What next for anti-doping: EVOLUTION OR REVOLUTION?

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THE ISSUE
Unfortunately, doping is a well-known problem in sport. The use of performance-enhancing drugs (PEDs) is widespread in elite and amateur level athletes. The World Anti-Doping Agency (WADA), created in 1999, implemented the World Anti-Doping Code in 2004 in order to regulate doping control and provide educational strategies to avoid doping (1). The Code documents the anti-doping rules, regulations and policies worldwide, which proposes 1.) to protect the fundamental right to participate in doping-free sport, consequently promoting health, fairness and equality for athletes worldwide and 2.) to promote effective anti-doping programmes at international and national level in order to detect, deter and prevent doping (2).

However, more than 20 years since the founding of WADA and a decade after the implementation of the Code, the magnitude of sports doping has not substantially abated (3). The true prevalence of doping is unknown, but some studies estimate a prevalence of 14–39%, which is far from that provided by doping regulations and policies worldwide, and/or illegal methods to obtain an unfair advantage.

The principles cited in the Code for doping control are: Education, Deterrence, Detection, Enforcement and Rule of Law (2). As this requires an effective testing system, the Athletic Biological Passport (ABP) was implemented in 2009, as a strategy for blood doping detection, and a few years later in 2011, the urinary steroidal model was also implemented (4). However, dopers continue to use PEDs and/or illegal methods to obtain an unfair advantage.

For example, analysis of blood samples collected during the 2011 and 2013 World Athletics Championships revealed evidence of blood doping (5).

Since 2004, the WADA has stored samples collected during Olympic Games for long-term retrospective re-analysis with more advanced analytical techniques. A total of 138 medals were impacted by doping, with the majority of positives (72%) identified retrospectively, which took 6.8 ± 2.0 years to be announced. The most detected type of PEDs is the Anabolic Androgenic Steroids (AAS). Amongst the most difficult AAS to be detected is testosterone, which generally is used together with a variety of other anabolic steroids such as nandrolone, stanozolol, oxandrolone, drostanolone, metenolone and mesterolone (6).

THE PROMISING “GAME CHANGER” DETECTION METHOD
First requirement for new game changing advances in anti-doping science to improve testing sensitivity and specificity is the need to adopt the most effective technologies available and not be satisfied with what one can afford or has access to. For instance, authors writing in the journal Nature in 2017, predict the impact of DNA sequencing will be on a par with that of the microscope (7). It is essential therefore that anti-doping science is able to use such powerful technologies and to keep up with rapid developments to increase the chances of finding the best possible solutions. Given this technology is routinely being used in biomedical research and precision medicine applications such as for cancer, stroke, Alzheimer’s, and understanding COVID-19 and its spread, then vital lessons can be learned and applied to anti-doping research. We have recently published this aspiration (8).

IOC RESEARCH GRANT
Thanks to a research grant from the International Olympic Committee (IOC) we were able to travel to Illumina (San Diego, California in August 2017), one of the company leaders in next generation sequencing, to plan and oversee the analysis of a subset of samples from a high dose recombinant human erythropoietin (rHuEPO) study previously conducted and funded by WADA (See Figure 1 for the study design) (9). This was an EPO intervention study with samples collected at numerous time points in 39 individuals – representing the largest study of its kind.

Fourteen months later (October 2018), we travelled to BGI, a competitor sequencing company based in Shenzhen, China, to test the same samples on what the Chinese are calling the ‘Ultimate Sequencer’. The same sequencing technology is having a big impact on the management of Covid-19. Sequencing is helping decipher not only how the virus is spreading in a particular location, but its origins and how it got there in the first place (10). Sequencing is also
being used to understand why some individuals are more prone to getting seriously ill, or dying when infected with Covid-19. The results of the sequencing of the anti-doping research samples from our HUEPO study were most exciting manuscript in preparation, G. Wang et al.). Briefly, we were able to identify distinct patterns across the time points using the RNA-seq data from either sequencer thereby capturing genes reflecting the response to EPO. As Covid-19 has delayed laboratory progress due to months of enforced lockdown, new funding is currently being sought to continue this exciting research.

H

ere lies the problem. WADA has committed US $80 million into scientific research since 2015. This funding support from WADA is much less than the transfer fee of one professional football player, such as Neymar (€220 million), Mbappe (€180 million), Philippe Coutinho (€145 million), and others. The research budget of WADA has also been considerably reduced over the last 10 years with almost US $7 million ($5 million/€5.7 million) spent in 2006 compared with US $1.5 million ($0.7 million/€0.72 million) in 2018, a reduction of more than 78% in a 12-year period. The undisputed reality is that “omics” technologies, despite massive potential to revolutionise anti-doping, have not been properly researched and tested. Anti-doping urgently needs new partners. The need for a concerted “omics” research initiative in anti-doping is also evident by the recent award of the largest research grant ever made in the history of the Partnership for Clean Competition (PCC) - $1 million awarded to Professor Rob Roach from the University of Colorado, USA (14). This award and the “omics” results we (and others) have generated to date, in the context of what is happening in medical/ disease diagnostics, confirm that it is only a matter of when, rather than if, “omic” methods will revolutionise anti-doping. However, a paradigm shift in terms of funding will only expedite this process and save money and pain in the long term.

A GAME CHANGER

The inspirational speech of the IOC president, Thomas Bach, at the fifth Tokyo Olympic Games in Japan, is missing a word: promise. Despite the 12% decrease in drug testing during the Olympic Games, there is no change in the number of positive anti-doping cases. Despite this unprecedented (in recent years) investment in anti-doping science by the IOC (with particular focus on storage and re-analysis), there would be no real prospect for meaningful reanalysis of samples for blood doping methods as new analytical methods become available. In summary, implementation of this very promising “game changer” detection method is expected to result in increased detection rates of blood doping without any increase in the cost of anti-doping. This outcome is expected to bring a culture change in terms of promoting clean competition. This overall success is also expected to intensify research efforts that involve state-of-the-art technologies such as next generation sequencing (i.e., RNA-Seq) and to advance newer approaches such as artificial intelligence (AI), machine learning, and deep learning to identify new and more robust signatures of doping (9).

THE APPROACH TO SUPPORT HARSHER DOPING SANCTIONS – MAYBE LIFE BANS?

A particular focus of our research in Eastbourne is to generate the evidence needed to justify a revision of the blood sample collection criteria approved by WADA to permit the use of tubes for stabilisation of RNA. Failure to revise the blood sample collection protocols in the run up to the Tokyo Olympics would represent a major victory for doped athletes. Despite this unprecedented (in recent years) investment in anti-doping science by the IOC (with particular focus on storage and re-analysis), there would be no real prospect for meaningful reanalysis of samples for blood doping methods as new analytical methods become available.

Given the short window detection of blood withdrawal and autologous blood transfusion showing significant lower expression of the transfusion and lower expression of AAS2 and SLCA4 after 15 days (15). Given the high accumulation of myoglobin, myoglobin-related biomarker, in skeletal muscle, studies involving molecular mechanism of long-term effects of the AAS usage has potential to identify possible biomarkers that can be used in new doping testing.

In order to achieve this goal, the Muscle Memory and Anabolic Steroids (MMAAS) Study is an international collaborative study developed by the University of Brighton (UK), University of Rome Tor Vergata (Italy) and Murdoch Children's Research Institute - MCREA (Australia). The hypothesis is to reproduce in an attempt to replicate the previous findings with particular reference to AAS usage and molecular effects on skeletal muscle. In addition, investigating the “muscle memory” mechanism in humans, monitoring human AAS user over time, may also allow the identification of novel molecular markers of AAS that can substitute the AAS use sign and potentially provide a new detection method.

Considering the long-term effect of muscle memory, it is possible that athletes are benefiting from a history of AAS use during their Olympic careers. A better understanding of the “muscle memory” mechanism could justify longer suspensions to end this abuse.

The long-term effect of “muscle memory” hypothesis is that muscle memory, potentially acquired by exercise and/or testosterone administration during hypertrophy are not lost after a period of detraining andatrophy (16). A “muscle memory” hypothesis could explain the observation that strength training adaptations induced by an increase in muscle mass are significantly better preserved in trained individuals despite a prolonged detraining period (17). In particular, the formation of extra myonuclei could be the local “memory mechanism” in muscle (18). The significance of this idea is that either a long or short-term exposure to AAS will have a sustained effect on muscle morphological changes, leading to sustained and unmatched enhanced future training effect. Given the persistence of muscle nuclei, the use of AAS combined with “AAS users over time” is a greater impact on muscle hypertrophy than either training or steroid use alone.

AN URGENT NEED

Despite some advances in the detection of AAS, there is an urgent need to develop new approaches that are resistant to the ever-increasing number of methods that are used for detection of AAS, including the detection of novel designer AAS.

New advances in biotechnology enable the use of powerful tools which have been successfully applied to diverse fields such as the diagnosis of cancer (9,19) and rare diseases with clinical and genetic heterogeneity (10), treatment for specific genetic diseases and to match transplant recipient and donor (11). Considering the efficacy of the new “omics” technologies, this approach can be used to enhance current anti-doping testing, as shown in previous studies that investigated the blood transcriptional signature after administration of HU-EPO in endurance trained athletes (12,13). Transcriptional profiling showed that transcripts were altered by HU-EPO and the expression pattern was observed up to 3 weeks after the last HU-EPO injection (14). A validation study using micro-dose of HU-EPO provided evidence that transcriptional biomarkers were used to prolong the detection window of blood doping (15). Three of these genes (ALAS2, CA1, and SLCA4) were also investigated in other studies that used RNA-based methods to monitor doping after blood withdrawal and autologous blood transfusion showing significant lower expression of the transfusion and lower expression of AAS2 and SLCA4 after 15 days (16). Given the high accumulation of myoglobin, myoglobin-related biomarker, in skeletal muscle, studies involving molecular mechanism of long-term effects of the AAS usage has potential to identify possible biomarkers that can be used in new doping testing.
Two complementary studies have been developed to investigate the "muscle memory" mechanism. On the one hand, we have created the largest research group in the world that is currently investigating the effectiveness of AAS usage on muscle growth and repair. This research has revealed that two participants had a unique ability to retain their myonuclear domain size, even when they are no longer taking AAS. Previous studies on powerlifters who took AAS in the past (PREV group), but are currently drug free, have shown that the "muscle memory" phenomenon is long-lasting and suggest that if an athlete serves a ban and returns to sport they may have a permanent advantage in their ability to build muscle – even when they are not taking any AAS at all. This finding has significant implications for anti-doping testing.

CONCLUDING POINTS

- A paradigm shift is needed, new game changer approaches are needed to enhance anti-doping.
- Use the best tools available, sequencing technology, artificial intelligence, machine learning and other approaches proven effective to deal with Covid-19.

New partners, anti-doping needs new partners.

- Use Olympic/Anti-doping assets, better use of anti-doping resources to enhance anti-doping (science).
- Collaboration, large international anti-doping collaborations are needed.

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8. Kaczor-Urbanowicz KE, Martin Carreras-Presas C, Aro K, Tu M, Garcia-Godoy F, Figueroa G. Elevated levels facilitate muscle re-growth and thus enhance "muscle memory". These findings indicate that the benefits of AAS usage are long-lasting and suggest that if an athlete serves a ban and returns to sport they may have a permanent advantage in their ability to build muscle – even when they are not taking any AAS at all. This finding has significant implications for anti-doping testing.

This data suggests that the myonuclei obtained via strength training and AAS usage are retained in humans and therefore could provide long-term advantages to AAS users, but more data is needed to confirm this hypothesis. This thesis aims to recruit similar groups to further investigate muscle memory. Additionally, RNA-Seq sampling on blood samples was used to explore the possibility of a transcriptomic signature of doping that could enhance AAS detection strategies.


Gisard Lima concluded his graduation in Sports Science and achieved the title of Master of Science in his country, Brazil. He also worked as strong condition trainer of the paralympic athlete Antonio Tenorio, in winning silver medal in Rio 2016. Currently, he is a PhD candidate at University of Rome ‘Foro Italicco’, Italy (beginning on Oct 2017 onwards). His PhD project is part of an international collaboration to investigate the pharmacodynamics of anabolic steroids use in the molecular mechanism of muscle memory and applications for anti-doping testing. Throughout his PhD course, he was affiliated at University of Brighton, UK, and joined the Prof Yannis Pitsiladis research group, in order to develop the project the Muscle Memory and Anabolic Androgen Steroids (MMAAS) study, which investigate the effects of steroid abuse in resistance-trained individuals.

He also was affiliated at Murdoch Children’s Research Institute (MRCI), Australia, for another collaboration to investigate the effect of anabolic steroids, but only in animal model, in collaboration with Prof Kathryn North. His research is aimed to improve the testing for doping detection, in samples that will be collected in further competition as well as to validate a method the assess samples that has been stored for a long term waiting for an more effective test (which he truly believes that can be the omics technologies).

Thesis title: Implications of RNA-seq in the detection of anabolic steroid use and the harnessing of the molecular mechanism(s) of muscle memory.

My research: Studies in both humans and mice have demonstrated that anabolic-androgenic steroids (AAS) can increase the number of myonuclear (DNA-marked) cells within muscle fibres. This acceleration of "myonuclear accretion" is due to a suppression of protein synthesis. In a mouse model these myonuclei have been demonstrated to be retained after AAS usage has ceased and these subsequently elevated levels are returned to normality only after several weeks without AAS. These findings indicate that the benefits of AAS usage are long-lasting and suggest that if an athlete serves a ban and returns to sport they may have a permanent advantage in their ability to build muscle – even when they are not taking AAS at all. This study on the powerlifters group, but any studies on powerlifters who took AAS in the past (PREV group), have demonstrated that these individuals have more myonuclei in their trapezius muscle than powerlifters who are currently using AAS (PAS group), clean powerlifters (C) and controls (C). Additionally, the number of myonuclei within the vastus lateralis was comparable between the PREV and P groups.

This data suggests that the myonuclei obtained via strength training and AAS usage are retained in humans and therefore could provide long-term advantages to AAS users, but more data is needed to confirm this hypothesis. This thesis aims to recruit similar groups to further investigate muscle memory. Additionally, RNA-Seq sampling on blood samples was used to explore the possibility of a transcriptomic signature of doping that could enhance AAS detection strategies.

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The use of technology to protect the health of athletes during the heat of Tokyo

ARTICLE BY KONSTANTINOS ANGELOUDIS(1), BORJA MUNIZ-PARDOS(2), NICKOLAS SMEETON(3), FERGUS GUPPY(4) AND YANNIS PITSILADIS(5)

Tokyo will host the Summer Olympics from July 23rd to August 8th 2021, with averaged air temperatures surpassing 30°C and humidity levels above 70% (1). Notably, forecasts indicate increments in the intensity and consistency of heatwaves globally because of environmental change (2). In recent years there has been an increasing number of heat illness cases in Tokyo, with over 65 deaths recorded in only one week in August 2018 (3). Interestingly, daily air temperatures during the summer of 2020 have been remarkably low when contrasted with the past two years. Despite the fact that this is by all accounts an abnormal season characterised by a broadened rainy period, 2021 is expected to face more intense heat and humid conditions, based on the LA Niña patterns models (i.e., powerful winds moving the hot waters of the Pacific Ocean from South America towards Indonesia). These predictions point towards warm irregularities that could probably be present in Japan during June-August 2021 (4).

Heat stroke is a life-threatening illness characterized by high body temperate that rises above 40°C, associated with central nervous system disturbances and multiple organ system failure (5). Policies to prevent classical heat stroke are not adapted for exercise-associated heat illness. This is due to the fact that the core body temperature is normal during exercise, the body temperature that rises above 40°C, associated with central nervous system disturbances and multiple organ system failure is unique to the heat illness and is the result of the metabolic heat production and the contraction of the contracting muscles. Due to differing factors and characteristics such as exercise duration, rule, endurance, intensity, mass, each sport is likely to offer a unique risk pattern, and each discipline within a sport can also have specific thermoregulatory demands. It is therefore necessary to characterise the thermoregulatory responses of athletes to each sport to adapt the current policies to the needs of athletes. There is also a need to develop innovative wearable devices capable of collecting, analysing and integrating a wide range of multidisciplinary parameters for application in elite sports. It is absolutely essential, however, that any mounted devices are unobtrusive and in no way hinder the performance or ability of the athlete to endure the demands of any competition. With this goal in mind, our group (i.e., a team of scientists, engineers, elite athletes and industry partners) have developed the “Sub2 mobile application” which is a state-of-the-art application for monitoring and analysing interdisciplinary data in real-time during competition events (e.g., marathon racing) (Figure 1). This application can also be applied as a preventive tool to inform on the health of athletes exposed to extreme environmental conditions with the collection of a wide range of biochemical, biomechanical and physiological and mechanical variables.

EXCITING POTENTIAL

This timely development has exciting potential applications given the Tokyo 2020 where this technology could help in the management of athletes during a medical emergency (e.g., collapse) allowing for an earlier intervention and intervention. For example, this application would have been beneficial to South African runner Callum Hawkins who collapsed a mile from winning the marathon at the Commonwealth Games at the Gold Coast (Australia, April 2018). Early recognition and diagnosis are imperative. Gastrointestinal temperature via ingestible devices is the only surrogate to rectal temperature (6) and real time core temperature monitoring may save precious minutes. In our group, we recently developed and used this real-time technology as a “hub” to aggregate a range of data feeds to assist athletes (7). Our research team has extensive experience in using this technology during various occasions (e.g., Major City Marathons, UCI and IAAF/WA World Championships, Tokyo 2020, World Rugby 7 Series). The need to include such applications, not only within elite sport but also workers and attendees during a sporting event, is clearly reflected by the dramatic environmental conditions which occurred during the World Athletics Championships 2019 (Doha, Qatar), where approximately 1/3 of the female athletes could not complete the marathon race held in extreme temperatures of >30°C and high levels of humidity >80% (8).

Collected from such applications would be of particular interest in a wide range of sports, especially during events characterised by similar extreme environmental conditions such as the World Beach Games which were also recently held in Doha, Qatar (12 Oct 16 vs. 2019) and involved 1404 athletes from 97 nations participating in a total of 13 sports (e.g., open water swimming, beach soccer, beach handball, beach football) (9).

In light of the above, it would be scientifically invaluable to better understand the impact that these technologies and innovations could have on athletes, workers, and all attendees at the Tokyo Olympics, where the environmental conditions are predicted to be as severe and extreme as those encountered at the 2019 World Athletics Championships in Doha (Qatar) or worse.

A concerted effort is currently underway by our group to ensure the necessary developments of these wearable technologies and innovations are validated in time to allow accurate monitoring and analysis of physical responses in real-time, to better protect the health of athletes and optimise sports performance.

EXPERT WORKING GROUP

The knowledge, experience and competencies at Eastbourne/Brighton are highlighted in this special edition and have been instrumental in guiding the efforts of Professor Yannis Pitsiladis (and his multidisciplinary research team and partners) who is a member of the IOC Medical and Scientific Commission and member of the Adverse Weather Impact expert working Group for the Olympic Games Tokyo 2020.

As part of this IOC expert working group, numerous outcomes are being generated including athlete brochures aids such as Heat the Olympic Games Tokyo 2020 “Heat injury and illness prevention for the health of athletes competing during sporting competitions in the heat” and research that can help protect the health of athletes competing in the heat in Tokyo is ongoing (and a small research grant awarded by the IOC entitled “Protecting athletes’ health through the prevention of heat illness during the 2020 Tokyo summer Olympics”, $50,000.00. 2020-2021). The Brighton marathon is one of the numerous test events to test these developments using a variety of different experimental conditions conducted in an ecologically valid environment, preceding the Tokyo Games (albeit the 2020 edition of the Brighton marathon was cancelled due to Covid-19).
DEHYDRATION AS AN ERGOGENIC AID

ARTICLE BY SHAUN SUTEHALL, ANDREW BOSCH AND YANNIS PITSILADIS

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Absence of evidence is not evidence of absence

Martin Rees, British astrophysicist

“Absence of evidence is not evidence of absence”

ECOLOGICAL VALIDITY

The fundamental concept that must not be overlooked when interpreting the available literature, is the ecological validity of the study to the situation of interest. For example, if the performance of an athlete, after ingesting a diuretic and urinating excessively and who subsequently begins an endurance task, is compared with an athlete who prepares normally, then dehydration may indeed be shown to impair performance

It is, however, difficult to elucidate from such research which was the cause of the decreased performance: 40 mg of furosemide or the associated dehydration.

Other studies, performed during competition, have demonstrated no negative effects of dehydration, with athletes regularly exceeding 2% body mass loss and at times >10%

This apparent ability of athletes to perform prolonged endurance exercise while “dehydrated” is further demonstrated by two separate case studies of Olympic marathoners, Haile Gebrselassie and Alberto Salazar, who had body mass losses of 9.8% and 8.1%, respectively, during competition

See Figure 1 for a theoretical model illustrating the effect of varying rates of fluid ingestion (i.e., A: an excess fluid intake; B: an ad libitum fluid intake and C: no fluid intake) on running performance. Illustration courtesy of Dr Barry Fudge

EFFECT OF ADDED WEIGHT

While the effect of altering the level of hypohydration in elite athletes during competition is currently unknown, the effect of added weight on endurance has been investigated

It was found that an increase of 10% in “non-functional” body mass resulted in a -10% increase in performance time. Using data from this study, we estimated running speed from 0% (1 min., 5km) at the start of a marathon to 10% (16.5 min. 5km) at the end of a marathon, assuming a linear change in mass over the duration of the marathon and compared this with an athlete who has no “impairments” from added weight (15 min. 5km).

In this example, the unimpaired athlete runs a marathon in 2:00:36, whereas the impaired athlete will complete the marathon in 2:06:52. Should this athlete carry just 3% of excess “non-functional” body mass, the resulting marathon time is still significantly impaired (2:02:28)

If we assume that the reverse applies i.e., losing weight during a marathon due to fluid losses results in a similar effect on times, but improvement rather than a reduction in running speed, then these simple calculations demonstrate the potential importance of shedding all “non-functional” body mass

Should this athlete carry 3% of excess body mass during a marathon? This is a process in which heat is accumulated within the body, primarily through a rise in metabolic heat production and an inability to dissipate this heat at a sufficient rate to the environment to maintain homeostasis

It is at times, falsely, believed that dehydration exacerbates this process and that it is a health risk to allow dehydration during competition

www.basem.co.uk
A closer look at the research studies conducted by PhD Student, Shaun Sutehall

**Shaun’s PhD reflects his unique ability to conduct research in the most challenging environments.**

Shaun has also received funding from Maarten AB (a Swedish Start-up) and the Sub2 Foundation (www.sub2hrs.com) to investigate the efficacy of adding sodium alginate and pectin to a carbohydrate beverage, given to athletes during prolonged endurance exercise.

**Applied novel techniques to traditional methods of improving performance**

Shaun has been on several research trips around the world including Ethiopia, Kenya, Scotland, USA and Greece and has worked with many elite, East African runners as part of the Sub2hrs Project (www.sub2hrs.com). His research interests centre around fluid delivery, carbohydrate and protein to improve performance and recovery, and apply laboratory findings in these areas to Olympic and other elite level athletes.

Shaun has also received support from a New Zealand Post Doctoral Fellowship awarded in 2015 and a Swedish Sports Foundation Travel Grant in 2016.

**Research studies**

Shaun’s PhD reflects his unique ability to conduct research in the most challenging environments. His PhD thesis, “Applying novel techniques to traditional methods of improving performance” comprises a series of field and lab-based studies such as a 3-month research field trip to South Africa and Ethiopia, where he led 14 South African athletes on a 4-week altitude training camp to Sululta, Ethiopia. Shaun has also conducted numerous research studies, some in the relative comfort of a laboratory but also in extremely difficult conditions such as in rural Ethiopia and Kenya.

**Shaun Sutehall**

Shaun Sutehall joined the University of Brighton in 2013 and completed his BSc Hons in Sport Science in 2016. Upon completion of the BSc and research project conducted under the supervision of Professor Pitsiladis, Shaun applied and was accepted for a PhD in the Department of Human Biology Sports Science at the University of Cape Town (UCT) to conduct his PhD under the supervision of Andrew Bosch (internal supervisor) and Yannis Pitsiladis (external supervisor). Yannis has a long standing collaboration at UCT with Andrew Bosch but also with other good friends such as Tim Noakes, Malcolm Collins, and Jeroen Swart.

**Expert supervision**

Under his expert supervision, Shaun has conducted numerous research studies, some in the relative comfort of a laboratory but also in extremely difficult conditions such as in rural Ethiopia and Kenya. Shaun’s PhD reflects his unique ability to conduct research in the most challenging environments. His PhD thesis, “Applying novel techniques to traditional methods of improving performance” comprises a series of field and lab-based studies such as a 3-month research field trip to South Africa and Ethiopia, where he led 14 South African athletes on a 4-week altitude training camp to Sululta, Ethiopia. While collecting blood and saliva samples for transcriptomic analysis. The aim of this study funded by the World Anti-Doping Agency (WADA) and South African Institute for Drug-Free Sports (SAIDS) was twofold: to determine the transcriptomic response (i.e., gene expression response) to altitude to allow differentiation from prohibited methods of enhancing performance and to determine if transcriptomics can be used to individualise altitude training.

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**References**

carbohydrate ingestion. See (2) for some of the publicity surrounding this innovative research. This field work and a pilot study was followed by two laboratory research studies performed at the University of Stirling, Scotland under the direct supervision of Dr. John Leiper and Professor Stuart Galloway. Here Shaun investigated the effect of sodium alginate and pectin on the gastric emptying rate of a 500 ml bolus of carbohydrate drink and the oxidation rate of ingested carbohydrate during prolonged exercise and the winners of these marathons, to work with elite athletes (and often York City, Berlin, Dubai and London) international marathons (i.e., New ELITE ATHLETES marathon team in Berlin, 2016 Celebration of the Sub2 Figure 2: level (Suluta, Ethiopia) laboratory at 2,800m above sea is being conducted at the Sub2 time – Kenenisa Bekele. The test the running economy of the plate running shoes versus (see Figures 1 and 2 ), providing implications for the use of carbon technology related to anti-doping (e.g., wearable technology) prevention of heat-related illness during competition using technology and for the use of carbon fibre plates in running shoes – a fair innovation or technological doping? (see Figure 3).

Alongside these PhD studies, Shaun has led or supported numerous other research projects related to anti-doping, wearable technology, prevention of heat-related illness during competition using technology and implications for the use of carbon fibre plates in running shoes – a fair innovation or technological doping? (see Figure 3).

References:

Establishing a Global Standard for Wearable Devices in Sport and Fitness

T he market of wearable technology is continuously growing and was valued at USD 15.74 billion in 2015 and is expected to reach USD 51.60 billion by 2022, at a CAGR of 15.51% between 2016 to 2022. Notably, the growth of the market is increasing in developed and developing countries and expected to grow even more now due to COVID-19. Wearable devices are largely used worldwide in health monitoring, telemedicine and fitness industries. Global companies such as Fitbit (U.S.), Apple, Inc. (U.S.), Xiaomi Technology Co., Ltd. (China), Garmin, Ltd. (U.S.), Samsung Electronics Co. Ltd. (South Korea) and others are developing wearable technology. Despite the high speed growth of the sector, there are several concerns shared amongst the scientific community regarding the use of wearable devices. These concerns include their accuracy, reliability, accessibility, quality assurance, population-specific validity, privacy, data interpretation and presentation to consumers, and standardisation of data from technical purposes. The absence of regulation in the field of sport and fitness, wearable devices creates the need for the implementation of a global standard for sport and fitness wearables.

IOC RECOGNISED

As the only formally recognised by the International Olympic Committee (IOC) sports medicine federation and a key organisation in the field of sport and exercise medicine, the International Federation of Sports Medicine (FIMS) together with its 26 Collaborating Centres of Sports Medicine (FIMS CCSM) (see Figure 2) has established a task force in association with our partner Wearables Technology (2019) and headed by Professor Yannis Pitsiladis (FIMS Chair) (2020) to address a quality assurance standard for wearable devices guiding companies to achieve these technical and methodological concerns to critically consider them (Figure 7).

The roadmap to the FIMS central resource for wearable devices for establishing protocols and standard operating procedures for the testing and certification of wearable devices has been drafted and currently being implemented (Figure 2, next page). Briefly, some highlights include the setting up of the Guiding Reference Steering Committee (FRSG) in January – March 2019. In September 2019, the first FIMS Collaborating Centre for Wearable Devices was established in the Growth, Exercise, Nutrition and Development (GENUD) Research Group at the University of Zaragoza (Zaragoza, Spain). The multidisciplinary GENUD Lab has been successful in designing and implementing interventions that combine a nutritional-physical activity-medical approach. GENUD has experts in assessing body composition and physical activity, and athletic performance assessment in both trained and sedentary children, adolescents, adults, and elderly individuals. (See Figures 5-8 for the key members of the GENUD laboratory on the next page).

SECURED FUNDING

It is worth pointing out that funding for this ambitious project has been secured, in part, at least from funding efforts by FIMS which are beginning to bare fruits with over €100 000 secured from MW Shakhnovskyy Foundation and FIMS CCSM in Latvia (Sports Medicine and Physical Health Centre, Riga) and Italy (Istituto di Riabilitazione Riva, Torino) with generous infrastructure support from the GENUD-FIMS.

GENUD also has extensive experience with the use and method validation of wearable technology (e.g., camera-based systems to measure movement velocity, accelerometers, brain stimulation wearables, and foot-worn inertial sensors) focusing on body composition, physical activity, and athletic performance assessment in both trained and sedentary children, adolescents, adults, and elderly individuals. (See Figures 5-8 for the key members of the GENUD laboratory on the next page).
## Where in the pathway to test?

**Panel consensus: test here.**

- Achieves nuanced, multilevel troubleshooting and constructive critiques
- Establishes high-level technical consensus and stakeholders from all likely stakeholders, and especially industry
- With this in mind, numerous interactive events are being held around the world (despite the restrictions due to Covid-19) to solicit the input of the stakeholders. Interesting insights are emerging from these events such as from the open forum held at the Annual Meeting of the New England Regional Chapter of the American College of Sports Medicine (ACSM) in November 2019 in Providence, Rhode Island, USA but also more recently, the panel discussion as part of the Yale Centre for Biomedical Data Science Digital Health Monthly Seminar Series in September 2020

**CONSULTATION PROCESS**

It is imperative that an initiative like establishing a global standard for wearable devices in sport and fitness considers the views of all likely stakeholders, and especially industry. With this in mind, numerous interactive events are being held around the world (despite the restrictions due to Covid-19) to solicit the input of the stakeholders. Interesting insights are emerging from these events such as from the open forum held at the Annual Meeting of the New England Regional Chapter of the American College of Sports Medicine (ACSM) in November 2019 in Providence, Rhode Island, USA but also more recently, the panel discussion as part of the Yale Centre for Biomedical Data Science Digital Health Monthly Seminar Series in September 2020.

### Large company representative: test here

(ie; data analytics to develop error-correction algorithms)
- Exploits large datasets available from marketed devices
- No redevelopment or risk to competitive advantage

CCSM at the University of Zaragoza, Zaragoza, Spain. The aim in the near future is for each of the FIMS CCSM that qualify for accreditation to deliver the FIMS Global Standard to be self-sustaining within 24 months.

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