

Technology in Sports Equipment

Understanding the Influence of Technology on Athletic Performance

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Image courtesy of Frank Steele. Retrieved from http://en.wikipedia.org/wiki/File:Dave_Zabriskie_-_USA_Pro_Time_Trial.jpg (accessed 25 October 2012)

Figure 1: Professional cyclist Dave Zabriskie rides a racing bicycle during a time trial. The solid rear wheel reduces the number of air current eddies which slow cyclists at high speeds.

Through better nutrition and training, the athletes of today are becoming faster and stronger. Old records are constantly being broken, and new ones set. While the vast majority of these achievements are likely due to the athlete themselves, improvements in sports technology have also played a notable role (1). New sports gear technologies have especially been relevant to the sports of rowing, cycling, swimming and tennis, giving rise not only to new records, but also ways in which the sport is played.

Cycling

At top speed, ninety percent of an elite cyclist's energy is used to counter air-resistance (2). By comparison, 3 to 7 percent of a runner's energy is spent overcoming air-resistance (3). Cycling behind a competitor or teammate, or drafting, can reduce drag on a cyclist by up to 38 percent (3). However, since most cycling teams already practice this technique, cyclists today are searching for new ways to reduce air-resistance and differentiate themselves

from their competitors.

A rough formula used to calculate the drag of a cyclist is $0.5qCA$, q being the air density, C being the drag coefficient, and A being the projected cross-sectional area of the front of the bike and rider. The cross-sectional area is the variable cycling teams can best modify and reduce, and has been the focus of recent technological improvements. Using wind tunnels and computer models, engineers have found that something as simple as attaching a water bottle on the lower part of the bicycle frame rather than the upper part, can have a major impact on reducing drag (2).

Engineers have also improved handlebars, primarily by smoothing over the edges. In 1992, the standard racing handlebars of the time contributed to 10% of the drag created by the bicycle (2). Over the years, engineers have been able to dramatically reduce the drag created by the handlebars. For example, aerobars (handlebars that are low and forward that a cyclist rests his elbows on) have been shown to reduce the time taken to race across 15 kilometers in a time trial by 60 seconds

(2). The handlebars of a bicycle are the first part of the bicycle to cut through the air, so minimizing turbulence is essential (2). Although smoothing over the edges barely reduces the projected cross-sectional area, it does prevent recirculating currents and eddies from forming in front of the cyclist's body. This helps the cyclist better cut through the air (2).

The wheels of a bicycle also have a large effect on the airflow around a bike (2). Racing bicycles have thinner tires to reduce the cross-sectional area of the front of the bicycle. More significant improvements have come from changing the spokes in wheels (13, 14). When a wheel spins at high speed, the spokes rapidly cut through the air, and the drag incurred slows down the wheel (2). Additionally, a large number of spokes cutting through the air disturbs the air current flowing around the bike, creating eddies which reduce the overall aerodynamics of the bicycle (2).

A simple solution to this problem is to remove the spokes entirely, and make the wheel a solid disk (2). While this increases the weight of the wheel, new lightweight materials mean that the positive impact of removing spokes far outweighs the detriment on performance due to additional weight (2). Solid disk wheels are used on all bicycles during indoor racing events. However, such wheels are not used outdoors (2). In the presence of a cross wind, solid wheels act like sails, throwing the rider off course. As a result, 3-spoked wheels that allow air to pass through them are favored for outdoor races (2). These provide reduction in drag, while still preventing cross-winds from being a problem.

Bicycles are approaching the limit of how thin they can be. Over the last decade engineers have shifted their focus from reducing the projected cross-sectional area to ensuring that air flows smoothly around the cyclist (2). The most advanced helmets aim to smoothen out the area between the cyclist's head and upper back. These helmets protrude from behind the cyclist's head covering the cyclist's neck, and thus eliminating the dip between head and upper back. This ensures that air turbulence

is minimized and eddies and recirculating currents are not formed behind the cyclist's head (5).

Rowing

Elite rowers face a similar dilemma as cyclists. They have to contend with drag from water, which creates 12 times the resistance of air (6). Manufacturers of top-end racing hulls, or shells, claim that the difference between shells can be the difference between first and second place (7).

Shell manufacturers are constantly looking for the perfect combination of high rigidity, balance, low surface area, and smoothness. Unfortunately, not all of these attributes can be achieved simultaneously. For example, the surface of the shell that comes into contact with the water, known as the wetted area, causes 80 percent of the drag (8). However, reducing the wetted area leads to a trade-off in stability, and a smoother material may be less rigid (8). A rigid hull is important, because the more a hull bends and torques, the less efficiently power is transferred from the rower to the water (9).

Much of the technology that has gone into reducing the friction between the shell and the water flowing past it comes from racing yachts, which often get their technology from the aerospace industry (10). An example of this is the riblet. Riblets are v-shaped grooves that run along the side of the shell parallel to the direction of water flow (10). Developed by NASA, they are “no deeper than a scratch,” but can cut drag by up to 8 percent (10).

No matter how rigid the racing shells are, sweep shells still experience oscillating non-zero transverse movement, or wiggle (11). In sweeping, each rower has only one oar. Although rowers are traditionally lined up so that they row on alternate sides, this does not achieve the symmetry in power application that is required to remove wiggle (11). In 2009, Cambridge University asked a member of its mathematics department, John Barrow, to solve the problem of wiggle in an eight-man sweeping boat. The issue occurs because despite alternating rowers, the forces on the shell are unbalanced. This is because the four rowers on one side are on average closer to the bow than the four rowers on the other side (11).

Figure 2 shows four possible rowing configurations where the transverse waves created by the rowers cancel each other out,

eliminating wiggle (provided each rower is applying the same amount of force). Interestingly, two of the configurations found by Professor John Barrow were experimented with in the 1950s (11). While configurations “a” and “d” were completely new, configuration “b” was already known as a “bucket” rig and was used in Germany in the 1950s. Configuration “c” was used by the Italian Olympic team, which subsequently won gold at the Melbourne Olympic Games in 1956 (11). However, one of the reasons that these rigs are unlikely to be used is that they only manage to eliminate wiggle if each rower is applying an equal amount of power on each stroke—an unlikely scenario (11).

Swimming

Another sport that struggles with water resistance is swimming. After the 2008 Beijing Olympics, official competition rules were changed to reduce the effect high tech swimsuits had on race times. This change came in response to the astounding 42 swimming world records that were broken in the Beijing Olympics. Thirty-eight of these new records were broken by swimmers wearing the Speedo LZR (12).

The Speedo LZR is made of nylon-elastane. Nylon-elastane is extremely light and helps compress the swimmer's body into a more hydrodynamic shape (12). Although compression is not new to racing suits, the LZR suit has three times the compression power at half the weight of the suit used in the previous Olympic Games (12). The compression is so strong it takes 20 minutes to squeeze one's body into the suit (12). This compression not only smoothes out the swimmer's body, but it also helps support the swimmer's hips, which hang lower and increase drag as a swimmer tires (12).

Instead of sewn seams, which disrupt water flow and increase drag, the swimsuit is held together using ultrasonic welding, which according to Speedo reduces drag by 6 percent (12). The suit is also composed of polyurethane panels that are placed at high friction points on the suit. This further reduces drag by a stunning 24 percent (12).

Tests have shown that swimmers wearing the LZR consume 5 percent less oxygen to achieve the same performance—a clear indication of the reduction in effort required by the swimmer (13). Although the suits were banned in 2009 under the new restrictions that only allow male

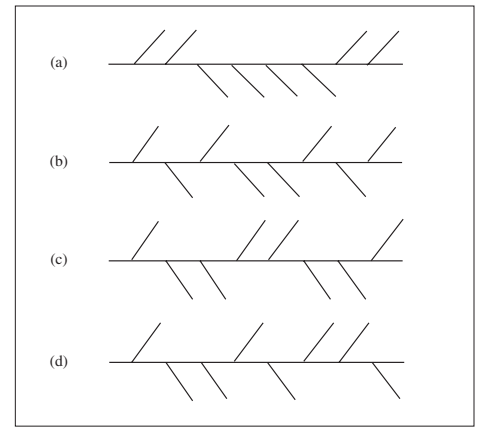


Image courtesy of John D. Barrow

Figure 2: Four possible rowing configurations which have zero transverse moment.

swimmers to wear swimsuits that go from waist to knee, they are a clear example of a technology that is revolutionizing a sport (14).

Tennis

Reducing drag is not the only way sports benefit from scientific advances. Tennis racquets have undergone two major transformations over the past twenty years. Racquet heads became larger, and strings have become better at helping players generate spin on the ball (15). A large racquet head gives a player more reach, and enlarges the “sweet spot” on the racquet (16). Contact at a racquet's sweet spot, which is located at the center of its head, results in the greatest conservation of energy of the ball upon impact, meaning that the ball moves more quickly (16).

Racquet head enlargement has only occurred recently because a larger racquet head requires greater string tension. More tension is needed to keep the strings taught across a longer distance, which in turn requires that frames be stronger (17). Bigger, stronger frames, formerly meant heavier, thicker racquets. Heavy racquets with thick frames suffer from an increase in air resistance during the swing and are detrimental to players who are looking to make fast serves and swings.

The shift in frame material first from steel to aluminum, and then from aluminum to graphite and foam, resulted in frames that are stronger and stiffer without being thicker (17). However, despite being strong enough to withstand increased string tension, graphite racquets were heavy. The relatively recent incorporation of titanium in modern racquet frames, truly allowed frames to become larger, lighter, and thinner (17).



Image courtesy of Guzmán Lozano. Retrieved from <http://www.flickr.com/photos/15650492@N08/4623704120> (accessed 25 October 2012)

Figure 3: Professional tennis player Rafael Nadal hits a topspinning backhand. The development of copolyester strings revolutionized tennis by allowing for the rapid, high-spin shots which characterize today's game.

Although racquets have become lighter and bigger, the biggest improvement in tennis racquets has come from improved strings (17). A player who can generate high amounts of spin is able to hit shots that drop down onto the court (much like a curveball in baseball). Hitting a shot that curves down allows players to hit harder shots without the fear that the ball will land outside the court. Studies have shown that adding 100 rotations per minute to the rate at which the ball spins reduces flight distance by 6 to 12 inches (17). Copolyester strings have been shown to create 20% more topspin than nylon strings (17). Counterintuitively, they create more topspin despite reducing friction between racquet and the ball. Copolyester strings slide with, rather than grip the ball along the racquet face (17). The strings then snap back and add spin to the ball after the ball has changed direction (17). The use of copolyester has had an astounding effect. In the words of Andre Agassi, "the advent of a new elastic co-polyester string, which creates vicious topspin, has turned average players into greats, and greats into legends" (15).

Technology has helped athletes hit better shots and race faster. Still, competition has not fundamentally

changed: it remains the man, not the tool, that must win.

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