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The impact of technological advancements on enhancing high-performance metrics in sports science

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Abstract

Innovations in technology have had a big impact on sports and exercise science. Without technology, modern sports and the various subfields of exercise research would be unthinkable. Technology use is constantly tinged with ambivalence and annoyance. Ironically, a major factor in the widespread use of technology is people's inability to fully understand its scope, complexity, and uncertainty about the usefulness of some technological advancements in sports. In reality, sports technology has greatly impacted the study of sports and exercise science. It's important to remember that technology has fundamentally altered our understanding of the athletic physique. Thus, this review explores how technology affects sports performance, including technological concepts, the aim of improving performance, different types of sports technology, and its advantages and disadvantages.

Keywords: Sports technology, rehabilitation, sports performance, ICT

Introduction

To get the best results on the pitch, modern sports combine advanced analytics, artificial intelligence, and natural athletic abilities with progressively complex technology. According to Barr (2016) ^[1], technology is only one of many variables that contribute to the success of sport, which excites people as a triumph of human endeavour. Sports have historically used technology in various ways, and elite sports particularly benefit from it. Since there are numerous definitions of technology, some individuals believe that it cannot be accurately described. On one hand, it refers to science and logical reasoning and includes every small gadget ever created. According to Cave and Miller (2015) ^[8], technology is making it easier for professional athletes, amateur runners, and armchair watchers to engage in the sport. Not only does technology exist outside of us, but it also exists inside of us. On any given day, the residue of painkillers and multivitamins remains in our bloodstream, a testament to the fact that so numerous athletes have been technologically enhanced or made more technologically advanced by contact lenses and other medical procedures. Technology is any intellectual, procedural, or material aspect of modern sport and exercise science that aims to progress (Feenberg, 1999, Miah, 2004) ^[12, 20].

The broad term covers everything from different viewpoints on human anatomy as technology to new advancements in running shoes and eyewear. Athlete testing (diagnostics), better sports equipment through better engineering and design, and expanded use during competitions were the main goals of technology use in sports before the digital age. Great examples of early sports technology include the instant replay screen (1955), physiological testing equipment (1920s), photo finishes (1888), and the first use of electronic timed touch pads for swimming (1957). Both as a necessary element of some sports (such as motorsport) and an instrument to improve performance in others, technology does play a big part in modern sports. Media broadcasting and communications, performance analytics, facilities, competition forms and adjudication, clothing and wearables, and sports gear are some examples of thematic applications of technology. Consequently, the relationship between technology and sport has been somewhat turbulent over time (Bass & Eynon, 2009) ^[4]. Initially, technology and sports didn't seem like the most logical pairing (Turner, 2013) ^[28]. Numerous tasks are consolidated into a single small device because of the rapid integration of technology, sports, and the equipment needed to participate. Current symbols, however, would not have developed as they

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have if sports science had not been specialised and customised to enable athletes to thrive in practical ways. Sports is advancing quickly thanks to technology, which also improves performance in other areas.

As a result, technological applications offer a range of duties, such as more effective training, stimulations, player administration and tracking, validity of results, greater spectator observation, performance development, and injury avoidance (Busch, 1998) [7]. Technology is a tool used by athletes to try to enhance their training and competitive settings to improve their overall athletic performance. It is thought of as a technological tool or method for accomplishing specific objectives. Consequently, the study investigates the impact of technology on sports performance.

1. Types of performance theories related with technology

Feen Berg (1999) [12] one of the most well-known technology philosophers, expressed his theoretical positions on technology. In essence, they serve as lenses through which we might perceive the consequences of innovation. Depending on how they are seen, technological advancements can have either positive or negative effects. Many fundamental criticisms of technology as ideology were noted by Heidegger (1998) [16], wherein advancements are sometimes seen as controlling their users by fostering dependence and warping human relationships, rather than being an aide of man. As a result, the theories are now Instrumentalist, Substantive, Determinist, Dynamic System and Critical Theory.

1.1 Instrumentalist theory

The instrumental theory of technology is the most widely accepted. Its foundation is the idea that technology is a "tool" that can be used to meet the demands of its users. Technology is viewed as "neutral," meaning it lacks any independent content for evaluation. However, what would the concept of "neutrality" in technology mean? According to instrumentalists, all technology is a tool that is primarily controlled by humans and can be used in either a beneficial or harmful way. They view the development of technology as an evolutionary process rather than a series of revolutions or technological leaps (Levinson, 1996) [19]. Think of social circumstances and human desire as the primary forces behind change. The instrumentalist perspective holds that technology is a neutral instrument with unique functions and techniques. Instrumentalists believe that a long period of slow, steady progress will eventually lead to technological advancement. The instrumentalist perspective, using technologically advanced tennis racquets as an example, views contemporary lightweight racquets as just another tool in the constant pursuit of better performances. Similar to other technologies, athletes are just using whatever resources are at their disposal to exceed their competitors.

1.2 Substantive theory

Despite the instrumental theory's appeal to common sense, a minority viewpoint contests the technology's objectivity. The most well-known examples of substantive theory are from the works of Ellul (1964) [11] and Heidegger (1998) [16], who both contend that technology is a new kind of socially constructed system that restructures the entire social environment as an object of control. This system is distinguished by an expanding dynamic that eventually engulfs every pre-technological outpost and moulds all aspects of social life. The substantive hypothesis is a different theoretical viewpoint that holds that technology is neither unbiased nor entirely

within human control. According to substantive theory, the effects of technology on people and the environment are more significant than its stated objectives. Concerning how it would perceive the new tennis racquet, this viewpoint is a negative one (Tenner, 1996) [26].

Newer racquets would be seen to carry certain ideals associated with them. For instance, even though the goal of the racquet architects may have been to create a better, lighter racquet that would enable players to smash the ball harder and quicker, the results of this new design appear to place more emphasis on speed and power than elegance. The determinist and the substantive positions both believe that once technologies are in use, they can take on a life of their own and that it will become more and more difficult to return to more "natural" performance-enhancing methods. Technology will ultimately determine what kinds of sports we play, what techniques we use to play, and who is most qualified to participate.

1.3 Determinist theory

Technological determinists believe that technology is the primary driver of societal change and perceive it as an autonomous force independent of direct human control (Chandler, 1995) [9]. Determinists believe that technological advancement is discontinuous. In other words, they do not see technological growth as a gradual, evolutionary process but rather as a continuous succession of revolutionary steps forward (Kumar, 2001) [18]. Alvin Toffler's book *Future Shock* from 1971 is one of the most often mentioned deterministic writings. He succinctly summarises the determinist worldview, writing, "Behind such prodigious economic facts lies that great, growling engine of change technology" after presenting multiple examples of faster economic expansion. Although he notes that other factors contribute to social change, he continues by saying that "technology is undeniably a major force behind this accelerative thrust" and that "by now the accelerative thrust caused by man has become the key to the entire evolutionary process of the planet." Technological determinists sometimes disagree on the ethical consequences of technology, even though they all believe that technology is a transformational and autonomous force. Determinists usually hold either utopian or deeply dystopian opinions about technology, according to Kaplan (1996) [17]. Utopian determinists believe that technology is a positive and uplifting force that will eventually eliminate most of the negative aspects of human existence. They contend that technology is advancing civilisation closer and closer to a perfect world. In conclusion, this techno-utopianism implies that technological advancement is neutral and supports a technologically determinist interpretation of history (Robins & Webster 1999) [23]. According to dystopian determinists, technology is an unavoidably morally repugnant or dehumanising force that will ultimately result in the moral, intellectual, or physical annihilation of humanity.

According to the determinist perspective, technology is neutral or devoid of values, but it has evolved into an independent or self-directed system. Using the tennis racquet as an example once more, the determinist viewpoint would view the newly developed racquet as a tool that, once introduced into the sport, would have a "life of its own" and force sportsmen to use it whether they desired to or not. By the racquet's very existence, if one athlete decides to utilise it, others will be compelled to follow suit. Additionally, if the newly developed racquet offers high-velocity servers an even bigger edge, this one piece of technology might alter how

tennis is played for all time.

1.4 Dynamic systems theory

In the movement sciences, the dynamic systems theory has become a strong theoretical foundation for modelling athletic performance. In light of this, the human movement system can be viewed from the perspective of dynamical systems as a highly complex network of interdependent subsystems (skeletal-muscular, circulatory, nervous, respiratory, and perceptual) made up of a large number of interacting parts (oxygen molecules, muscle fibres, connective tissue, metabolic enzymes, blood cells, and bone). According to the dynamical systems theory, movement patterns develop through universal self-organisational mechanisms that are present in biological and physical structures (Williams *et al.*, 1999) ^[31]. According to dynamic systems theorists, the creation of coordinated structures or transient collections of muscle complexes significantly reduces the biomechanical levels of freedom of the motor system (Turvey, 1990) ^[29]. The motor system's decreased dimensionality and complexity promote the growth of functionally favoured synchronisation or attractor states to facilitate goal-directed actions. The dynamic systems are highly organised and stable within each attractor area (an attractor's immediate vicinity), resulting in predictable movement patterns for certain objectives.

However, variation across many attractor zones enables adaptable and flexible motor system function, permitting each person to freely explore various performance environments. Because of the contradictory link between stability and variability, experienced athletes can maintain their level of motor output while changing it throughout the competition. Movement behaviour variability enables performers to investigate task and contextual restrictions to gradually develop stable motor solutions and improve motor learning. A more thorough explanation of the stability-variability dilemma in skill learning is given by Handford *et al.* (1997) ^[15]. Many prominent researchers have long expressed the worry that sports biomechanics research demands to go from a descriptive to an analytical level (Elliott, 1999) ^[10]. According to Bartlett (1997) ^[2], the majority of performance-focused sports biomechanics research lacks a strong theoretical foundation and seldom refers to motor control theory, general biomechanical principles, or the underlying physical laws that govern them. Due to its multidisciplinary approach to the processes of coordination and control in the human motor system, dynamic systems theory may thus offer a useful theoretical framework for performance-driven sports biomechanics research (Glazier, Davis & Bartlett, 2002) ^[13].

1.5 Critical theory

Modern technology represents the ideals of a certain industrial civilisation, particularly those of its elites, and is no more unbiased than mediaeval churches or The Great Wall of China. Technology criticism acknowledges that we should ultimately be in charge of technology. Feen Berg (1999) ^[12] encourages a shift towards a technology theory that is more sceptical. Critical theory contends that technology is an "ambivalent" process of progress poised between several possibilities rather than a thing in the traditional meaning of the word. This "ambivalence" of technology, which differs from neutrality, is characterised by the importance it accords to social norms in the development of technical systems as opposed to only their application. This perspective sees technology as a battleground rather than a destiny. It is a social battleground; however, a better metaphor may be a

parliament of things where civilizational options are discussed and chosen. Technology's politics and values are seen in a critical theory. Therefore, sceptics of the proliferation of new tennis racquet technology would encourage more candid discussions about the politics of the game and ponder issues like "Who will have access to this equipment?" "Who decides whether a particular gear should be legal or prohibited on the professional tour?" and "What long-term effects will new racket technologies have on the game?"

2. Types of sports technologies

Coaching, sports psychology, and contemporary sports are all changing as a result of technology. Modern technology is used to enhance performance in a wide range of sports, including cycling, tennis, skiing, football, speed skating, surfing, squash, swimming, golf, running, and many more. Today's sports use technology in countless ways, and every new development has the potential to be beneficial. Sports technology is divided into five categories using a basic typology; however, the categories are not exclusive of one another, and often the same technologies may fall under more than one category. Technologies that fall under this category include self-optimization, database, motion, landscape, and rehabilitative. However, sports have not yet been impacted by certain technology. We can better comprehend the technology options that athletes will eventually have exposure to and how they will impact their performance in sports by researching a wide range of sports technologies (Omeregic, 2016) ^[21].

2.1 Landscape technologies

This kind of technology impacts the athletic environment, particularly how spectators view sporting events. One significant advancement in landscape technology is the rise of modern multipurpose sports complexes furnished with artificial grass, Mondo tracks, soaring cameras, collapsable domes, and Jumbo Tron screens. According to Bates (1996) ^[5], modern athletes are strongly connected with technologically advanced athletic environments. Track and field athletes adjust their tactics because they can observe their competitors on the Jumbo Tron as they get closer to the finish line. Some even throw the discus and javelin. The frequency with which the high-tech stadium attempts to mimic the atmosphere of stadiums with older designs is astounding. Like other facets of life, exercise and sports science have been greatly impacted by technology (Winkler, 1996) ^[32]. In reality, it is hard to imagine today's modern sports and the various subdisciplines of exercise science without the modern technology that is taken for granted. Can you imagine conducting biomechanical research without computers, determining VO₂ max without underwater assessment, or getting ready for track and field contests at the Olympic level without the aid of modern training and evaluation methods? Consider watching athletic events on TV with only one or two camera angles. Using 24 satellites and base stations that serve as points of reference, the global positioning system (GPS) determines geographic coordinates and monitors an action precisely. Using a handheld GPS device, for example, when hiking provides information on altitude, distance, duration, and average velocity. A graph illustrating the slope and decrease of the landscape is also included.

Activity levels can be measured and monitored using global positioning systems and accelerometers (Schutz & Herren 2000; Rodriguez, Brown & Troped 2005; Troped *et al.* 2008) ^[25, 24, 27]. As GPS receivers become more widely available and

affordable (in laptop computers and cell phones), they may be used more frequently to track and promote physical activity. The field of sports and exercise, research has been profoundly impacted by the influx of sports innovations, but perhaps more importantly, technology has begun to change the athletic body in numerous ways. On the contrary, technology's constant presence has made it harder for us to fully understand the scope and magnitude of its effects and has made us more uncertain about how different technological advancements should fit into our lives.

2.2 Rehabilitative technologies

The medications and methods used to treat minor to major wounds are examples of rehabilitation technology. They also include drugs used by healthy athletes who want to counteract the harmful effects of their exercise regimens. Professionals in sports training or sports medicine use these technologies, which are frequently seen at athletic training facilities and clinics. Rehabilitation therapies include any kind of anti-inflammatory drug, including acetylsalicylic acid. As rehabilitation technologies, athletes with painful muscles and joints can also use whirlpool devices and ultrasound. By introducing currents into the wounded area, more recent developments like electrical stimulation and slim improve blood flow and improve the healing process. In addition to mechanical and computerised treatment, acupuncture and chiropractic adjustments—which are not fundamentally technical in the traditional sense—are used. Rehabilitation technologies can also be considered performance-enhancing tools since they allow athletes to practice and perform at a level they would not otherwise be able to.

2.3 Technologies for self-optimisation

For many people, this technology is the most apparent and widespread since it can significantly and often permanently alter an athlete's physical or mental composition. Among these technologies, the usage of illegal performance-enhancing drugs is the most well-known. Self-technologies include other controversial advancements in sports. Sports psychology treatments, bionic or prosthetic limbs, genetic engineering, and healthcare services are examples of additional self-technologies. Some self-optimisation technology, such as the bionic prosthetics developed by Oscar Pistorius, can be seen as a part of sports in the future. Scientists working to tweak genes to create a vaccination that builds muscle are already aware of the implications of their work for sports. Consequently, a human genome project that maps all of the genes in the body is a general modification of athletes or gene doping, which can enhance muscular growth. It's unclear, though, if the long-term consequences are dangerous. According to this perspective, technology is morally neutral. Its nature is neither good nor destructive. Rather, what matters is the goal or purpose, for which technology is merely a tool. While many people who are unable to continue their daily lives demand equipment like a wheelchair or a prosthetic device (Haisma, van Derwoude, Slam, Bergen & Bussmann, 2006; Pasquina, Bryant, Huang, Roberts, Nelson & Flood, 2006)^[14, 22], advancements in this technology, like an energy-storing prosthetic foot, make a lower limb amputee's gait faster and more efficient (Brodtkorb, Henriksson, Johanesen-munk & Thidell, 2008)^[6].

2.4 Optimised motion technologies for performance

It refers to the instruments and methods used to assess the form and performance of an athlete's body. Videotape

analysis is the most common method, while there are much more sophisticated systems that provide comprehensive computerised data on an athlete's biomechanics. Like other types of technology, movement technologies are often undetectable in competitive settings. In addition to helping to improve the athlete's present technique, the knowledge generated by movement techniques may also allow for conceptual or style changes that allow a professional athlete to compete in a mechanically and artistically unique way. Sports have changed significantly since the invention of technology. Goal-line technology, or high-speed video processing, may change the way referees respond when a ball crosses the goal line without them being there or visible.

The arrival of (small) digital cameras, wireless connections, and mobile computing devices has completely changed how coaches and sports psychologists interact with individual athletes and teams. Real-time biometric player data generated by individual body-worn sensors can be used to assess a player's progress over time or to inform coaching choices during a match. However, Warburton and colleagues (2009)^[30] found that simulation cycling significantly elevated steady-state heart rate and energy expenditure when compared to conventional cycling at constant, submaximal workloads; ratings of perceived exertion were similar for both types of cycling.

2.5 Database technologies for improved athletic performance

It uses computational technology to give coaches and players access to all the data they may require about themselves and their opponents. Database projects have had a substantial impact on how many, if not most, professional athletes and coaches do their business. Information feedback technology (like a Nike GPS sports watch or a Polar heart rate monitor) allows individual athletes to continuously track their changes in important physiological and performance variables. Even when people aren't aiming for an Olympic gold medal, technology can be helpful and encouraging in their career goals. It can motivate people to maintain a consistent exercise routine or to heal from an injury.

It has long been a fantasy of limiting human mobility by using special training methods and inherent advantages. The degree of competition in modern sports, especially elite athletic performance, has been close to the limits of human nature. The extensive use of modern science and technology, such as computer advancements, genetic engineering, energy technology, information technology, and modern science and technology theories, has fully comprehended the wide range of sports-related functions and effects. As a result, training techniques have been updated, site equipment has been upgraded, the nature of sports training environments has changed and improved, and the magnitude of competitive sports has expanded drastically.

Conclusion

Sports have transformed into contemporary technology accessories as an exclusive social trend. Sports have evolved as a result of technology since it greatly affects how athletes live their daily lives and how their physical attributes appear to be. Technology is therefore constantly changing the way sports are played, how injuries are treated, and how performance outcomes are improved. Sports technology has been engineered by humans to support their desired goals or intended results in any particular sport. Using this technical approach, athletes attempt to improve their training and

competition settings to improve their overall athletic performance. It involves knowing how to use the newest technology and specialised tools that accomplish tasks faster. For coaches and athletes to make thoughtful choices about how sports technology affects their performance, they must be well-versed with the latest technological advancements concerning their sport.

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