Sports and tech: How athletes make use of the latest inventions

Running is one of the fastest growing sports in the world. In Europe 50 million people do it on a regular basis, according to the Dutch Measure network. They spend nearly €10 billion a year on shoes, clothes and related technology. Two out of five Europeans now claim to practise a sport on a regular basis, with running and cycling at the top of the list. The motivation is clear: not only is an active and healthy life increasingly valued in our society, but the equipment available has become more sophisticated than ever.
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Amateur athletes now use high-tech materials that were until recently available only to professionals, while constantly measuring their performances and analysing their health. Meantime, the pros have also improved their performances thanks to materials like fibreglass, carbon fibre and polyurethane. Data analysis helps reduce the risk of injuries, but even when an injury occurs new therapies and prostheses accelerate the healing process.

Sports: The doping fallacy

*Enforcement has a spotty track record, but the fight against harmful drugs is part of what makes us civilised.*

Hard as it is to believe, there are people who support the use of performance-enhancing drugs in sports. The simplest defence perhaps is the libertarian one: people should be allowed to do what they want with their bodies, even if it involves taking risks. Then there's the
argument, not entirely wrong, that enforcement of anti-doping rules hasn’t worked – that, as one Oxford professor puts it, “only the dumb dopers get caught.” So why waste time, effort and money on anti-doping crusades?

A slightly more thoughtful defence of doping invokes science. It argues that competitive sports benefit from ever more sophisticated technologies. Chemistry is just another technology, which we use routinely to enhance daily life – to feel better, to resist disease, and even to live longer. What’s different about taking a drug in order to become citius, altius, fortius – faster, higher, stronger, according to the Olympic motto?

These arguments, incidentally, have little to do with the devastating allegations of systematic doping by Russian athletes at the 2014 Winter Olympics in Sochi. That’s about cheating, not about science or philosophy.

The libertarian defence could have some merit if athletes performed in a vacuum. Of course the state should not govern everything a person ingests, how much she sleeps or what exercise is appropriate.

But if some athletes choose to dope themselves, they are inevitably forcing the entire peloton (to use a cycling term, appropriately) to do likewise if others want any chance of winning. And if the highest-level athletes do it, so will the second tier, and then the juniors...

Enforcement failure is an unpersuasive argument. Do theft, corruption and murder become socially – or legally – acceptable where enforcement has failed?

So that leaves us with the scientific defence. Admittedly we rely on science daily to enhance the body’s performance – with everything from painkillers to anti-inflammatories to stimulants. Throughout the world these products are regulated with one aim: to avoid doing harm. That’s the most sensible criterion to define what should and should not be acceptable in sports.

With the huge amounts of money that now slosh around the sports world, the temptation to win by whatever means is greater than ever. Do we really want to witness the battle of the chemists rather than highly trained athletes pushing their personal limits?

In the 21st century, unlike Ancient Rome, athletes no longer have to put their lives in danger to entertain us. Even in “dangerous” sports like boxing or motor racing or extreme snowboarding, various rules and practices reduce the danger. The fight against doping in sports is a part of what makes us civilised.
New materials for new records

Aluminium, carbon and even bamboo: sport results today depend highly on the materials used by athletes. Beyond the competition among sportsmen, the battle of technologies has just begun.

Anyone who doubts the radical impact that technology can have on sport should consider the swimming contests at the 2008 Olympics in Beijing. A few months before the games, British swimwear manufacturer Speedo launched a new all-in-one swimsuit known as the LZR Racer. Made from polyurethane rather than conventional fabrics, the LZR Racer was said to reduce a...
swimmer's drag and also boost oxygen flow to the muscles. It proved a stunning success: competitors wearing the suit at Beijing scooped 94 per cent of the swimming gold medals, breaking numerous world records in the process.

That outcome, and the continued setting of new records as other sportswear companies produced their own variations on the LZR Racer, eventually led international swimming’s governing body to ban the full-body suits in 2010. But while observers complained about “technology-doping”, swimming is far from the only sport in which technology has made a huge and sometimes controversial mark.

**World records with fibreglass**

In a 2009 study, Steve Haake, a sports engineer at Sheffield Hallam University (https://www.shu.ac.uk/) in the UK, worked out the effect of technology in a range of Olympic disciplines over the last century. He found that while better equipment had allowed 100-m runners to go just 4 per cent faster, both pole vault and javelin performance had improved by about 30 per cent. In the former, fibreglass poles introduced in the early 1960s allowed athletes to break the world record 19 times in just a decade, raising the maximum height from 4.8 metres to about 5.5 metres.

Ultimately, javelins had to be redesigned to reduce performance. They were being thrown so far by the 1980s that authorities, fearing for public safety, ordered that their centre of gravity be brought forward by 4 cm. That small change was enough to reduce the maximum throwing distance by about 10 per cent.

Then there’s cycling. In contrast to the steel bicycles of the late 19th century and aluminium racers of the second half of the 20th, modern high-performance bikes are now built from a single piece of carbon fibre. Intended to be extremely aerodynamic, they are designed using computer programs that model fluid flow and tested in wind tunnels.

**Bicycles made of bamboo**

Veit Senner (http://www.professoren.tum.de/en/senner-veit/) and colleagues at the Technical University of Munich are working to further optimise modern bicycle frames. One goal is to improve the safety of mountain bikes by subjecting carbon-composite frames to brutal treatment in the lab. Researchers use infrared, ultrasonic and X-ray imaging to

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*Dartfish: videos that lead to Olympic gold*

*Sprinter Usain Bolt worked with the Swiss video analysis software Dartfish (http://www.dartfish.tv/) before the 2012 Olympics to improve his starting performance and, as a result, managed to beat his own world record. More than*
observe how layers of carbon within the frame separate on impact – something that cannot be seen from the surface.

The German group is also developing a frame for a racing bicycle made largely from bamboo, which, unlike carbon fibre, can be recycled. They have carried out an extensive test programme to make the frame stronger, stiffer and more robust. According to Senner, many innovations in sporting technology come about through a combination of new materials and improved design. He cites modern “parabolic” skis, introduced in the 1990s, as an example. Unlike older skis, which were more or less straight, parabolic skis are narrower in the middle and wider at each end. This design makes turning much easier, since all a skier has to do is rotate the skis on to their edge via a slight movement of the hips and knees, apply a little pressure and the curved edge forces the skis to naturally “carve” an arc in the snow. “High-performance skiers could carve with old skis but ordinary people couldn’t,” he says.

Just as parabolic skis required new materials with high torsional stiffness – in other words, that didn’t twist very much – so too the development of new skis by researchers at Ecole Polytechnique Fédérale de Lausanne (EPFL) and Swiss company Stöckli has involved varying material properties as well as working out the relative thickness of each material layer (which can include wood, polymer, aluminium, glass and carbon). The idea, explains EPFL’s Véronique Michaud, is to tune two properties of the skis – flexibility (how much they bend) and torsional stiffness. “We’re looking for an optimal compromise between ease of turn and stability when going fast,” she explains.

**Inspired by insects**

120,000 professional athletes who have won 3,000 Olympic medals use the software, as do sport federations and football clubs like France’s Paris Saint-Germain. At the 2014 Winter Olympics in Sotchi, Russia, 68 per cent of the medal winners had Dartfish. Athletes and their coaches use it to analyse movements and compare them to previous performances. With the help of data extracted by the software, such as speed and angle, athletes can focus on improving specific moves.

**Ghost images**

Launched in 1997 under the name Simulcam by Serge Ayer of the Ecole Polytechnique Fédérale de Lausanne (EPFL), Dartfish was designed to compare video recordings of athletic performances. Two years later, skiing fans witnessed the first ever TV replays showing not one but two skiers simultaneously, with the second competitor’s descent overlaid by the ghost image of the leader’s performance. With its 13 offices around the world, Dartfish is now the world leader for video analysis.
Scientists are not only developing new materials but also helping sportsmen and women improve their techniques. Josje van Houwelingen, a physicist at the Eindhoven University of Technology in the Netherlands, has developed a new system to improve the strokes of elite swimmers. The system involves creating small bubbles at the bottom of a swimming pool and using an array of six cameras together with a fluid-dynamics algorithm to study how a passing swimmer affects the motion of those bubbles.

Van Houwelingen is particularly interested to find out whether swimmers could boost their propulsion by creating certain kinds of vortices, just as insects take advantage of vortices they create in the air as they flap their wings. “Insects have been observed to get extra propulsive force by pushing against those vortices,” she says. “Maybe swimmers could get a similar benefit.”

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**Making sweat talk**

*One of the biggest limitations in measuring physiological variables during athletic activity is the sheer weight of the equipment. The sensors developed by Adrian Ionescu (https://people.epfl.ch/adrian.ionescu?lang=fr) at the École Polytechnique Fédérale de Lausanne can be used for real-time analysis of the electrolytes and biomarkers in sweat based on technology nearly 10,000 times smaller than current systems. His research is also being applied to design future sensors that can detect gases in our environment and our breath. Hydration, fatigue and nutrition will all be quantifiable as will the amount of allergens and pollutants in the air. “These biosensors will become a reality,” says Ionescu. Swiss start-up Xsensio (http://xsensio.com/) is working on the first models.*
This is just the beginning. Cycling may see the advent of spray-on clothing that keeps riders dry and safe but also light, as well as sensors to monitor a rider’s physiological changes and “phase-change” tyres that vary their tread depending on terrain. “Human Enhancement Technologies” could also become far more widespread. South African amputee runner Oscar Pistorius caused controversy when he competed in able-bodied competitions using artificial limbs, but in the future biomedical devices and prosthetics may be used by athletes to enhance their capabilities rather than simply restoring them.

By Edwin Cartlidge
How Switzerland became a sailing nation

Without seashore, the alpine nation won the America’s Cup twice. One reason: ingenious engineering. The benefits that advanced materials and other cutting-edge technologies can bring to elite sporting contests were highlighted by the twin successes of Swiss syndicate Alinghi in the America’s Cup. Set up by businessman Ernesto Bertarelli, Alinghi showed that even land-locked Switzerland could win the coveted sailing trophy when it beat Team New Zealand in 2003 and 2007.

Véronique Michaud, a materials scientist at the Ecole Polytechnique Fédérale de Lausanne, allows that part of Alinghi’s success came from its top-notch crew – much of which, including skipper Russell Coutts, had been poached from Team New Zealand. But equally crucial were the boats. To optimise the technology, Alinghi developed two boats with slightly different designs for each race. Starting in 2000, a team of about 20 researchers and students at EPFL carried out a series of experiments and drew on computer models to make the carbon-fibre composite hulls as stiff but light as possible. The researchers also placed thin fibre-optic sensors inside the boats to monitor how their masts changed shape in order to better tune the rigging.

The work paid off. In 2003, Alinghi stormed to a 5–0 win over Team New Zealand, which was hamstrung by a series of technical difficulties, including a snapped mast in the fourth race. Victory came less easily four years later, when Alinghi triumphed 5–2, but with a winning margin of just one second in the final race. “At this level of competition, the slightest improvement in performance can make all the difference,” notes Michaud.
The Euro’s footballs: Marketing and high-tech

A key element of the quadrennial UEFA European Championship, or EURO, is the ball, which has been designed by Adidas since 1972. It’s always a major marketing success: in 2012 more than 7 million were sold. The ball, however, is not just a marketing product but also a high-tech object. While the 1972 version was made of leather, the modern ones contain various sophisticated materials.
The EURO 1988 in Germany was the first without a leather ball. Since then, footballs have been made of polyurethane – a type of plastic created in 1937 by German chemist Otto Bayer. With this material, modern balls are lighter and absorb less water when it rains because the patterns on the surface are bonded, not sewn. Also, the balls do not dent when hit by players. Polyurethane is commonly used in car seats, mattresses and shoes.
Ending the pain

Every sportsman takes risks. Computer simulations and data analysis can now help prevent injuries, while individual prostheses hasten the recovery process.
When a highly paid professional athlete is out of action, the bills quickly add up. According to the Global Sports Salaries Survey, injuries in the top professional leagues cost football teams worldwide an average of $12.4 million per year. The most common mishaps involve knees, shoulders, elbows and ankles, explains Andreas Imhoff (http://www.professoren.tum.de/en/imhoff-andreas/), head of the Sports Orthopaedics Department from the hospital Klinikum rechts der Isar of the Technical University of Munich.

Sometimes an injury develops slowly, through incorrect movements. Gait Up (http://www.gaitup.com/), a Swiss spin-off of the Ecole Polytechnique Fédérale de Lausanne (EPFL), has developed a movement tracker to help prevent this. The athlete wears a matchbox-size plastic box weighing just a few grams on his shoes or chest. The tracker’s numerous sensors then record movement patterns. Using analysis software, a trainer can identify errors in these patterns. In theory, it can also work in real time. “We’re planning to adapt it so that marathon- runners can identify errors in their running style during the race itself,” said Benoit Mariani, founder and CEO of Gait Up. “We’ve also used movement analysis on skiers, swimmers and players of team sports.” Several scientific studies have shown that this approach can reduce the risk of injury.

**Fewer injuries thanks to data analysis**

So far so good, but what happens when a tendon or muscle fibre tears, or when an athlete accidentally falls or collides with another one? Isn’t that simple bad luck? Ireland’s Stephen Smith has never believed that. When this former professional coach examined injury statistics...
Smith was therefore convinced that there must be a reason why teams didn’t suffer to the same extent. And that it could be found in the data.

Many factors influence an athlete’s behaviour and therefore the risk of injury: movement style, vital signs, psyche, fitness level, diet, sleep and of course previous injuries. Smith’s company, Kitman Labs, collates all these data and uses an algorithm to calculate individual risk profiles. A trainer can then use an app to see how high the injury risk is for each of his athletes and on that basis decide who plays and who stays on the bench. Kitman Labs has already advised teams in the U.S. football, basketball and baseball leagues, reducing injuries by up to 30 per cent in two years.

Giants like IBM and SAP are getting into the game, too. “The real market, however, is amateur sports, which is where most injuries occur,” says Mark Lehew of SAP’s Sports & Entertainment Industry Business Unit. “Professional athletes are trained and know how to fall.” Indeed, according to a study by the Ruhr-Universität Bochum, every year one million people in Germany injure themselves so severely playing sports as to require medical assistance, which itself has also improved considerably. “Before, we had to cut joints open but now we can use minimally invasive arthroscopic procedures to operate on many different areas,” says Imhoff. “And we use biodegradable implants, which shortens an athlete’s recovery time tremendously.”

The perfect prosthesis

Modern computer simulation techniques can help surgeons. Rüdiger Westermann, Professor of Computer Science at the Technical University of Munich, uses a computer to simulate the forces that act on a patient’s bones. With this information, he can predict how bones grow. If a patient is fitted with a standard prosthesis, the bones may develop in such a way that the prosthesis works itself loose. “Our simulations give surgeons tips on which type is best for which bone, and where best to fit it.”

Westermann’s simulations are also useful for healthy athletes. “If we could just simulate the entire body, including muscles and tendons, it would be possible to simulate the perfect motion sequence for an athlete.” That is still some way off. But it would then be possible to calculate not just the perfect training schedule, but the perfect discus throw, shot-put or pole vault. The world records of the future could come straight out of a computer.
Active ageing: a European research priority

To face the increasing pressure on health and social-care costs, the European Institute of Innovation and Technology (EIT) – the European Union’s research and development organisation – has launched the EIT Health project. It aims to accelerate entrepreneurship and innovations that promote healthy living and active ageing by bringing together 140 pharmaceutical and medtech companies, research institutions and universities.

Meanwhile, the Technical University of Munich is addressing the issue of restricted mobility with its “Active Hands” project. The goal is to develop a system to support individuals who have trouble performing daily tasks due either to old age or to central nervous system diseases. ETH Zurich is heading in the same direction with its “Hand Tech” project, which could help stroke patients regain control of a paretic hand.

One of the world’s largest healthcare initiatives, EIT Health (http://eithealth.eu/wp-content/uploads/2015/03/Inn_Projects-2016.pdf) was launched this year with a budget of €2 billion over 10 years.

Smart courts Technis, a start-up in Lausanne, Switzerland, has developed a tennis court that provides players with real-time information on foot impact and errors. The company also offers augmented-reality challenges, like aiming the ball at virtual targets on a court. Embedded in the court surface, the technology will soon be available to professionals as well as amateurs.

By Jens Lubbadeh

The connected athlete

Amateurs can now enhance their performance and their health by using wireless devices and biosensors that monitor behaviour, environment and physiology. Future applications will go even further.

Data have invaded every area of our lives – even exercise. Embedded accelerometers and GPS, not to mention gyrometers, provide valuable information on our speed, direction and step count. Peripheral sensors measure physiological parameters such as pulse and blood pressure. All these data are fed into applications to set targets, just like a personal trainer.

New technologies have not yet sidelined sports coaches altogether, according to Steven Vos (https://www.tue.nl/en/university/departments/industrial-design/department/staff/detail/ep/e/d/ep-uid/20150459/), professor at Eindhoven University
of Technology (TU/e). “The problem with current software is that it explains how to train, but in line with the elite sports concept, i.e. going ever faster and further,” he says. “But that’s not recommended for people who are not in proper physical condition.” He adds: “Exercise undeniably has a positive impact on health, but the benefits take time. That’s why too many people stop their workouts prematurely.”

Approaches need to cater to each individual to make exercise as appealing as possible. Vos hopes to do that by designing smart systems that can attract, monitor and motivate amateur athletes. “Smartphones have become a natural extension of our body,” he says, making a variety of data continuously available. Using this information, researchers have already identified five different profiles of budding athletes, a first step towards personalised programmes to encourage people to exercise.

**Mechanical muscles**

Until now, most applications have been used in endurance sports like running, because they are widely practised and compatible with today’s sensors. But other sports, such as tennis, also require proper technique. Leap Technology (http://leaptechnology.com/), a Danish start-up, has developed sensors made of materials featuring mechanical characteristics similar to muscles. These fibre-like materials, which adhere directly to the skin or are woven into fabric, are made in malleable, stretchable and super-thin electroactive polymers that can detect the slightest fluctuation. “It takes minimal force to distort them, which makes them mechanically transparent and does not hinder movement,” says Alan Poole, the company’s head of marketing. The system can analyse how muscles and joints work, for example, to perfect a lifted backhand on the courts. It can also be used to study how an athlete interacts with equipment: to optimise how a foot hits the ground when running, while factoring in the shoe’s distortion. The sensors are scheduled to hit the market in about two years.

Other technologies are directed at athletes’ brains. Jakob Eg Larsen (http://www.dtu.dk/Service/Telefonbog/Person?id=7165&tab=1), a professor at DTU – Technical University of Denmark, has developed neuroscience applications such as the electroencephalogram (EEG) for smartphones. He teamed up with the company Emotiv to create the “smartphone brain scanner”. This system features a headset fitted with electrodes that collects data on brain activity. The data are then transmitted wirelessly to an application that produces 3D images of the brain. Resolution is not as high as with a laboratory EEG, but its portability makes it easy to use in natural conditions. Neurofeedback, a treatment used for psychological illnesses, could be adapted to improve training. This technique monitors data on brain activity to train the brain to regulate certain functions using video displays.

**Virtual vs. human coach**
More professional techniques are becoming widely available to amateur athletes. To gain muscle strength and prevent injury, Massimo Mischi (https://www.tue.nl/en/university/departments/electrical-engineering/department/staff/detail/ep/e/d/ep-uid/20001026/), an associate professor at TU/e, has found a way to make weight-lifting training sessions more effective without using heavier weights. His discovery, based on a natural muscular reflex, increases the impact of workouts by 25 per cent to 100 per cent, depending on the specific muscle involved. The Dutch company Hipermotion (http://www.hipermotion.com/products/maxdfm/) has applied the technique to develop its new fitness machine, the MaxDFM.

A virtual coach offering personalised advice and ideal muscle build – Olympus for amateurs? Perhaps not. Future applications could even make such recommendations as, “If you want to run a half marathon in your condition, go see a real coach,” says Vos. These technological advances applied to amateur sports will more likely enhance our health more than our performance.

**European mobile applications that boost running performance**

Endomondo (https://www.endomondo.com/) (Denmark) Tracks the distance, route, and duration of runs as well as the calories burned. Users can set their goals to beat a friend’s or their own previous performance.

Spotify (https://www.spotify.com/dk/) (Sweden) Using phone sensors to measure a runner’s tempo, it chooses music that helps keep the pace.

Zombies, Run! (https://zombiesrungame.com/) (UK) Immerses joggers in a world where they must run to escape zombies and fulfil various missions. The soundtracks make for training sessions full of suspense.
Runtastic (https://www.runtastic.com/fr) (Austria) Offers a personal exercise diary to keep track of running metrics. Other features include a customizable dashboard, detailed exercise information and progress sharing over social networks.

By Yann Bernardinelli @YB_SciRedac (https://twitter.com/YB_SciRedac)

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