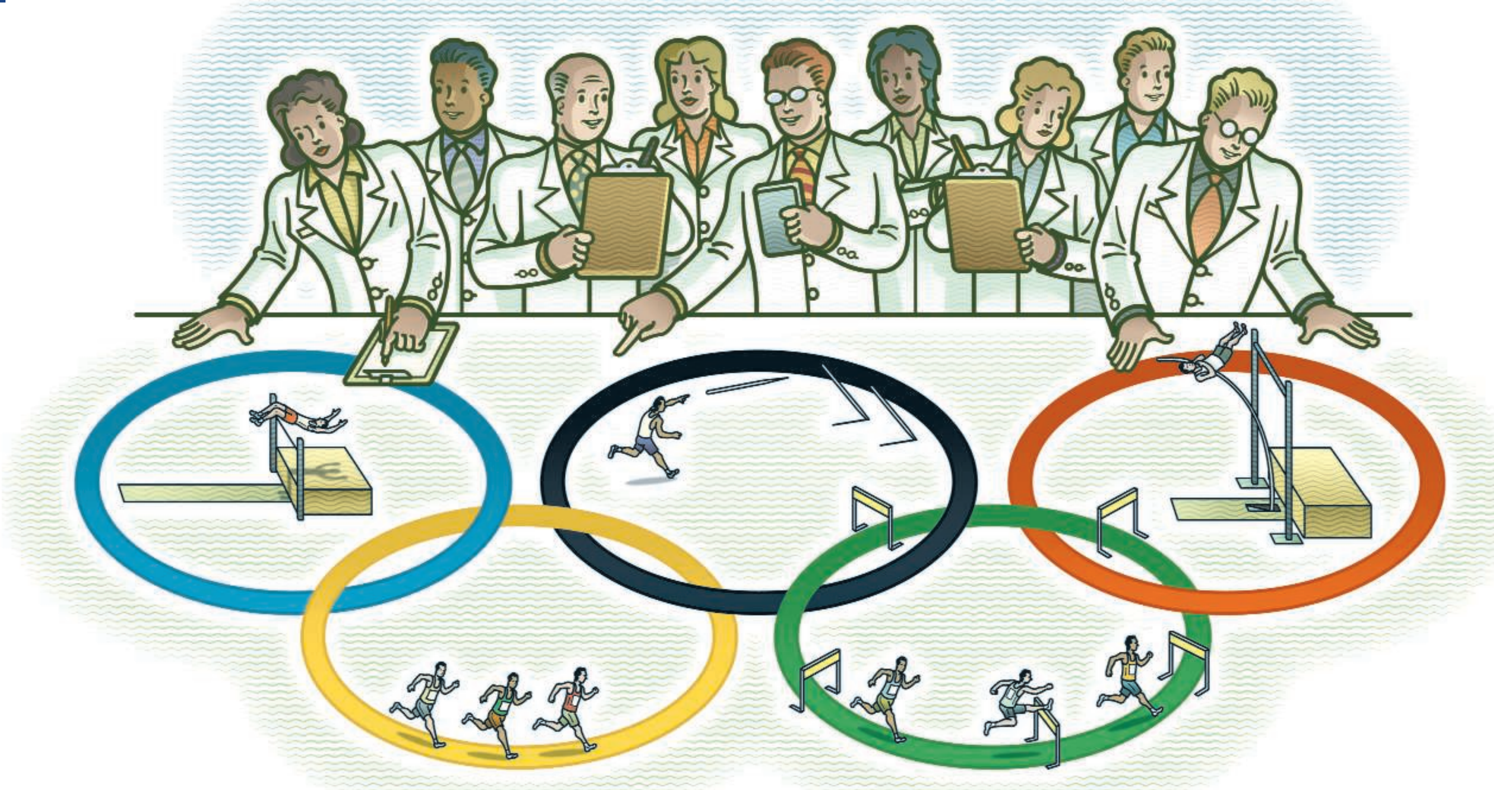

Science at the Olympics

Neuroimaging, high-tech materials, new asthma meds, detection-eluding drugs, thermoregulation—will all these make athletes stronger and faster at the 2008 Summer Games in Beijing? *Science* investigates

1 Will Beijing's Dirty Air Hurt Performance?

Will performance suffer if athletes hit a wall of hot, polluted air in Beijing? Probably, say experts, although there may be some surprising twists.

Among those chasing medals, perhaps the biggest fear is a pollution-induced asthma attack in someone who isn't normally asthmatic. On the other hand, some speculate that asthmatics—who take medicine as a precaution against pollution and other triggers—might actually have an advantage during a bad air day.

Asthma is more common among elite athletes than in the general population, especially in endurance sports. Common symptoms—wheezing and shortness of breath—afflict perhaps up to 20% of elite athletes, because they spend so much time training outside. (Swimmers suffer from breathing air with chlorine.) Moreover, acute asthma attacks called exercise-induced bronchoconstriction (EIB) strike widely: up to 33% of swimmers, for example, even those without chronic asthma.

GASPING FOR AIR
Former U.K. gold medalist Steve Ovett collapsed from asthma after an 800-meter race in the 1984 Los Angeles games. He finished fourth, spent 2 days in hospital, and blamed pollution.

Precautions. A masked runner in an April 2008 long-distance race in Beijing.

The attacks happen because top athletes breathe in more than 150 liters of air per minute—through their mouths rather than their noses. "You can't pull out the pollen and the particulate matter, and they go directly into the lungs," says Timothy Craig of Pennsylvania State University College of Medicine in Hershey. By the time the air reaches the airways, it is also irritatingly dry. In response, the airway membranes inflame, muscles tighten, and mucus accumulates—all quickly constricting the passageways in the lungs and making it hard to breathe.

EIB is impossible to prevent entirely, but inhaled corticosteroids and β_2 agonists can help. The International Olympic Committee (IOC) allows these drugs, given medical proof of asthma. Using the drugs could potentially give medicated asthmatics an advantage over other athletes in terms of averting an attack, says Kenneth Rundell, a physiologist at Marywood University in Scranton, Pennsylvania. Recently, however, the U.S. Food and Drug Administration approved another asthma drug, montelukast sodium, for preventing EIB. Because it is not known to enhance performance, the

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IOC hasn't banned it and any athlete can take it.

Aside from the risk of EIB, little is known about the subtler impact of pollution on athletic performance. One exception is a study of 15 college ice-hockey players who didn't have asthma. Rundell asked them to pedal an exercise bike as hard as they could for 6 minutes. Compared with breathing clean air, total power output fell roughly 5% when the athletes breathed soot particles in concentrations similar to air near a busy highway. Rundell thinks the power loss, reported in the January issue of the *Journal of Strength and Conditioning Research*, is due to inflammation driven by pollution. In another study, published in *Inhalation Toxicology* in 2005, Rundell showed that montelukast sodium guards against pollution-induced EIB: "Where the pollution is very high, one could probably benefit quite a bit."

National teams have prepared for Beijing by screening athletes for asthma to get IOC permission for restricted drugs. And to reduce the amount of time athletes spend breathing polluted air, some teams will arrive in Beijing just before an event. The USOC even designed carbon-filter masks that its athletes can wear.

The IOC, in turn, may reschedule endurance events if the air quality is bad. But IOC officials note that in test events conducted last August in Beijing, there were no complaints from national teams about the polluted air. A look back at the 1984 Olympics, in smoggy Los Angeles, suggests they may have a point: 67 asthmatic members of the U.S. team won a total of 41 medals.

Even so, Olympic officials have conceded that pollution may mean that fewer world records are broken in Beijing than in past Olympics.

–ERIK STOKSTAD

2 Can Ice Vests Provide a Competitive Chill?

At the 2004 Athens games, 30 minutes before the women's marathon, Deena Kastor of the United States began her "warm-up." Instead of jogging in the 35°C heat, she donned an ice-filled vest, sat down, and waited for the start of the 42.2-kilometer run. More than 2 hours later, staying cool seemed to pay off. A kilometer from the finish, Kastor pulled into third place to secure a bronze medal. "The vest definitely helps performance because I am delaying the point in the race in which I overheat," says Kastor, who will race in Beijing.

The logic seems unimpeachable. As body temperature climbs to 40°C, strength and endurance evaporate. So cooling off before competition should enable an athlete to push harder and longer. Runners, rowers, cyclists, and others are already using ice vests. But how much does "precooling" help, and for which events? "It definitely lowers body temperature," says Iain Hunter, an exercise scientist at Brigham Young University (BYU) in Provo, Utah. "The question is, does it improve performance? And that's a lot less clear."

Since the 1970s, numerous studies have shown that precooling can dramatically affect some measures of athletic output. A 1995 study of 14 male runners found that if they were first chilled for 30 minutes in a chamber at 5°C, they could run on a treadmill at a certain level of exertion for an average of 26.4 minutes, a whopping 3.8 minutes longer than they averaged otherwise.

Olympic events are typically races over fixed distances, however, and the few studies of race times show much smaller improvements. In 2005, BYU's Hunter and colleagues studied 18 female cross-country runners, who had ingested encapsulated thermometers, as they participated in 4- and 5-kilometer races. Some wore ice vests for an hour before their race, and, on average, their core body temperatures were half a degree lower than those who did not, even at the ends of the races. But the researchers found only an insignificant difference of a few seconds in the two groups' average times.

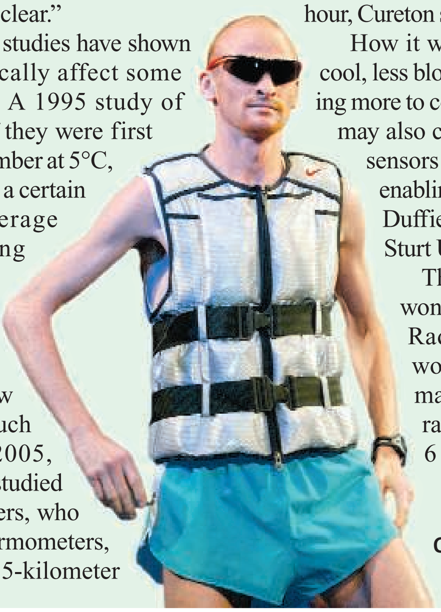
Similarly, Kirk Cureton and colleagues at the University of Georgia, Athens, put nine male and eight female runners through simulated 5-kilometer races on treadmills. When the runners wore ice vests during a 38-minute warm-up of jogging and stretching, they finished the time trial 13 seconds faster on average than when they warmed up without them. That was a 57-meter lead over their warmer selves, and "even if it was 10 meters it would be important," Cureton says.

But Cureton and colleagues found that temperature differences vanished by race's end, suggesting that precooling is less valuable for long races like the marathon. It likely helps for races lasting between a minute and an hour, Cureton says. It definitely hurts in sprint events.

How it works is a mystery. When the skin is cool, less blood flows to it to carry away heat, leaving more to course through the muscles. Precooling may also change the input from the body's heat sensors to the brain, which regulates pacing, enabling the athlete to push harder, says Rob Duffield, an exercise physiologist at Charles Sturt University in Bathurst, Australia.

This much is certain: Using an ice vest won't make an athlete unbeatable. Paula Radcliffe of the United Kingdom, the world record holder for the women's marathon, wore one before the Athens race. She overheated and dropped out 6 kilometers from the finish.

–ADRIAN CHO



Chilled. Australian Olympic marathoner Lee Troop models an ice vest, 2004.

WHAT'S AGE GOT TO DO WITH IT?

Medalists span the decades

11 Italy's Luigina Giavotti, 11, won silver in gymnastics in 1928.

13 Marjorie Gestring, 13, of the U.S. won gold in diving in 1936—the youngest gold medalist ever.

14 Hungarian swimmer Krisztina Egerszegi, 14, won gold in 1988.

15 U.S. runner Pearl Jones, 15, won gold in the 4 x 100-m relay in 1952.

33 U.S. swimmer Dara Torres, 33, won two gold and three bronze medals in 2000. Now 41, she is swimming in Beijing.

34 U.K. sprinter Kelly Holmes, 34, won gold in the 800- and 1500-m events in 2004.

46 Ethel Seymour, 46, won a bronze medal on Great Britain's gymnastics team in 1928.

59 Bill Northam of Australia, 59, won gold in yachting in 1964.

72 Swedish shooter Oscar Swahn, 72, won silver in the team double-shot running deer event in 1920.

CREDIT: AP PHOTO/ROB GRIFFITH; SOURCES INCLUDE: OFFICIAL OLYMPICS WEB SITE, SPORTS REFERENCE, MENZIESERA.COM, GYMNASTICS ZONE

3 Do New Materials Make the Athlete?

NAKED TRUTH

Swimming goggles were first allowed in 1976.

Some of the first known spiked track shoes were invented by Joseph William Foster in the early 1890s.

Greek athletes usually competed nude. According to one ancient writer, Pausanias, a competitor deliberately lost his shorts so that he could run more freely during the race in 720 B.C.E., and clothing was then abolished. Other explanations abound.

In 1960, Ethiopian marathoner Abebe Bikila earned an Olympic gold medal without wearing any shoes. But bare feet on the Olympic track these days are passé, as athletes slip into ever more high-tech gear. Shoes, swimsuits, and clothing are getting lighter and stronger, adhering like glue to athletes' bodies and moving more fluidly through air and water.

In Beijing, U.S. track and field athletes will be wearing Nike shoes and clothing that incorporate threads made of Vectran, a superstrong liquid crystal polymer that withstands high temperatures. The result, according to Nike, is lighter, stiffer shoes to reduce friction and clothes that reduce drag by 7% compared with the Nike outfits worn at the 2004 games in Athens.

Sprinters will also benefit from even tighter compression garments. In theory, these improve performance because of proprioception, that unconscious ability that enables you to pinpoint your nose when your eyes are closed. Physiologist Russ Tucker of the University of Cape Town, South Africa, says that because runners need to contract muscles precisely—at the proper angle, velocity, and time—tight-fitting garments help the brain identify where in space the limb is poised so they know when to activate the muscle.

In the water, the Speedo LZR Racer suit, which debuted in March 2008, is all the buzz. Swimmers donning the suit have broken 46 world records so far. The suit includes polyurethane panels placed strategically around parts of the torso, abdomen, and lower back that experience high amounts of drag in the pool. It also incorporates a corset-like structure that keeps the body in a streamlined position. Raúl Arellano, a biomechanist at the University of Granada, Spain, says the LZR Racer suit could benefit older athletes like 41-year-old Dara Torres of the United States, especially in areas where fat tends to accumulate.

Some of the technologies needed to develop the suit "didn't really exist 10 years ago," says Jason Rance, head of Aqualab in Nottingham, U.K., the division of Speedo that designed the suit. Those include ultrasonic welding that eliminated the need for seams, and technology that allowed parts of the suit to be finely sanded and a water-repellent substance added to prevent water from leaking in.

But the suit has raised eyebrows. "Who's going to win the gold medal, the swimmer or the technician?" asks Huub Toussaint, a biomechanist at the Free University in Amsterdam, who worries that the suit gives swimmers an unfair edge, although the international body governing the sport approved it.

For all the hype surrounding space-age shoes and clothing, there's a flip side: Any boost to performance could just be psychological. South Africa's Tucker, who races for fun, says the compression garments make him feel powerful and secure. Such a superhero aura might give any competitor a mental edge. "It doesn't really matter if the advantages are physically real or not," he says, "as long as the athlete gets some benefit."

–ANDREA LU

4 Can Neuroscience Provide a Mental Edge?

For Olympic athletes, physical strength, speed, and stamina are a given. But when elite competitors go head to head, it can be the mind as much as the muscles that determines who wins. A collaboration between sports psychologists and cognitive neuroscientists is trying to figure out what gives successful athletes their mental edge.

Positive thinking. Canadian swimmer Brittany Reimer.

One focus is why some athletes rebound better than others after a poor performance. Even at the Olympic level, it's not uncommon for an athlete to blow a race early in a meet and then blow the rest of the meet, says Hap Davis, the team psychologist for the Canadian national swim team. To investigate why—and what might be done about it—Davis teamed up with neuroscientists including Mario Liotti at Simon Fraser University in Burnaby, Canada, and Helen Mayberg at Emory University in Atlanta, Georgia.

The researchers used functional magnetic resonance imaging (fMRI) to monitor brain activity in 11 swimmers who'd failed to make the 2004 Canadian Olympic team and three who made the team but performed poorly. The researchers compared brain activity elicited by two video clips: one of the swimmer's own failed race and a control clip featuring a different swimmer. Watching their own poor performance sparked activity in emotional centers in the brain similar to that seen in some studies of depression, the researchers reported in June in *Brain Imaging and Behavior*. Perhaps more tellingly, the researchers found reduced activity in regions of the cerebral cortex essential for planning movements. Davis speculates that the negative emotions stirred up by reliving the defeat may affect subsequent performances by inhibiting the motor cortex.

Davis and neuroscientist Dae-Shik Kim at Boston University (BU) School of Medicine are now using diffusion tensor imaging to visualize the connections between emotion and motor-planning brain regions. Kim hypothesizes

CREDIT: JERRY LAMPEN/REUTERS/CORBIS

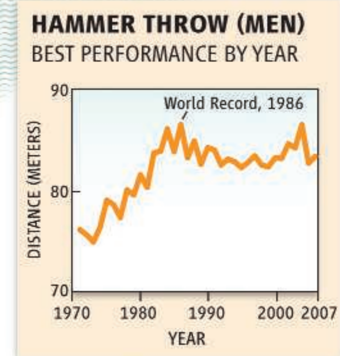
5 Does Doping Work?

It depends on how much proof you want. By the tough standards of modern medicine, there's little hard evidence for the efficacy of dozens of compounds on the list of the World Anti-Doping Agency (WADA). They are rarely tested in placebo-controlled trials; for most, the evidence is what medical researchers would call "anecdotal."

Many substances on the list are probably useless, most researchers say, if not outright detrimental for athletic prowess. "The science behind it is pretty weak," concedes Swedish oncologist Arne Ljungqvist, a former Olympic high jumper who chairs WADA's Health, Medical & Research Committee.

Not that we don't know anything about what works. Decades ago, double-blind trials for amphetamines and other stimulants showed that they can enhance performance in short, explosive activities, such as sprinting. Anabolic steroids have been proved beyond any doubt to increase muscle mass and enhance performance among male athletes in sports that require strength, such as weightlifting and shot-putting; in women, they appear to work for endurance sports as well. History provides more circumstantial evidence: In many sports, the amazing rise in performances came to a halt after the crackdown on anabolic steroids began in earnest in the 1980s, and some records have not been broken since then.

But for many other compounds the evidence is thin, says Harm Kuipers, a physician and former speed-skating world champion who studies doping at Maastricht University in the Netherlands. One of the hottest substances of the moment, erythropoietin (EPO), has been tested for performance enhancement in only four double-blind trials, Kuipers says; they showed that it increased maximum oxygen uptake and performance, but apparently for short durations only.



Data are lacking because rigorous trials are expensive, and there's little incentive to fund them. The drugs' target population, top athletes, usually can't be recruited into studies because it might ruin their careers. Also, the list of substances and combinations is endless; cyclists once used a cocktail of strychnine, cognac, and cocaine, for instance. And the risk of side effects can make ethics panels frown.

Still, some say WADA should promote more efficacy studies. The agency is currently spending millions of dollars to improve detection of human growth hormone, a banned substance that appears to be very popular and is very hard to detect. Yet, the "science on efficacy is really soft," says Donald Catlin, who until 2007 led a major antidoping lab at the University of California, Los Angeles. "I'd prefer to have true evidence before we go after it."

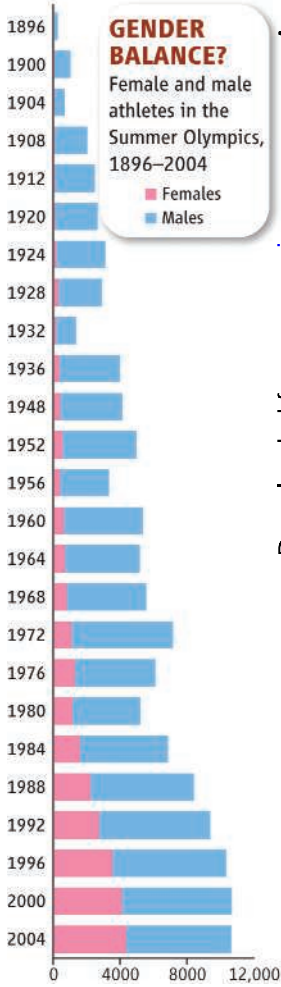
If WADA, created in 1999, had a more scientific attitude, it would drop many drugs from the list, which it inherited from the International Olympic Committee, says Kuipers, who sat on the panel for several years. Countless substances—such as beta-agonists, corticosteroids, and narcotics—are listed simply because athletes used them, or were rumored to use them, even though they are widely believed to be useless.

A spot on the list may actually encourage athletes to experiment with a substance, Kuipers says: "The doping list is a shopping list for some." Such experiments can be dangerous. In healthy people, for instance, an overdose of insulin—another listed substance that few believe does athletes any good—can lead to a fatal drop in blood sugar levels.

Ljungqvist takes the opposite view: Removing substances from the list would signal that it's okay to use them, he says. And WADA wants to protect athletes from any drug they don't need, if only to send a message to their young fans. Ljungqvist agrees that this means that practically anything can end up on WADA's list—and that athletes risk ending their careers by taking something that doesn't bring them one bit closer to a gold medal.

–MARTIN ENSERINK

Early player. British tennis Olympian Charlotte Sterry, 1908.



that these connections might differ in athletes who are better able to shake off a bad performance. So far his team has scanned about a dozen BU athletes. Meanwhile, Davis and collaborators have been looking for interventions that would perk up the motor cortex. Additional fMRI studies, as yet unpublished, suggest that positive imagery—imagining swimming a better race, for example—boosts motor cortex activity, even when athletes see a videotaped failure. Jumping exercises have a similar effect, Davis says.

The work has already changed the Canadian team's poolside strategy, he says: "We pick up on [any negativity] right away and intervene." Davis has the swimmers review a video of a bad performance within half an hour and think about how they would fix it. Anecdotally, it seems to be working, he says. "We're seeing more people turn it around."

The fMRI findings suggest that quick, positive intervention helps athletes bounce back, says Leonard Zaichkowsky, a sports psychologist at BU who collaborates with Davis and Kim. But coaches often take a different approach with athletes. "Typically what happens is they've got hard-assed coaches reaming them out for a bad performance," he says. "It's the opposite of what they should be doing."

–GREG MILLER

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