

Future of human enhancement

Physical and cognitive augmentation tech, such as bionic limbs and gene editing, may soon be deployed to augment and enhance otherwise healthy humans.

This think piece explores trends in human enhancement and their potential impact on sport and physical recreation from four perspectives.

1. **Enhanced physiology** (developments in repairing the body)
2. **Augmented biomechanics** (technologies that may be added to remove deficiencies or add more capability)
3. **Neurotechnology and improving cognition** (efforts to improve mental capacity and integrate the brain's function with computing networks)
4. **Nutri-genetics and ingestible robotics** (what we're likely to put inside our bodies to improve function and diagnose and improve its performance).

- Bone, muscle and neurons in line for upgrades as new medical tech advances.
- Advances in wearables and prosthetics end physical disabilities. Prospectively enhancing the able-bodied with super-human strength, speed and stamina.
- These advances will pose ethical questions about the level of permissible enhancement, the consequences and further pressures they will place on inequality within society.

This resource is part of a series which considers the changes and trends most likely to impact the future of the play, active recreation and sport sector and what we can do to best prepare for change.

Summary implications

3D printed upgrades	<ul style="list-style-type: none">• Seamless injury repair: The ability to repair significant injuries and potentially upgrade capability will change athlete's career patterns and options• Extension of participation: New techniques for repair and reversal of aging would extend significantly the time individuals were able to participate in active leisure.
Genetics to Predict and Optimise	<ul style="list-style-type: none">• Genetic based predictions influence leisure activities: leisure activities could be aligned with a greater understanding of the needs of future populations (as determined by their genetic projections).
Bioengineering the human form	<ul style="list-style-type: none">• Gene-doping as the norm: A foregone conclusion, or a development to be avoided at all costs?
Wearables	<ul style="list-style-type: none">• Training supplemented by wearable AI: Those able to use training wearables are likely to be at a significant advantage with continual feedback on performance.• Smart clothes that complement movement: the barriers to physical participation for the aging could be removed by clothes that complement movement.
Bionics/ Prosthetics	<ul style="list-style-type: none">• New forms of human capability: Advances in bionics may redefine what we believe to be possible.• Physical ability becomes technology dependent: If all physical disabilities can be remedied by augmenting technologies, then we will need to redefine disability as lack of access rather than a lack of core ability. If augmentations add to the able-bodied, then the 'naturally abled' may have a similar experience to that of today's disabled community.
Internet of Things and Sensors	<ul style="list-style-type: none">• Players and coaches as data scientists: The level of data available in the future is going to potentially overwhelm participants and coaches seeking to compete at the highest levels.
Immersive technologies as training aids	<ul style="list-style-type: none">• Convergence of eSports and physical training: Is there an opportunity to develop cross-over opportunities that use immersive eSports environments to improve real world physical skills?
Mental training and assessment	<ul style="list-style-type: none">• AI-based assessment adding training pressure: Will attention-monitoring headbands add to the levels of mental pressure already experienced by young people?
Brain Computer Interfaces	<ul style="list-style-type: none">• Ethical question on level of permissible enhancement: At what point in the BCI development does a debate need to be had about their introduction?
Nootropics	<ul style="list-style-type: none">• Managing the 'legality' of wonder pills: Some nootropics may not be banned substances for athletes, but what might the side effects be and is there any real benefit?
Nutrigenomics	<ul style="list-style-type: none">• Genetic data will require careful management: Companies specialising in nutrigenomics promise significant levels of data production both for individuals and teams. Assuming the market grows as anticipated, the quality and privacy of this will need careful management. These skills may not be currently well-rehearsed in sport and recreation agencies.
Ingestible Robotics	<ul style="list-style-type: none">• Internal monitoring as a competitive edge: The deployment of ingestible robotics to monitor elite performance could well become a competitive edge.

Background

Speed and impact of technological advances

- Humanity stands on the brink of significant tech advances. This tech revolution is distinguished by its lightning speed, large scale and unprecedented impact.
- Beginning early in the 21st century, this tech revolution has seen the rise of machine learning and artificial intelligence (AI)¹.
- This speed of change means no invention is ever finalised or fixed, as each is a starting point for another invention. The iPhone, introduced in 2007, led to around two billion smartphones by 2015 with dramatically refined technology.
- This revolution is also defined by unprecedented returns to scale that allow greater value with relatively fewer employment-associated costs. E.g. in 2014 Facebook paid \$19 billion for WhatsApp, which had 400 million users but only 55 employees.
- The revolution also merges a range of domains and connects them across physical, digital and biological platforms.
- This factsheet focuses on the emergent trends in human enhancement from the four perspectives of:
 - a. Enhanced physiology – developments in repairing the body
 - b. Augmented biomechanics – technologies that may be added to remove deficiencies or add more capability
 - c. Neurotechnology and improving cognition – efforts to improve mental capacity and integrate the brain’s function with computing networks
 - d. Nutri-Genetics and ingestible robotics – what we’re likely to put inside our bodies to improve function and diagnose and improve its performance.

Enhanced physiology

New medical technologies will repair damage and potentially enhance current biology. Beyond this, developments in understanding and manipulating genetic outcomes, will likely result in the ‘natural’ human form changing significantly over the next few decades.

What’s changing?

3D printed upgrades

- Advances in 3D printing have the potential to be a vast improvement over bone-graft options, and other synthetic replacements.
- Human cells and tissues can also now be printed, and research into printing complex organs and muscles is well advanced. interestingengineering.com
- The approaching affordability and availability of 3D printing to the home user will also be a big game changer.

¹ AI refers to any computer programme or system that can perform tasks that resemble acts of human intelligence. Examples of this include spam filters, voice transcribers, and virtual assistants like Apple’s Siri and Amazon’s Alexa.

Genetics to predict and optimise

- Avoiding injury in the first place better than relying on 3D printing to replace bone, muscle and neurons. Advances in genetic understanding could enable prediction to become routine in the future.
- Genetics plays an integral role in athletic performance and injury risk. By analysing genetics, it may become possible to create a cost-effective one-time test. [mdpi.com](https://www.mdpi.com)
- It may be possible to predict cardiac phenotype in paediatric patients to guide future monitoring and support counselling patients about future athletic pursuits. [cincinnatichildrens.org](https://www.cincinnatichildrens.org)
- Singularity University's Future of Sports believes genetics will be removed as a determinant in future professional sports, with the human body regulated to ensure everyone is genetically 'equal'.

Bioengineering the human form

- Gene-editing technologies will assist to hasten the future of sport as promoted by the Singularity University. edition.cnn.com
- Though it has been around since the 1980s, gene-editing is more precise and affordable than ever. This is thanks to the development of the 2010 CRISPR² system, which uses bacteria to cut DNA in precise locations.
- Advanced research into gene-editing will lead us into an era of genetic manipulation that goes far beyond healthcare and is already tackling aging.
- Such developments come with significant ethical questions including those that will challenge the integrity of sport. synbiobeta.com
- There is a ban on gene doping in sport, but some argue that legalising it is the only sensible option to make events fairer and safer. onezero.medium.com
- The gene doping debate is likely to intensify sharply over the next decade. The selection process for 2022 Winter Olympics will include genetic sequencing.
- In the equine area, the industry is already debating whether we should be trying to create super horses. horsesport.com
- NZ is likely to continue to advocate for international frameworks to manage these issues (a la WADA) and is likely to adhere to any international framework.
- Issues like gene doping show the importance of strengthening Drug Free Sport NZ's investigation and intelligence capability.

2 Clustered regularly interspaced short palindromic repeats

Augmented biomechanics

Advances in wearables and prosthetics promise an end to physical disabilities, with bionics replacing lost eyes, ears, and limbs – and the prospect of enhancing the able-bodied with super-human strength, speed and stamina. The associated data generated will drive unprecedented levels of insight.

What's changing?

Wearables

- Combining AI analysis of wearable-derived performance statistics continues to expand the level of data available to users. Products like Ambiotex are already offering the prospect that participants of any level can train like professional athletes. ambiotex.com
- Wearable devices that not only track what you do but offer AI-driven 'coaching' to help improve performance are also entering the market. ncub.co.uk
- Silicon Valley start-up Seismic is taking wearables to the next level with a line of "Powered Clothing". exoskeletonreport.com
- It may soon be possible to dispense with smart clothing altogether and directly apply a magnetic layer to the skin that monitors movement techxplore.com

Bionics/Prosthetics

- Advanced prosthetic technologies are also enabling access capabilities previously outside human experience (cyborg), e.g. opening up the possibility of humans hearing ultrasound better than bats.
- Vision will likely be upgraded beyond typical human capability. E.g. a surgically inserted intraocular lens provides 3x better vision than perfect eyesight. medium.com
- Overcoming significant design challenges and increasing the speed of development are being addressed by combining technologies and opening up design to broader collaboration. qz.com
- New forms of augmentations can change perceptions of disability. Amputees can celebrate their prosthetics as fashion accessories. mashable.com
- Bionic technology is removing physical barriers faced by less-abled individuals, while raising questions of what it is to be human and the prospect of becoming capable of influencing our own evolution. youtube.com

Internet of Things (IoT³) and sensors

- Embedding sensors in a range of augmentation tech will generate an exponential amount of data about our world and will be invaluable in future sport training programmes. iot.eetimes.com
- The majority of objects in our lives will be able to sense and share and report data and work autonomously when other sensors tell them to.
- IoT is revolutionising the way elite coaches facilitate training, manage players and address critical situations in each game. www2.deloitte.com

³ The IoT describes a network between physical devices and the people who use them. 15 billion devices are already linked through the internet, essentially forming one massive circuit. New connections are made every second through AI, transmitters and sensors and this number is anticipated to increase exponentially

- NZ is ranked highly as a nation in terms of IoT readiness, being well positioned to maximise the value of data, with a connected and innovative culture, a growing data economy, and a safe, open data environment to build on.

Neurotechnology and improving cognition

Developments in new ways of assessing brain capability, how it may be linked to external computing capability, and augmenting its capacity with embedded computing power, open up the prospect of significantly enhanced mental function that would enable faster, seamless access to information and interaction with machines.

What's changing?

Virtual reality as a training aid

- Virtual reality (VR)⁴ environments could revolutionise how players hone their decision-making skills and speed up their reaction times. [researchgate.net](https://www.researchgate.net)
- Immersion in technology will become the norm, and objects that don't offer VR capabilities, such as traditional sports, will start to appear 'broken'.
- By 2025 new sports are anticipated to emerge that will be designed to test participants' performance across the spectrum of virtual and physical realities. eSports will begin to poach athletic talent, as new games will require speed, strength and endurance.

Mental training and assessment

- A new generation of cognitive assessment and elite training technologies are emerging to assist players in enhancing mental capacity.
- Tech startup [Receptiviti](https://www.inbenta.com) is assessing a different angle of players' neural function by using AI and machine learning to understand mental strength. [inbenta.com](https://www.inbenta.com)
- VR is being used to analyse brain function. Magic Leap's SyncThink measures brain health using a wearable device that tracks eye movement. [fastcompany.com](https://www.fastcompany.com)

Brain computer interfaces

- Developers are experimenting with ways to change and enhance the function of the human brain. Startup Kernel is envisioning a so-called mind, body, machine interface. [youtube.com](https://www.youtube.com)
- Superconducting computing chips can now process information faster and more efficiently than the human brain. In future, computers could link to the brain through a non-intrusive interface to super-charge human cognition. [nature.com](https://www.nature.com)
- This brings us close to the merging of technology and humanity - referred to as the singularity.
- Stephen Hawking believed that the brain is essentially a computer, and it will be possible one day to copy it and provide life after death. Futurist Ray Kurzweil adds that within the next 20 years, [mobile devices will connect to our brains](https://www.venturebeat.com). [Venturebeat](https://www.venturebeat.com)

⁴ VR is a form of simulation that is essentially fake but feels real. It is anticipated that 160 million VR headsets will be sold by 2020 (up from 12 million in 2016). There are currently 200,000 developers creating VR content.

Pills, nutri- genetics and ingestible robots

The growth of the multi-million-dollar business of sports nutrition will continue to grow as participants look for new ways to enhance fitness. Nootropics to improve brain function, genetically matched diet and ingestible robotics will also increase in popularity in the quest for improved wellbeing.

What's changing?

Nootropics

- Nootropics are ingredients that suppliers are promoting as memory enhancers. Supplement manufacturers are claiming improvements in attention, focus, memory, and even brain health. Predicted to be a \$6 billion industry by 2024. xtalks.com
- The latest and best nootropics will be expensive. Those who can afford early access will become much smarter; possibly splitting our species into one group who are continually enhancing and another condemned to follow organic speeds of evolution. medium.com

Nutrigenomics

- Personalised nutrition is likely to become more commonplace, as genetic testing of participants will enable sports dietitians to use the information to tailor diets that reflect specific variant gene-nutrient interactions.
- By 2026, the consumer genetic testing market is anticipated to be worth \$611 million. Increasing genetic testing will improve dietary and health knowledge and recommendations. sharonpalmer.com
- Specific sports code-aligned services are already on the market that aim to improve performance through genetics. soccergenomics.com

Ingestible Robotics

- Combining what we eat with technology is set to increase. According to the report [Smart Pills Technologies Market \(2012-2017\)](#), the global smart pills market has already reached nearly a US\$1 billion dollars.
- Ingestible technology is already helping Canadian athletes train for the anticipated extreme heat and humidity of the 2020 Tokyo Olympics. For Canadian athletes, knowing how to stay cool during competition could be as simple as swallowing a pill. [runningmagazine.ca].
- Microelectromechanical systems (MEMS) will be able to detect everything around them including light, temperature, vibrations, pressure, magnetism, chemical composition, humidity, location and acceleration. It's anticipated there will over 1 trillion active sensors by 2025. sevenfigurepublishing.com
- Ingestibles are likely to become autonomous and directed. Scientists have developed an electronic capsule that can be ingested and controlled wirelessly to deliver drugs to reduce surgical procedures. The 3D-printed pill can be controlled externally using Bluetooth and could be developed further to detect infections or an allergic reaction in the future. irishnews.com