulation.[15] The adhesive between the lining and upper layers should not stop breathability or the transportation of moisture away from the foot.

The material for the heel counter needs to be strong and rigid. The toepuff needs to be resilient, hygienic and firm. In much sport footwear, the toepuff is soft for the construction process. Other parts of shoe are usually attached to an insole. The insole needs to be absorbent and to allow the moisture to pass through it. Other properties of insole are flexibility, durability, light weight, uniformity, inhibit bacteria, structural integrity, and stain resistance to perspiration and soiling. The insock is a piece like the insole but it is stitched on to an upper. The insock material needs to withstand stitching and, like the insole, it also needs to take up moisture. Other properties are the same as with the insole.

Functional properties of the sole are durability, waterproofness and dimensional stability. Various sports require such properties as flexibility, rigidity, breathability, thickness/thinness, and good traction or less traction to the ground. When choosing an ideal sole for functional footwear, movements of the foot and body need special consideration. The same applies to the environment and terrain where the sport is performed. Thickness and firmness of the sole materials maximise or minimise shock absorbency. SATRA has some recommendations for sport shoe soles in Fig. 5.4.[16] Firmness is softer in running shoes than in racket sports shoes.

### 5.4.2 Materials for the uppers of sport footwear

Development of materials is rapid in the sport footwear market. Materials for the upper and lining are becoming more and more technical, as are those for the sole. Shock absorption and support for various parts of the sole are continually being examined, and innovations launched regularly.

The basic raw material for textile production is fibre. Fibres can be natural or man-made. Natural fibre, such as cotton, is often used for the rear in functional footwear. Man-made fibres are synthetic and natural polymer based. Woven, knitted and non-woven textiles are used for the upper and lining of the sport shoe. The fabric has two to four layers constructed from different textiles which are laminated by adhesive or by foam.[17] Most often, fibres in woven textiles are polyamide, polyester, polypropylene and polyethylene. Plain and twill weave structures are most often used in footwear upper and lining materials. Knitted textile is used often as a backer to give durability and strength. Nylon is a common fibre to use in lining and upper textiles. Textiles are also used coated with PU (= polyurethane) and with PVC (polyvinylchloride) film. PU and PVC films are flexible, durable, protective and decorative.[16] Woven textile and non-woven backers are used to support the synthetic film. Microfibre as a material has similar properties to leather. It is elastic and resistant to tearing, splitting and abraison. Microfibre is also permeable to vapour and it breathes. It is used in many types of sport shoe upper pieces. Other materials used for sport shoe uppers are rubber and moulded PVC. Rubber uppers are waterproof and a PVC mould dip technique is used for skates and ski boots.[5]

Leather is a traditional upper material. It performs much like human skin. It is breathable, comfortable, porous, insulating and aesthetic. Leather is tanned and produced from various types of animal skins, such as calf, cow, ox, pig, goat, deer and kangaroo. The tanning and finishing processes of leather give it its final characteristics. Leather can be water resistant which is important in hiking boots and golf shoes. Full grain leather is used, for instance, for golf shoes and soccer boots.

Thread for the sport shoe upper is mainly made from synthetic fibres. A synthetic fibre is strong, flexible and stretchy. It has good breaking strength, is elastic and uniform, and resists bacteria and mould. These requirements are important because many sports are practised in rough terrain.

Materials for fastening are plastic, metal and beaded fabrics. Plastic and metal are used for buckles, eyelets and hooks, and for zippers. Narrow beaded fabrics are used for loops, laces and Velcro. Raw materials for insole are leatherboard, cellulose board, non-woven materials, plastic and even metal (when no flexing is allowed, e.g. shotput shoes). Non-woven materials are made from polyamides, acrylic and polyester fibres. Supportive pieces between the upper and lining are made from non-woven materials and from thermoplastic materials. Supportive materials are stiffeners, toepuffs and reinforcement in pattern pieces.

### 5.4.3 Sole

The sole can be divided into various layers for various purposes. The midsole gives cushioning, support or rigidity and stability. Devices inside the midsole give stability (arch supporters). Ethylvinylacetate (EVA) is one of the most common midsole materials for many types of sport footwear. The outsole, with correct traction, gives durability and slip resistance. Outsoles with specific degrees of traction are designed according to the requirements of the specific sport. Some sports (like soccer, rugby) need flexibility from the sole; indoor sports require slip resistance. A styrenebutadiene rubber (SBR) is used in many outsoles because of its durability. Vulcanised rubber is used in many types of sport soles.[5] Some sport shoes, e.g. sprint shoes, need rigidity. This is achieved with nylon.

## 5.5 Future trends in functional footwear

Sport footwear is becoming more fashionable and aesthetic, as well as more technical. Footwear fashion and function are becoming united.[2] Colour is, and will be, an important part of functional footwear. Surface design of materials is playing an important role as a design feature. Innovations in materials and components are important. The fashion aspect is important in that the strongest consumer sector is children and teenagers. Price is important for these consumers. Also, fashion will be even more important among adults looking for casual and comfortable footwear mixed with sport footwear styles. Men value the brand and model; women value comfort. Retro-inspired shoes will continue their success in the sport footwear business, reflecting the 'retro' lifestyle trend that has been established.

The materials and components of the shoe increasingly meet the performance requirements, with more future-oriented technology and more functional characteristics. It seems that technology enables sport footwear to be designed and produced to meet the more specialised demands of an athlete. Environmental issues are considered, and fibre and fabric will have more multifunctional properties. The end-user of sport footwear is provided with more personal service to meet his/her requirements. They are able to choose 'own designed' footwear through, for example, web pages. It is already happening, and it will expand in the future. Insole or footbed development has been enormous in recent years. This will continue. The sport shoe field is very wide, and encompasses many special sport performances. Manufacturing industries are serving individuals and their needs in every field of life, and the sport footwear industry will do the same.

This chapter has briefly described some areas of functional footwear, including functional footwear design, what fit means in functional footwear and what materials and components are used in functional footwear. These topics have been discussed at a general level. There are so many sport activities with their special requirements. Sport shoes can be categorised as athletics shoes, court shoes, field shoes, winter sports, track and field sports, outdoor sports and speciality sports. Each category includes a wide variety of sports, such as those listed at the beginning of the chapter. To acquire knowledge and information on one particular sport, it is best to visit athletes, coaches, sport clubs, sport events, etc. and to interview professionals. Publications about the partcular sport are worth reading. One recommended book is Mel Cheskin's *The Complete Handbook of Athletic Footwear*,[5] which is full of information on all sport shoes. More information about foot anatomy can be found in many anatomy books. Recommended too are sport medicine doctors and physiotherapists who work closely with athletes and know much about their injuries and therefore about athletes' feet. Visiting sport science research centres adds interesting and important knowledge to the sport you are interested in. Research centres often specialise in a particular sport and know much about it. In Britain, Loughborough University, for example, is involved in active research. In the USA, BioMechanica LLC in Portland, Oregon, conducts a lot of research in the sport field. If you want to know about production technology of sport footwear, you are advised to contact universities and polytechnics which offer studies in this area. In Europe, Ars Sutoria in Milan, Italy, offers short courses in sport shoe pattern cutting. General knowledge on footwear technology helps in understanding how the upper is attached to the bottom and how the sole is produced. Technology in most sport footwear is the same as or similar to that in other footwear. In the UK, there are courses in footwear technology at the Tresham Institute in Wellingborough, Northamptonshire, at the London College of Fashion, Cordwainers, in London, and at South Fields College in Leicester. In Germany, there is a college in Pirmasens (Pirmasens Schuhfachschule), and in Finland, Häme Polytechnic/ Wetterhoff in Hämeenlinna. Information about materials and components can be found from material suppliers and from special trade fairs. Every continent has its own trade fairs. The biggest one in Europe is Lineapelle in Bologna, Italy.

## 5.6 References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