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Vision enhancement technologies, augmented reality and sports integrity considerations

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Competing Interests

Yannis Pitsiladis is a member of the IOC Medical and Scientific Commission, a member of the Executive Committee and Chair of the Scientific Commission of the International Sports Medicine Federation (FIMS), a member of the Scientific and Education Commission of the European Federation of Sports Medicine Associations (EFSMA), a member of WADA's Health Medical Research Committee (HMRC). Yannis Pitsiladis is also the Founder of the original Sub2 marathon project and Human Telemetrics Ltd (London).

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Abstract

The *International Olympic Committee (IOC) consensus paper on sports-related ophthalmology issues in elite sports* is a timely first consensus paper on this important emerging topic. Implementing its recommendations will undoubtedly help support athlete health and well-being. However, like most medical interventions aimed at restoring health, important sports integrity considerations with vision enhancement and augmented reality approaches must be considered. If necessary, regulations are adopted by relevant International Sports Federations and possibly the World Anti-Doping Agency (WADA) to safeguard meaningful competition. This highlights some of the emerging technologies and methods in vision enhancement and augmented reality that will revolutionize the sport, and therefore sport (and sports medicine) has a responsibility to be proactive in safeguarding the implementation of this technology rather than an outright ban which will prove impractical and difficult.

Vision enhancement technologies

The *International Olympic Committee (IOC) consensus paper on sports-related ophthalmology issues in elite sports* is a timely first consensus on this emerging topic. Implementing its recommendations will undoubtedly help support athlete health and well-being. However, like most medical interventions aimed at restoring health, there are important sports integrity considerations with vision enhancement approaches that must be considered, and if necessary, regulations adopted by relevant International Sports Federations and possibly the World Anti-Doping Agency (WADA) to safeguard meaningful competition.

As stated in the IOC consensus paper, vision, like speed and strength, is a critical component in elite sports performance (1). Therefore, strategies that correct or enhance vision will likely significantly impact sporting performance. Numerous biotechnology companies are creating solutions to enhance human vision and visual performance (e.g., smart contact lenses). Whether the vision enhancement technology is positioned on the sclera (e.g., Mojo Vision, Figure 1 (2)) or contained within glasses or a headset (e.g., Innovega, Figure 2 (3)), the use of such technology as a display allows the athlete to be informed on best performance strategies (Figure 3). In addition to enhancing vision *per se*, such vision enhancement technologies have the potential to replace smartphones, smartwatches, augmented reality glasses, virtual reality headsets and even sports visors, especially when the user wishes to conceal the use of such technology to gain an advantage (e.g., competitive sport). There is also interest from sports brands to engage with vision enhancement solutions. Brands such as adidas (running), Trailforks (cycling/hiking), Wearable X (yoga), Slopes (skiing) and Birdies (golf) (4); all these brands have declared their interest in augmented reality contact lenses.

Figure 1: The prototype Mojo Vision smart contact lens with a 14,000 pixels per inch MicroLED display, the world's smallest at just 0.5 mm in diameter, and densest with a pixel-pitch of just 1.8 microns, 5GH ultra-low latency radio to stream AR content, continuous eye tracking via custom-configured accelerometers, gyroscopes, and magnetometers, medical-grade in-lens batteries, and eye-controlled user interface (2).

Figure 2: The vision enhancement technology by Innovega is made of display glasses and a smart lens that picks up the images and media from the eyewear display and projects it directly on the retina.

Outer filters allow one to see the natural world simultaneously while preventing crosstalk between light paths (3).

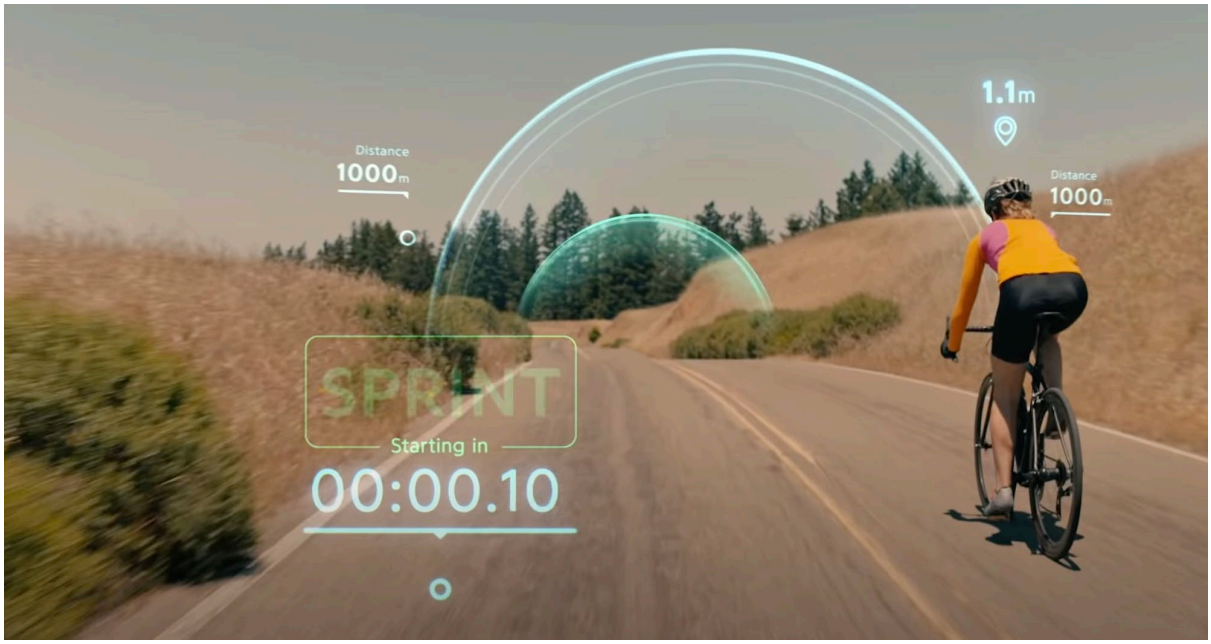

Figure 3: An example of vision enhancement technologies for use in sport (2)

While such visual enhancement technologies are not market-ready, applications for FDA approval are being considered (e.g., 2). It is, therefore, only a matter of time before such vision enhancement technologies enter the world of sport, where vision is one of the primary senses impacting performance. The world of sports, and sports medicine, need to consider this technology to protect the health of athletes proactively but also preserve the integrity of competition. Options for implementing such technology could be via the standard Therapeutic Use Exemptions (TUE) process (5). The aim is to establish the conditions that must be satisfied for a TUE to be granted, thereby permitting this method (currently not prohibited) to restore normal vision rather than enhance it beyond normal. This aim will be prone to the same difficulties as with different endocrine diseases and disorders such as adrenal insufficiency, diabetes, male hypogonadism, pituitary deficit, and thyroid diseases. For such a solution to be implemented in elite sports, the WADA Prohibited List (6) would need to expand to include vision enhancement methods. In readiness for this development, the WADA Prohibited List Expert Advisory Group could conduct a feasibility study to include human enhancement technologies,

not limited to vision enhancement. If prohibited either via WADA or the technical regulations of an IF, the physician who treats these athletes (e.g., the ophthalmologist) will need to be aware of their specific role and responsibility in applying for a TUE or the equivalent alternative if provided by the IF and in adequately monitoring the use of the prohibited enhancement technologies.

Like with all innovations, both positive and negative consequences emerge from such augmented reality technology developments. These technologies may allow, shortly, the analysis of tear fluid *in situ*, measuring intraocular pressure, checking for early onset of glaucoma, continuous glucose monitoring (7) or even hydration status (8,9). Visual enhancement technologies will undoubtedly provide a performance advantage by placing the athletes' relevant content into the world, thus enhancing feedback, decision-making efficiency, and unobstructed vision. Contrast enhancement, edge detection, and magnification are all enhanced with such technology. No longer will the athlete need to shift their attention from the target to the periphery and back, but they will seemingly do both simultaneously using visual enhancement technologies. It is only a matter of time before this technology can be used to assess vision health, on-eye diagnostics, disease monitoring and real-time biometrics. The benefits will be endless in terms of protecting the health of athletes, but there also needs to be a considered approach in implementing such technologies to safeguard sports integrity. Sport and virtual reality are also becoming more intertwined (e.g., Metaverse)(10). The virtual world holds new possibilities for enhancing training, sports competition, and fan experience. The world of sports and sports medicine needs to be ready for this technological revolution.

References

1. IOC consensus paper on sports-related ophthalmology issues in elite sports. Moe MC, Özmert E, Baudouin C, Binadra A, Crafoord S, Jo YJ Kiratli H, Moore M, Pitsiladis Y, Rolle U, Tan B, Yanık Ö, Budgett R, Erdener U, Steffen K, Engebretsen L (Submitted) BMJ Open Sport and Exercise Medicine.

2. www.mojo.vision accessed 18th May 2023

3. https://innovega.io/ accessed 18th May 2023

4. https://techcrunch.com/2022/01/04/smart-contact-lens-startup-mojo-vision-partners-with-adidas-and-other-sports-brands/ accessed 18th May 2023

5. www.wada-ama.org/en/athletes-support-personnel/therapeutic-use-exemptions-tues

6. www.wada-ama.org/en/prohibited-list

7. Ascaso FJ, Huerva V. Noninvasive Continuous Monitoring of Tear Glucose Using Glucose-Sensing Contact Lenses. Optom Vis Sci. 2016 Apr;93(4):426-34. doi: 10.1097/OPX.0000000000000698. PMID: 26390345.

8. Bron AJ, Willshire C. Tear Osmolarity in the Diagnosis of Systemic Dehydration and Dry Eye Disease. Diagnostics (Basel). 2021 Feb 25;11(3):387. doi: 10.3390/diagnostics11030387. PMID: 33668748; PMCID: PMC7996182.

9. Fortes MB, Diment BC, Di Felice U, Gunn AE, Kendall JL, Esmaeelpour M, Walsh NP. Tear fluid osmolarity as a potential marker of hydration status. Med Sci Sports Exerc. 2011 Aug;43(8):1590-7. doi: 10.1249/MSS.0b013e31820e7cb6. PMID: 21233774.

10. Huang Z, Choi DH, Lai B, Lu Z, Tian H. Metaverse-based virtual reality experience and endurance performance in sports economy: Mediating role of mental health and performance anxiety. Front Public Health. 2022 Oct 3;10:991489. doi: 10.3389/fpubh.2022.991489. PMID: 36262242; PMCID: PMC9574247.