Technology in Athletics

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Introduction

The close relationship between technology and sport is not a modern phenomenon. Before 700 B.C. the ancient Greeks had the idea of shaping a throwing implement with excellent aerodynamic properties to produce the discus, an early masterpiece of sports engineering that remains integral to modern athletics. In fact, throughout the ages the development of sport and technology, or the purposeful application of knowledge, have gone hand-in-hand to the point where now technology is a necessity in sport for assuring safety and fairness, measuring performance and contributing to performance improvements. In addition, without the development of modern information and communications technology there would be limited media exposure and global outreach to fans, diminishing awareness and participation and thereby changing the nature of the sports we know.

It is very challenging to find a scientifically satisfying way to classify all the technology related to or influencing sport, even just one sport like athletics, as a starting point. Any approach will uncover overlaps and therefore have weaknesses. For the purpose of this article on athletics the following two categories have been selected:

Technology with direct influence on athletic performance - This includes all technology that is used in competition and is, therefore closely linked to the rules of the sport. In addition, there is certain testing technology used to verify compliance with the rules and to ensure fair play included here. The scope of this category can be seen in the following list:

- Discipline specific equipment used by the athletes and regulated by the rules (spikes, javelins, poles, prostheses, etc.);
- Discipline specific facilities used by the athletes and regulated by the rules (tracks, throwing cages, landing mats, sand pits, etc.);
- Performance measurement technology ensuring the correct application of the rules (timing apparatus, measurement apparatus, wind gauges, etc.).

Technology with indirect influence on performance - This includes all technology used by the athlete for performance enhancement out of competition, for showcasing the sport in and out of competition, in education of athletes or coaches and for the setup of athletics facilities. Finally, in includes technology used to ensure compliance with anti-doping regulations in training and after competitions. The scope of this category can be seen in the following list:

- Training equipment (weight training machines, modified competition equipment, etc.);
- Nutritional products (proteins, carbohydrates or electrolytes);
- Athlete's equipment that is not regulated by the rules (clothes or some shoes);
- Analysis technology (movement analysis systems, dynamometric analysis devices, technology for doping control sample analysis, etc.);
- Medical technology (X-ray, MRT, therapy equipment, etc.);
- Media technology (computer animations, Skycam, Spidercam, mobile phone apps, video boards, etc.);
- Education (video, e-learning, computer programs, etc.).

These lists show that there is debate possible. For example, nutrition could actually have a direct performance influence in competition, especially in the endurance disciplines. Or, could we say that the use of video finish apparatus is only to increase the accuracy of judging or is it also a tool to enhance the spectator and media consumer's experience of an event?

What the lists do highlight is that the scope of technology's influence and impact on athletics is extremely wide. It could take volumes to explore the topic completely but, keeping in mind that the main aim of this overview is to provide a starting point for more detailed study, our focus here will be on the following: 1) the drivers of development in sport technology, 2) outlines of selected technologies from both of the classifications mentioned that have developed significantly in recent years and 3) a short discussion of the question of equity and fair play in the application of technology.

Drivers of Development

In the history of athletics there are numerous examples of the application of technology to increase individual performance, including the use of hand-held weights, or ***haltere,*** in the long jump, leather straps in the javelin throw, thick, porous soled shoes in the high jump and running shoes with 68 small or brush spikes. These mentioned are not allowed under current rules but that has not stopped athletes, their coaches and other stakeholders in athletics from being innovative and applying technology that has been accepted by the rules.

It is interesting that many of the technologies introduced to the sport have emerged from research and development in other fields such as aerospace, construction, defence, medicine, automotive, consumer electronics and information technology. Examples of "technology with a direct influence on athletic performance" include the synthetic or polyurethane running track, which has become the standard for high-level competition as it allows competition to take place in all weathers and facilitates faster times in the running events. Polyurethane was originally developed for use in the engineering, construction and automotive industries. Then there is the appropriation of glass-fibre composite materials into the design of vaulting poles, replacing the classic materials bamboo and steel used previously, revolutionising both the technique of the event and the results achieved. Glass-fibre technology also came from the construction industry where it was developed for use as insulation.

Looking again at the history of the sport, we see that technology has been used to try to ensure fairness or equal conditions in competition: the angular set-up of the landing area in the throwing events, based on basic geometry, was considered in the design of ancient stadiums and a complex starting apparatus was used in antiquity to avoid false starts in running races. A study of the modern IAAF competition rules will reveal detailed descriptions of equipment specifications or arena dimensions that are evidence of efforts with the same intents. In fact, even taking into account the experiences with tracks and vaulting poles, the IAAF has normally been hesitant in permitting technological innovations that were simply targeted towards maximising results or could cause a fundamental change in a discipline. However, it has encouraged the introduction of technology to increase safety, reduce the possibility of injuries or improve the judging accuracy: landing mats for the vertical jumps, throwing cages, electronic timing and distance measurement devices, starting blocks with false start detection apparatus, etc.

Away from the athletes themselves, the needs of spectators and media audiences are very important factors in the development of technology linked to all sports. In modern athletics stadiums we see the needs of spectators addressed through the use of large LED (light emitting diode) video screens, high-quality sound systems and on-field scoreboards to name a few technologies in our classification of "technologies with indirect influence on performance". Television created a revolution in how non-participants consume sport and there has been a constant development here driven by the need of media providers to gain their own competitive advantage: think about "instant replay", "slow motion", overhead and trackside cameras, graphic presentation of results and other information, specialist sport channels on satellite or cable networks, etc. In many team sports, the referees carry microphones for the benefit of the stadium and TV audiences, in Formula 1 racing small cameras show the viewer exactly what the driver is seeing and in curling viewers can listen into the conversations between players on the ice, enhancing the viewer's experience as they get inside the technique and emotion on the field of play. The Internet will only add to this evolution with smart phone applications, real time statistics, social networks, tweets and blogs, all designed to bring fans closer to performers and increase loyalty, especially in team sports.

Finally, there are the commercial interests linked to supplying participants. User innovation and requirements are often the driving forces behind technological advances and manufacturers are interested in these advances, which they equate to new products and profitability. Inventive practitioners have started many new and extreme sports (windsurfing, skateboarding, mountain biking, etc.) by creating their own equipment or modifying existing resources and then sharing their discoveries with others to benefit from and build on. This, in turn, has led to the development of existing industries or even new industries to supply consumes. In athletics for example, both elite and recreational runners have created a demand for greater performance in running shoes in terms of comfort, weight, durability and injury prevention. Nowadays consumers are able to provide manufacturers with almost instantaneous feedback leading to yearly, if not more frequent, product upgrades. The industries and giant companies that have grown to produce sport shoes, clothing and other equipment have, in turn, helped to develop sport through the modern marketing and sponsorship system.

Technologies With Direct Influence on Athletic Performance

The list of ways that technology is used to directly impact athletics performance is potentially very long. In the sections that follow we have made a selection of those that are of particular interest.

Tracks / Surfaces

Already mentioned above, the running track, which defines the look of the sport of athletics, went through a revolution with the introduction of polyurethane surfaces in the late 1960s. Until then cinders or grass were the most common surface materials, even for high-level competitions. The cost of constructing a synthetic track is significant, especially in developing countries, but this must balanced against the fact that proper maintenance of the older surfaces was a time-consuming art form and the many stories about weather-created differences in conditions between different parts of tracks, even between adjacent lanes, that affected the results of races. Now the consistency between tracks, and the same track on different days, varies much less than in the past. The same synthetic surfaces can be used for indoor facilities. The generally greater ground force reaction provided by these surfaces has led to improved results in all events. On the downside, the harder tracks have been associated with a greater risk of overload injuries.

Starting blocks

Australian Charlie Booth and his father are widely credited with the 1929 invention of the starting blocks used in sprint races. Prior to that, athletes would use small trowels to dig foot holes that provided them with a better push off at the start of the race. Over time, starting blocks have been made from different materials, starting with wood and steel then progressing to the lighter aluminium. The front-to-back spacing and inclination of the footplates are adjustable and, in some models, even the width between the footplates can be selected. First created with the aim of increasing performance, the starting blocks used at high-level competitions now incorporate speakers that ensure that the sound of the starting gun reaches all competitors in a race simultaneously and sensors to detect the athletes' initial movement or reaction time. The reaction time, which is used to indicate a false start, can be communicated instantly to both the stadium spectators and TV audiences

Spikes

Spiked shoes are not a new technology as they have been an indispensable piece of equipment in the running and jumping disciplines since the 1860s. Usually spiked shoes are very light, which reduces the energy effort during the leg movements, but their main purpose is to provide increased traction. They have been developed together with general sport shoe technology from the 1920s. led by manufacturers including Addidas and Puma in Germany, Asics in Japan and Nike in the USA. The main changes in recent years have been in the materials used as synthetic fabrics and plastics have replaced leather and other natural materials. While the number of spikes in the shoe is limited (a rigid or semi-rigid spike plate is allowed to contain between 3 and 9 spikes), the shoe may not be designed for any additional assistance. Some shoes have spikes in the rear (e.g. in the high jump). In the spikes for high jump the thickness of the sole is limited to 13mm.

Timing equipment

The first Olympic Games at which fully electronic timing equipment was used were in Munich in 1972. However, even as early as the 1932 Games times were measured electronically with an accuracy of 0.01 sec. Hand-timing has been gradually phased out, first at the highest level competition and then to the point where, nowadays, electronic timing is the norm for serious competitions at senior level and in many other cases in developed countries (the cost of electronic timing equipment the training of operators remain issues in many less developed countries and even at the local level in developed countries). This change has affected performance statistics as the records based on electronic timing are certainly more reliable but usually slower than hand times by a significant 0.23 sec on average. Today video based systems where the timing and the photo finish are synchronised have replaced the initial electronic systems. These greatly facilitate the judging of sprint races. The timing equipment is also connected directly to the starting gun and a false start detection system. False starts are automatically detected when the reaction time of the sprinters (certain pressure against the starting blocks) is at least 100 ms or slower.

Wind gauges

Record performance in athletics competitions can not be accepted if the tail wind exceeds a certain value. The maximum limit is 2.0 m/s across all disciplines (with exceptions in the combined events). Modern wind gauges work with an ultrasonic sound (so called sonic anemometers) that measure the sound waves through the air between pairs of transducers. As a sound has a typical velocity in air, any differences to this standard can be measured and therefore determine the degree of movement air.

Distance measurement systems

In the throws and horizontal jumps electronic distance measurement has become the norm at high-level events. These systems utilise lasers, reflectors, simple geometry and computers to produce accurate measurements quickly. This makes a big difference in the operation and presentation of competitions, especially those that are shown on television where waits for the results of an effort must be as short as possible to retain the interest of viewers. Again, there are issues of cost here that affect developing countries.

Vaulting poles

No technological advance has changed an event as dramatically as the introduction of glass-fibre poles in the late 1950s. The main reason for the effect of the material on the performance is the ability of glass-fibre to store potential energy generated in the approach and take-off phases and then release it back to the athlete during the jump. The subsequent catapult effect has led to the men's world record advancing from 4.80m to the present 6.16m by Renaud Lavillenie (FRA). The most frequently used materials are E-glass and S-glass. For some years the lighter carbon fibre has been used to reduce the pole's carry weight so the athletes can run a higher velocity in the approach.

Landing Mats

Innovation in landing mats for the vertical jumps has meant replacing the piles of sand or saw dust previously used with synthetic foam encased in a poly-vinyl chloride (PVC) cover. This has greatly increased the safety of landing, making possible both the substantially greater heights in the pole vault we see today and a major change in the technique of high jump. The flop technique, developed by Dick Fosbury (USA) and others in the mid-1960s, would not have been possible without the possibility of the jumper landing injury-free on the back or neck.

Javelins and Hammers

Although not as dramatic as in the pole vault, the design of javelins and hammers have evolved in recent years, driven mainly by safety concerns. The design of the javelin dates back to the beginning of the sport in ancient Greece. For a long time, javelin makers sought to maximise the distance a javelin would fly by adjusting the aerodynamics and placement of the implement's centre of mass and improving the material of the implement to reduce vibrations in flight. However, when Uwe Hohn (GDR) threw 104.80m in 1984 concerns were raised about the distance that could be achieved with a deadly implement in the confines of modern stadiums. In 1986, new specifications were introduced for the men's javelin and the centre of mass was shifted 4cm to the front. This reduced the flight distance and helped judges in determining the exact landing point (see BORGSTRÖM, 2000 and BREMICKER, 2000). Similar changes were made to the women's implement in 1999. The changes in both cases meant that the record lists had to be started again and throwers had to make certain adjustments to their techniques.

In the hammer throw, improvements in technique and training methods have meant that modern elite hammer throwers are capable of launching the implement at higher velocities than throwers in the past, increasing the dangers associated with the event. In addition, there have been incidents at events that confirmed these concerns. The situation has been addressed through changes to the specifications of the hammerhead, wire and handle (see WILSON, GUY & MATRAHAZI, 2006) and an evolution in the regulations linked to the landing sector and safety cage design. While the safety of the throwers, officials, spectators and others have undoubtedly been improved by the various changes, these not have not led to a significant impact on performances in the event.

Technologies With Indirect Influence on Athletic Performance

As with the sections above, the list of ways that technology indirectly impacts athletics performance is potentially very long so, again, we have made a selection of just a few that are of special interest and have developed in recent years.

Running shoes

Perhaps the piece of athletics equipment that has received most attention in both the sport and general media is the running shoe. Replacing the leather shoes previously used by runners, rubber-soles shoes were first mass-marketed in the USA as canvas-top "sneakers" by Keds in 1917. In 1972, Bill Bowerman, the athletics coach at the University of Oregon in the USA, made a technical breakthrough by shaping a rubber sole in a waffle iron in his kitchen. This started a revolution in running footwear that has not only impacted the training of performance-oriented athletes, it also helped to create the so-called running boom, bringing tens of millions of participants into the sport of athletics and greatly expanding the sport shoe industry.

Laser velocity measurement systems

Previously, kinematic analysis of running events was made with high-speed film or video techniques, but the newly developed laser diode system LAVEG (LAser VElocity Guard – JENOPTIK Technologie GmbH, Jena, Germany) opens up new prospects in this area. The distance-time and velocity-time functions as well as individual kinematic parameters of a motion are recorded in on-line mode and are immediately available. The total amount of the equipment involved is considerably reduced compared to video or film techniques and the specific advantage of the LAVEG system consists in the fact that its accuracy does not depend on the distance between the object measured and the measuring device. The analysis of performances using the "analogous" LAVEG measurement system not only helps to identify the performance differences between the athletes, but can also help to answer questions that lead to improvements in training programmes.

Video analysis systems

Advancements in the technologies around video cameras and computer software have lead to the development of a number of valuable coaching aids. Companies such as Coaches Eye, Nac Sport, Sportec, Dartfish and others offer systems with a variety of features that allow the coach to accurately analyse videos they make of an athlete's movements and then use this data as the basis for providing feedback. This ability greatly increases the possibilities for both new and experienced coaches to really see and understand a movement and guide the development of technique. Entry-level video analysis systems are even being offered as smart phone applications.

Other movement analysis systems

The tools available to coaches also include instruments that can precisely measure forces and other aspects of movement, including force plates in laboratories, inertial sensors worn by athletes and portable LED systems. One commercially available product, the Optojump system (Microgate S.r.l, Bolzano, Italy) combines video technology and software with a system of transmitting and receiving bars, each with a row of LEDs that make it possible to measure flight and contact times during the performance of a series of jumps with an accuracy of 1/1000 sec. It can also be used for sprint tests and talent diagnosis. The dedicated software makes it possible to obtain a series of parameters connected to the athlete's performance in real time with maximum accuracy and then track changes in an athlete or group over time.

Global positioning systems

A fourth example of the performance measurement technology that has recently embedded itself in the sport is the increasing use of global positioning system (GPS) technology. First developed for military use, this technology is now being applied for performance and training diagnostics to measure variables such as position, distance covered, velocity and acceleration. These devices are used by both performance-oriented athletes and by recreational runners, often in conjunction with the computing and communications power provided in smart phones, as an aid to controlling and evaluating training and for sharing information with others.

Training management systems

Our final example is of software that will assist coaches and athletes to monitor all aspects of training, such as diet, rest, energy levels, etc, that could affect performance. The different products have different capabilities and functions but generally they enable the users to record and manage large amounts of data for multiple athletes, to track these over time and to show them in tables or charts. Their impact is that they all move the management of the training process beyond the hand-written training diary that was the norm until a few years ago. They are available as downloadable software, on web-based applications and even as smart phone applications.

Fairness and Equity in the Application of Technology

Philosophically speaking, differences in the quality of equipment should not determine the athletes' competition results. The conditions for competitors should be equal and performance should be based on physical, mental and technical abilities of the athletes only (see JULIN, 1992). In principle, if the competition regulations are defined in sufficient detail, the control mechanisms function properly and the competition is widely communicated, the possibilities for athletes to gain an advantage through competition equipment become very limited.

However the ideal of equality of opportunity could be questioned if we consider the access to equipment during the athletes' preparation and training. The same goes for other technologies or applications of knowledge. There are already examples where this is problematic. In disabled sport it is now clear that the design and construction of the blades used by amputee runners and jumpers, not really competition equipment but more a part of the athlete, can have a significant effect on the sporting results, and sometimes it is the deciding factor. In such cases the competition could be said to be between the prosthesis manufacturers and not the athletes.

It is at least theoretically possible for competition rules to control such issues, even if keeping up with the pace of change in technology is a challenge. Harder to manage is where manipulations are possibly legal but of questionable or disputed ethics. For example, there are a number of commercially available hypoxic tent systems for simulating the conditions at high altitudes and providing an ergogenic aid for endurance athletes. Putting aside the question of availability and cost, in some countries the use of such devices is considered doping but in others it is not. Could training at high altitude also be considered a form of doping? What is the moral difference? Then there are cases in sports in which visual acuity is important and athletes have had surgery to improve eyesight to better than normal and in sports where throwing power is critical and athletes have their ulnar collateral ligament surgically shortened, presumably to address an injury, but end up being able to throw harder than before. Even more difficult are situations where it is not currently possible to detect the application of sophisticated technology, for example manipulations of an athlete's genes.

At the high-performance end of sport, research has provided valuable information on training or technique that affects performance. To take advantage of the findings from such research, sophisticated systems for talent identification, biological and psychological monitoring of the athlete, nutritional support and recovery/regeneration all play an important role. But do all athletes, particularly those in developing countries, have equal access to results of such research or to the resources needed to act on the findings? What about education, itself a form of technology, for coaches? Is that equally available?

The access to technology clearly illustrates existing inequality and the advantages for athletes from countries with greater resources. It is no surprise that developing countries are generally less successful in sports where more technology and engineering and more resources are required such as cycling, bob sledding, sailing or rowing.

The big question is: how much more could or should governing bodies like the IAAF, the International Olympic Committee or other agencies do to level the playing field in terms of technology in sport?

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