



SUPERHUMAN ATHLETES

Enhancements such as doping are illegal in sport — but if all restrictions were lifted, science could push human performance to new extremes.

UK sprinter Dwain Chambers faces the race of his life next month, as he attempts to win an Olympic medal at the 2012 games in London — and complete a long journey back from the disgrace of his 2003 suspension for doping.

Chambers, who has devoted much of his time since then to persuading others to steer clear of performance-enhancing drugs, has admitted to using six different substances banned by the sporting authorities. These included two anabolic steroids — a designer drug and a testosterone cream — to accelerate recovery; the hormone erythropoietin (EPO), which increases production of red blood cells, to allow him to do more repetitions in training; human growth hormone for

BY HELEN THOMPSON

recovery; a thyroid hormone called liothyronine to decrease sluggishness; and a narcolepsy drug called modafinil to increase mental alertness and reaction time.

The quest for ultimate enhancement is as old as the games: the Greek physician Galen passed on knowledge from the ancient games to the Romans, praising the effects of eating herbs, mushrooms and testicles. But Chambers' story is just one example of how today's competitors are taking that quest to a whole new level.

ILLUSTRATIONS BY GARY NELL



“There’s an arms-race quality to performance-enhancing technologies in sport,” says Thomas Murray, former president of the Hastings Center, a bioethics and public-policy foundation in Garrison, New York.

An amateur cyclist, Murray is among the many sports fans appalled by the seemingly endless string of doping scandals that result. “I could probably do a four-mile climb much better with EPO,” he says, “but I could also do it much better if I put a motor on my bike.” That’s not the point of sport, he says, and neither are drugs — an attitude shared by the International Olympic Committee and just about every other professional and amateur sports organization.

But others argue that enhancers have become so prevalent that the only realistic option is for the sporting authorities to let athletes use what they want, as long as they do it safely.

“If the goal is to protect health, then medically supervised doping is likely to be a better route,” says Andy Miah, a bioethicist at the University of the West of Scotland in Ayr. “Better yet, the world of sport should complement the World Anti-Doping Agency with a World Pro-Doping Agency, the goal of which is to invest in safer forms of enhancement.”

Science alone cannot resolve the ethical conundrum presented by this debate. But it can shed light on the purely technical question: if performance-enhancing techniques were allowed, how far could the human body go?

POWER PILLS

For strength and power, the best-known drugs are probably those in the vast family of anabolic steroids, a group that is constantly expanding as the structures get slight modifications in a bid to evade detection in drug tests. “There are about 2,000 different tweaks you could do to a steroid molecule that would all probably make you big and strong,” says Don Catlin, a pharmacologist at the University of California, Los Angeles. The compounds mimic the way testosterone works in the body, triggering protein synthesis and building more muscle tissue. A course of steroids combined with exercise can translate to a 38% increase in strength in men, potentially more in women.

Another popular strength enhancer is human growth hormone, which increases levels of the protein insulin-like growth factor 1 (IGF1). This spurs muscle growth, although it is debatable whether or not that growth actually does increase strength. In the only study to show positive effects in recreational athletes¹, those taking human growth hormone saw their sprinting capacity increase by 4%. That may seem small, but it could make all the difference for, say, a 50-metres freestyle swimmer or a 100-metres sprinter, says Kenneth Ho, an endocrinologist at the University of Queensland in St Lucia, Australia, who co-authored the study. “If you look at what breaks records, it comes down to 0.01 of a second.”

In endurance sports, in which strength is less important than increased stamina, athletes can get dramatic results from blood doping, which aims to increase the number of oxygen-carrying red blood cells. They can accomplish this through blood-cell transfusions or by taking EPO. In one study², blood doping increased normal humans’ stamina by 34%, and in another³, it allowed them to run 8 kilometres on a treadmill 44 seconds faster than they could before. And work published last month⁴ by Max Gassmann and his colleagues at the University of Zurich in Switzerland, there are signs that the hormone has an effect on the brain, increasing an athlete’s motivation to train.

Drugs currently in the pipeline at pharmaceutical companies may also find themselves being co-opted for illicit use by athletes. One family, designed to treat muscular dystrophy and other muscle-wasting disorders, inhibits the activity of myostatin, a protein that keeps muscle growth under control. Similarly, a group of drugs called HIF stabilizers, which are aimed at treating anaemia and kidney disease, regulates a protein that turns on genes for the production of red blood cells, including the gene for EPO. And there may be a part for cognitive

enhancers to play, too. “There’s a range of compounds coming out that try to improve the ability to think more clearly when you’re fatigued,” says Chris Cooper, a biochemist at the University of Essex in Colchester, UK.

Improvements don’t just come from the pharmacy. Athletes also rely heavily on nutritional supplements, which are legal. “They’re 98.5% hype,” says Conrad Earnest, an exercise physiologist at the University of Bath, UK. But one supplement that does work for some athletes is creatine, which contributes to the synthesis of the energy carrier molecule ATP during exercise. Earnest estimates that athletes taking creatine could see their performance improve by as much as 8%.

Another effective supplement is beetroot juice. Researchers at the University of Essex have found that the nitrate present in the juice increases nitric oxide levels in the body, allowing muscles to use oxygen more efficiently. As a result, the team found that divers could hold their breath for 11% longer than normal⁵, which could help swimmers who want to minimize the number of breaths they take in short-distance events.

Most of these performance enhancements come with a slew of side effects, however. Steroids can cause high blood pressure, thickening of the heart valves, decreased fertility and libido, and changes such as chest hair in women and shrunken testicles in men. And boosting the number of red blood cells thickens the blood, increasing the risk of having a stroke.

Adding to the uncertainty, a number of the drugs are used to treat serious diseases such as cancer, AIDS and muscular dystrophy, so they have been tested largely on desperately ill patients with below-normal levels of growth factors and hormones. It is hard to know how to extrapolate those data to the sports arena, says Cooper. “Elite athletes are very different beasts from normal people in the sense that they’re genetically enhanced,” he says, “because they’ve been selected to be good at what they’re doing and they have a lot of training.”

Furthermore, testing in healthy people — subjecting them to the dosages and combinations that athletes are likely to take — would be an ethical can of worms. Because of that, says Charles Yesalis, an emeritus professor of sports science at Pennsylvania State University in State College, “there’s no way to know what advantages different combinations of steroids, nutritional supplements and specialized diets could produce. It’s a witches’ cauldron.”

CODE BREAKING

Gene doping — enhancing performance by adding or modifying genes — has been the subject of locker-room gossip for the past ten years. There are plenty of natural mutations for which to wish. The Finnish cross-country skier Eero Mäntyranta, who won three gold medals in the early 1960s, had a mutation that made his body’s EPO receptors more efficient. In 2004, a toddler made headlines for having a mutation that disabled myostatin, giving him the physique of a petite body builder. And the gene that encodes angiotensin-converting enzyme, which has been hailed as the gene for physical performance, has one variation known to boost endurance by increasing oxygen delivery capacity and capillary density, and another that is associated with muscle growth and strength^{6,7}.

Advances in gene therapy could one day make it possible for any athlete to enhance their DNA. For example, in experiments aimed at treating muscular dystrophy in the elderly, a group led by physiologist Lee Sweeney of the University of Pennsylvania in Philadelphia introduced a gene to cause over-expression of IGF1 in mice. The treatment boosted muscle strength of young adult mice by 14%, earning the rodents the nickname ‘mighty mice’⁸.

Other researchers are turning genes on and off with drugs. In 2008, Ronald Evans and his colleagues at the Salk Institute for Biological Studies in La Jolla, California, worked with GW1516, a drug that activates a gene that increases the ratio of ‘slow-twitch’ to ‘fast-twitch’ fibres in muscle. As the names suggest, slow-twitch fibres contract more slowly than fast-twitch, but they are more efficient at aerobic

activity. Evans and his team found⁹ that in mice, GW1516 combined with exercise increased the rodents' endurance by 70%.

However, both Evans and Sweeney are sceptical about how useful athletes will find such therapies. "In humans, I expect the same general relationship — the under-exercised will be the ones who will have the most benefit from exercise mimetics," says Evans. "My view is that endurance athletes are physically advantaged and will have the least benefits."

Gene therapy has its share of health risks, including potentially severe immune reactions to the viruses used to ferry genetic material into cells. The results may also be hard to control. "If you're going to turn a gene for something like EPO on, you better be able to turn it off," warns Catlin. Gene doping, he says, "is not a good idea, but I wouldn't be surprised if someone's out there trying it".

HUMAN 2.0

Drugs are not the only way to potentially enhance performance. Surgery and, ultimately, technological augmentations could also help athletes towards the podium. Baseball pitchers who have undergone surgery to replace a damaged elbow ligament with tissue from a hamstring or forearm tendon claim that they can throw harder after the two-year rehabilitation process. But Scott Rodeo, an orthopaedic surgeon at the Hospital for Special Surgery in New York City, warns that the science doesn't back up the stories. "To truly say you're making this elbow better would be a bit of a stretch," says Rodeo.

Replacing entire joints would be unlikely to work for an elite athlete: too many screws could come loose and the artificial joint wouldn't quite match the mechanics of a natural one. The materials would also wear out within a few years under the physical demands of elite sport. Still, Rodeo says, that assessment could change if researchers make major advances in engineering skin, tendons and other replacement body parts in the laboratory.

Miah sees potential in more imaginative surgical enhancement. "Consider using skin grafts to increase webbing between fingers and toes to improve swimming capacity," he says. "These kinds of tweaks to our biology are likely ways that people would try to gain an edge over others." Another frontier is nanotechnology, adds Miah. Researchers are already experimenting with blood supplements based on oxygen-carrying nanoparticles for use in emergency situations. From there, he says, "there is a lot of discussion about the possibility of biologically infused nanodevices that could perpetually maintain certain thresholds of performance".

Mechanical prosthetics are already a reality, such as the 'cheetah-style' legs used by amputees including Oscar Pistorius from South Africa, a Paralympic gold medallist who was approved this month to



“WHAT WE’LL SEE IS THE EMERGENCE OF ALL KINDS OF NEW SPORTS.”

run in the 2012 Olympics. But scientists are split on whether current artificial limbs actually confer an advantage over the flesh and blood variety.

Bryce Dyer, a prosthetic engineer at the University of Bournemouth, UK, explains that although Pistorius's spring-like prosthetics allow him to speed up at the end of a race, they put him at a disadvantage coming out of the crouch at the start of a race or when turning a curve. "When he's running straight ahead, he eventually hits a natural state of harmony like bouncing on a trampoline," says Dyer, "but then he sometimes runs right off the track because he can't turn."

Pistorius's prosthetics lack the stiffness of a human ankle and can't generate the same forces as they hit the ground. To get around this, Pistorius pumps his legs faster. "It's a biomechanically distinct way of running fast, but there's no evidence that it's advantageous," says Hugh Herr, a biomechanical engineer at the Massachusetts Institute of Technology (MIT) in Cambridge.

Technology might get around these problems. "Stepping decades into the future, I think one day the field will produce a bionic limb that's so sophisticated that it truly emulates biological limb function. That technology will be the Olympic sanctioned limb," says Herr, whose lab at MIT is currently working on a bionic running leg. "Without any such human-like constraints, the Paralympics limb will become [the basis of] this

human-machine sport like racecar driving."

According to Herr, performance-enhancing technologies will advance to a point at which they will not only extend human limits, they will demand an Olympics all of their own. "For each one there will be a new sport — power running, and power swimming, and power climbing," projects Herr. "Just like the invention of the bicycle led to the sport of cycling. What we'll see is the emergence of all kinds of new sports." ■

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