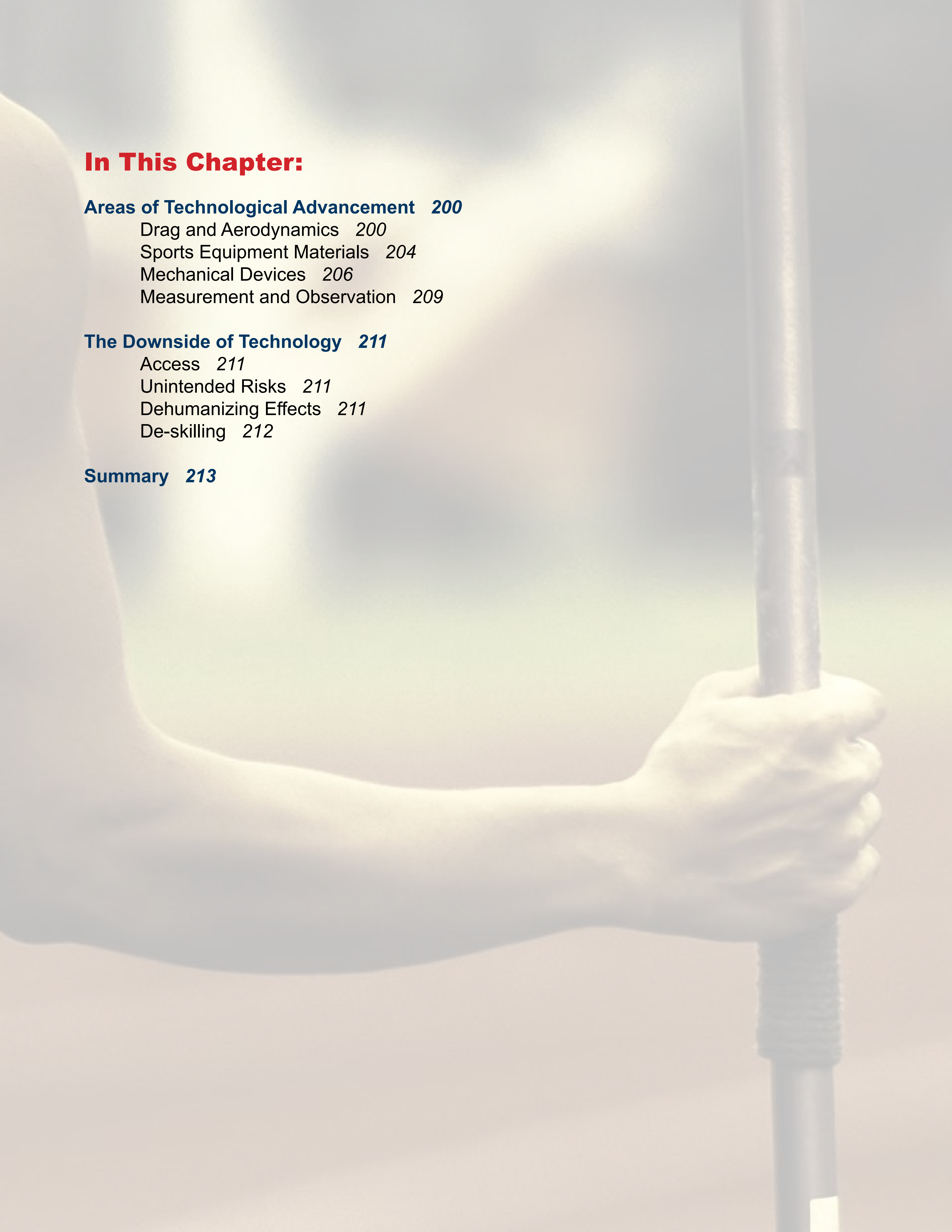


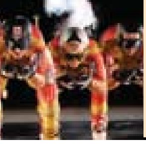
In This Chapter:

CHAPTER 9

Technology and Sport

After completing this chapter you should be able to:

- describe the role of technology in the refinement of sport;
- explain how technology has led to changes in sports equipment;
- discuss the pros and cons of technological advancements in sport;
- recognize that not all technological advancement is for the better.



In many ways, technology and sport have grown and matured together. Some argue that elite sport mirrors the larger technoculture and the high-tech revolution in all areas of society. Modern sport grew from roots within the industrial revolution. Technology changed methods of production from craft-based systems to an unskilled assembly line. This allowed for more leisure time, which encouraged people to participate in leisure activities, including sport. New sports were invented, such as soccer and football. Inventions like the bicycle were at first considered toys of the rich. But assembly-line production of the new equipment soon made it affordable to a large portion of the population.

Obviously, with new equipment came new opportunities for competition. Bicycle races were held within the first year of its invention. Other innovations such as artificial ice surfaces occurred at the same time, allowing growth of related sports. Artificial ice allowed ice hockey to be played in areas that weren't cold enough to have natural ice.

So, did athletes seek out technology to improve performance? Or did new technologies drive athletes to go swifter, higher, and stronger? This is a tough question. It can be argued that the increased emphasis on performance came *before* the invention and introduction of many sport technologies.

Although the pace of new sports being invented has slowed dramatically, technology has played a huge role in the refinement of existing sports. Advancements in engineering, materials, and manufacturing techniques in other areas have allowed sports equipment to progress to more complex designs, which in turn has allowed better performances in all sports.

Defining Technology

Technology is very difficult to define, and we often use the word in multiple ways. It is synonymous with science and rational thought, encompassing every little gadget we've ever held in wonder in our hands. It is the collective machinery that powers Western societies and the microchips that power our personal computers. In this chapter, the term *technology* is used to describe any tangible, conceptual, or procedural element of modern sport and exercise science aimed at progress.

Even with all these advancements, it is interesting to recognize the tension that exists between the technological landscapes of North America and the *paradox of performance* in elite sport. The paradox of performance describes the condition where elite athletes are encouraged to improve their performances but are restricted in terms of the means by which they may do so. Race car drivers may be able to go faster by putting different tires on their cars, or by eliminating drag by altering the car body, but the rules restrict such changes. Many professional sports now restrict technologies of all kinds, and sport is one of the only spheres in Western societies where there is an effort to prevent too many technological innovations. It would be difficult to imagine, for instance, desiring a computer that functioned less quickly and efficiently and that required more effort than the current model to complete a given task.

Areas of Technological Advancement

Technological advancements have been made in many different areas of sport. These innovations have led to changes in the shape and size of equipment as well as the materials used to make equipment and clothing. Mechanical devices that make athletes faster and more efficient have been invented and refined. Technology has also increased our ability to measure sport performance. And don't forget, you take advantage of technology every time you turn on the television to watch your favorite sport.

Drag and Aerodynamics

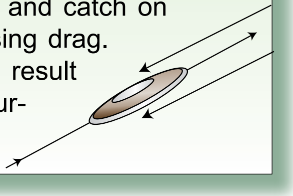
Resistance to movement is called **drag** (see Chapter 8 for more on fluid drag forces). As drag increases,

more power or energy is required to travel at a given speed. In the case of objects that are thrown, increased drag will result in a decreased flight distance. Since most sports involve traveling through air or water in some way, it is important to reduce drag as much as possible to achieve a peak performance.

What a Drag!

You may remember from Chapter 8 that **profile drag** is the result of the shape of an object. An object's shape can be changed to decrease the amount of profile drag, a process known as **streamlining**.

The other type of drag is **surface drag**, or friction. As an object travels through a fluid, the molecules of the fluid rub and catch on the surface, again increasing drag. Different surface textures result in different amounts of surface drag.



The study of objects moving relative to a fluid, such as air, is called **aerodynamics**. Aerodynamics has played a large role in the development of many sports, including the javelin (see box *Liftoff*). The javelin presents an interesting situation because aerodynamics must be taken into account for three reasons. The first is obviously the minimization of drag to increase the distance of the flight. The second is that javelins need to produce some **lift** to stay aloft longer and therefore increase the distance traveled. Since generating lift causes increases in drag, a balance needs to be found. The third factor is that the rules state the javelin must contact the ground with the tip first.

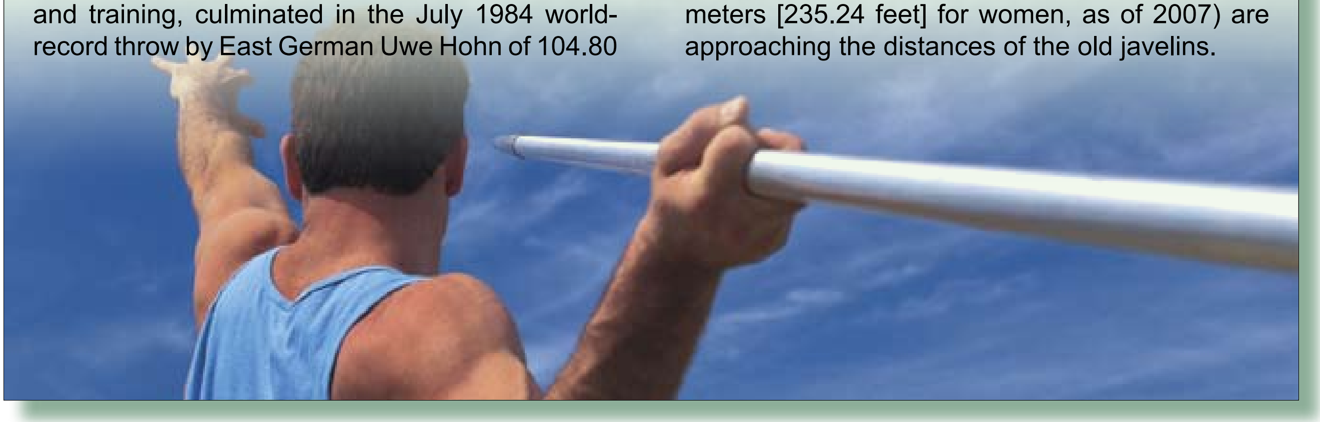
Shape and Size

Over the years, technology has played a role in refining the shape of many types of sports equipment. Observation of fish and marine mammals showed naval architects the importance of streamlining.

Liftoff

Much research was carried out on the flight of javelins in the 1960s and 1970s, including work done at the U.S. Army Ballistic Research Laboratory. A device was constructed that used compressed air to fire javelins at preset velocities and release angles. In addition, wind-tunnel work and high-speed filming of javelin throws were used to better understand the flight of a javelin and how changes in design could be used to increase the distance of a throw.

Similar work in the former Soviet Bloc states, combined with improved throwing biomechanics and training, culminated in the July 1984 world-record throw by East German Uwe Hohn of 104.80 meters (343.83 feet). This world record prompted the International Amateur Athletic Federation (IAAF) to institute rule changes to cause the javelin to underperform. The primary goal of the rule changes was to move the javelin's center of mass farther away from the center of pressure, causing the tip of the javelin to return to a downward-pointing position more quickly following its release by the thrower. World's best distances immediately fell in 1986 after the introduction of the "new rules" javelin. However, the latest world-record throws (98.48 meters [323.10 feet] for men and 71.70 meters [235.24 feet] for women, as of 2007) are approaching the distances of the old javelins.



Altering the shape of boats and ships to reduce drag resulted in higher speeds. A good example of this knowledge was the shipbuilding practices of the Vikings. Their warships, known as longboats, were very narrow so they could reach as high a speed as possible, giving the Vikings the element of surprise during raids. They used wider ships to transport cargo.

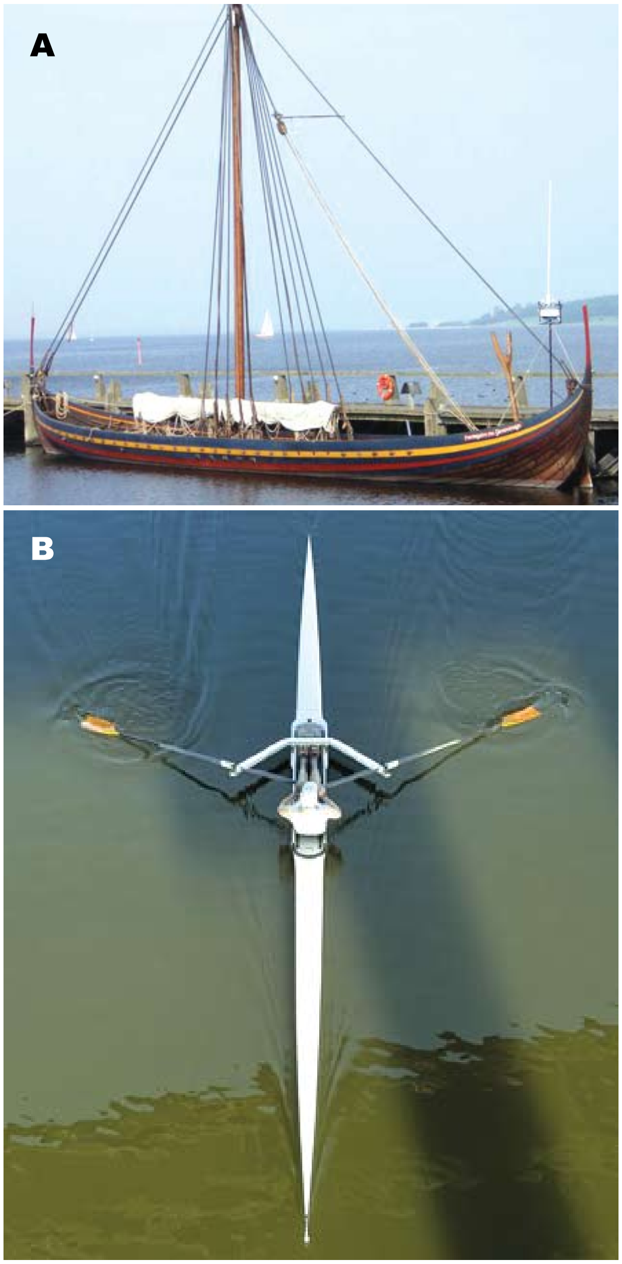


Figure 9.1 Longer and narrower boats reduce water drag and increase potential speed. **A.** Viking longboat. **B.** Single rowing scull.

As the sport of rowing began to grow in the mid-1800s, boat builders used these principles to construct longer and narrower boats (Figure 9.1). The hulls of the boats were made smooth to further decrease the water drag and increase potential speed. Coupled with the development of outriggers that moved the oarlocks farther away from the rower, racing rowing boats (known as shells for their eggshell-like fragility) became quite distinct in appearance. A single scull (one-person boat) was very narrow, with a width of about 1 foot (0.3 meters) and a length of 25 to 28 feet (7.5 to 8.5 meters). Interestingly, since the late 1800s there has been little change in the dimensions and overall appearance of racing shells.

Objects moving through the air are also subject to drag, which reduces the speed at which they can travel. However, unlike boats in water, air drag is not as obvious at low speeds. Early cars and airplanes were completely unstreamlined. It wasn't until many years after the initial development of cars and airplanes that an emphasis was placed on changing their shape to make them travel through the air more easily. For passenger cars, streamlining was not done on a regular basis until the 1980s.

In sports where higher speed of movement occurs, such as cycling (up to 60 mph; 90 km/h; downhill skiing (75 mph; 120 km/h), and speedskating (37 mph; 60 km/h), **air** (**wind**) **resistance** plays a large role in success. Air resistance can be reduced in two ways. One is to reduce the profile drag through streamlining; another is to decrease the frontal surface area of the athlete or equipment (Figure 9.2).

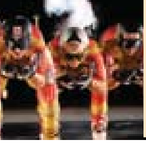
In the past 20 years, much time has been spent on decreasing profile drag in bicycles. Both the shape of the bicycle and wheels and the position of the cyclist have been altered to lower air resistance. Using aerodynamic wheels can cut up to one minute from an Olympic-distance 40-km (25-mile) time trial. An aerodynamic frame can cut another one or two minutes from the time. Considering that about two minutes separated 1st from 10th place at the 2004 Olympic time trial, there are significant advantages to using aerodynamic equipment.

Figure 9.2 In sports where higher speed of movement is critical for success, air resistance can be minimized by reducing profile drag through streamlining or by reducing the frontal surface area of the athlete or equipment. As a result, athletes often adopt a more crouched-over position.

Body Position

In cycling, speedskating, and downhill skiing, it was quickly recognized that standing or sitting upright had detrimental effect. A more crouched-over position was adopted in all three sports. Racing bicycles were designed with dropped handlebars to allow cyclists to bend their bodies into position, which reduced frontal area. In extreme forms, a recumbent (sitting with legs in front) bicycle was found to decrease the frontal area drastically. In the early 1930s, a recumbent bicycle was used to set the "hour record" (farthest distance ridden in one hour); it hasn't been beaten by a conventional bicycle to date. The international cycling governing body did not recognize the record since it wasn't done on a traditional upright bicycle. The current hour record for recumbents is 86.752 km (53.917 miles).

Altering body position has a significant effect since the body produces much of the profile drag. In cycling, moving from an upright position to an aerodynamic one can reduce 40-km (25-mile) time-trial times by up to six minutes. As a result, many of the top cyclists including Lance Armstrong (seven-time winner of the Tour de France) spend time each year in low-speed wind tunnels perfecting their riding positions. However, there is a trade-off. Often a more aerodynamic position (e.g., more bent over) affects the joint angles at the hips, resulting in lower power output from the muscles. In fact, Armstrong had to deal with this problem in 2004, when a consortium of manufacturers spent $250,000 developing a new time-trial bicycle for him. Each change to improve aerodynamic efficiency resulted in decreased sustainable power output. The final result was that Armstrong did not use that bicycle in races but competed with an older one.



Texture

Surface drag (friction) also contributes to air resistance and water resistance. It may seem counterintuitive, but a slightly rough surface has lower friction drag than a perfectly smooth surface. The dimples on a golf ball are an example. The slightly rough surface traps a single layer of air or water molecules – known as a **boundary layer** – which reduces drag because now the fluid molecules are rubbing against other molecules of the same fluid rather than against different types of molecules. Fluid molecules rubbing against fluid molecules results in much lower friction.

Early attempts at producing racing suits for downhill skiing resulted in suits that were very slippery. In fact, they were considered dangerous because they did not slow a skier after a fall. There was insufficient drag between the suit and the snow to stop the skier from sliding into trees or spectators at high speed. The International Ski Federation banned the suits in the name of safety.

Swimming has benefited in recent years from changes in suit material to reduce surface drag. In conjunction with engineers, Speedo explored the flow of water around the limbs and bodies of swimmers. This research, in addition to observations from nature that sharks and marine mammals have different textured skin in different areas, led Speedo to design new bathing suits. These new bathing suits cover much more of a swimmer's skin and have varied textures (Figure 9.3). In some areas, ridges in the suit run parallel to the water flow. In others, the ridges run perpendicular to the flow so that water attaches to the surface of the suit, reducing surface drag as well as profile drag by decreasing eddies that may form. Manufacturers claim decreases in total drag of about 15 percent.

Figure 9.3 As swimmers continue to pursue faster swimming speeds, manufacturers continue to push the envelope with new and improved swimsuit technologies.

Sports Equipment Materials

In about 150 years, sports equipment progressed from wood to iron to steel to aluminum and finally to carbon fiber. This progression resulted from the search for stronger, lighter, and stiffer materials.

Materials in sports equipment can be classified according to strength. However, the term *strength* needs to be used carefully because it can mean many things. There is tensile (or pulling) strength, compressive (or pushing) strength, and shear (or sliding) strength. Different materials possess different maximal resistances to these different domains. If the maximal strength is exceeded, a material may bend or yield to a point where it just breaks.

Most equipment breakages occur because of fatigue, however, not because the maximum strength or stress has been exceeded. Materials can tire. A piece of plastic can be broken if it is bent repeatedly. Each time it is bent it is said to be loaded, or stressed. Note that a **load** doesn't have to cause bending for fatigue to occur. This is particularly true for very stiff materials (e.g., metal titanium) or a composite material (e.g., carbon fiber).

During practice or competition, materials used in the construction of equipment can be repeatedly stressed. Although none of the stresses exceed the materials' maximum strength properties, the sports equipment still fails after accumulation of many loads. As a result, selecting materials for sports equipment is a difficult task, especially considering that lighter materials allow for better performances (consider a lighter tennis racket or hockey stick).

Another factor for a designer to consider is the stiffness of the material. A stiffer material can be considered more efficient for transmitting force

Figure 9.4 Tennis rackets have come a long way from the original wooden designs.

between the athlete and the ground or a ball, since energy is not going into the deformation of the equipment.

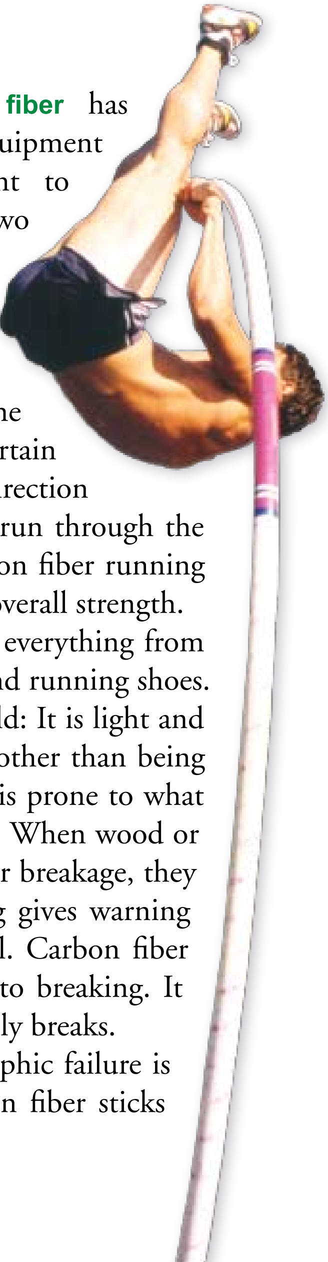
These characteristics have led designers and builders from wood to stronger and stiffer materials. The result is that current sports equipment is not only lighter but also much more efficient (Figure 9.4).

From Wood to Aluminum

Wood was the most common material for most sports equipment up until relatively recently. Tennis rackets, hockey sticks, boats, and even bicycles were made of wood for the simple reason that it was readily available and easy to work with. Skilled craftsmen were able to shape different varieties of wood – each with its own characteristics in terms of strength, weight, and stiffness – into many distinct pieces of equipment. The quest for lighter and stronger bicycles was one of the first forces pushing manufacturers into steel. Another benefit of steel is its resistance to environmental effects. Wooden tennis rackets and oars needed elaborate presses to keep them in shape. Steel or aluminum rackets do not need those devices and therefore require less maintenance and attention.

More recently, the changes in materials used in sports equipment have occurred very rapidly. The reasons for these rapid changes are complex but, in general, have occurred very soon after the introduction of newer materials and innovations in the engineering world. Going from steel to aluminum, for example, requires different welding techniques. In addition, the aluminum has to be readily available at a reasonable cost.

Carbon Fiber



The introduction of **carbon fiber** has completely revolutionized equipment manufacturing. It is important to note that it is a composite of two different materials. Carbon fiber is a cloth-like material that is made of strands of carbon. It is held together by a resin, which gives it some of its properties. The composite has strength only in certain directions, depending on the direction that the strands of carbon fiber run through the resin. Building up layers of carbon fiber running in different directions improves overall strength.

Carbon fiber is now used in everything from race cars and bicycles to skates and running shoes. Its primary advantages are twofold: It is light and very stiff. The major downside, other than being difficult to work with, is that it is prone to what is known as **catastrophic failure**. When wood or most metals get close to failure or breakage, they first start to bend. This bending gives warning that the material is about to fail. Carbon fiber composite does not bend prior to breaking. It keeps its properties until it actually breaks.

The best example of catastrophic failure is seen in ice hockey, where carbon fiber sticks