The impact of technology on elite sports performance

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Abstract

The use of technological applications is now widespread across many major sports science disciplines and the adoption of these tools to gain a 'competitive advantage' is an increasingly important feature of elite sports. These innovations have shaped the way data is collected and processed, how information is relayed between coaches and staff or to athletes, and has had a big impact on the way in which athletes are monitored in the daily training and competition environments. This review highlights and provides examples of some of the latest technologies for data collection and processing, feedback methods and training tools. We finish by discussing some considerations for sports scientists and coaches before implementing new technologies.

Keywords: Technology, sport, performance, feedback

Introduction

The field of sport and exercise science has become highly technical, challenging applied scientists and coaches to match his or her practical application of knowledge with the constant arrival of new technologies. The heavy reliance on technology may be attributed to the inherent desire to gain an advantage over the opposition in elite and competitive sports, in order to provide additional information that can be fed back to coaches and/or athletes.

Technology has been philosophically defined as any physical instrument(s) that can be used for problem solving (Soltanzadeh, 2015). Based on this definition, the use of technology is not new to sport, nor does it purely suggest the use of expensive gold standard measurement tools. Rather, it suggests technology involves a moving scale from low cost and easy to use measurement tools (e.g. goniometer, hand held camera) up to expensive and sophisticated systems (e.g. isokinetic dynamometers or three dimensional motion systems). Because of the large array of tools available to coaches and applied sport scientists, this choice, paired with the increased desire to collect and process information rapidly and at minimum cost to the user, may increase the chances of selecting the fad option, rather than an appropriate tool. A number of technology in sport reviews have previously been published (e.g. a systematic review of global positioning systems (GPS) and micro-technology sensors in team sports, Cummins, Orr, O'Connor & West, 2013; a review of vision-based motion analysis in sport, Barris & Button, 2008; video use in coaching, Wilson, 2008; integrated technologies such as GPS, accelerometer and heart rate monitors in team sport, Dellaserra, Gao, & Ransdell, 2014). In differentiating from previous reviews, our aim with this manuscript is to provide an overview of some of the new sport technologies available, and open up the debate of how the use of technology can improve or impair performance.

Developments in data collection

Certainly, one of the major benefits for scientists has been the progression from laboratory-based settings to those real-time in the field. The ability to know increasing detail about individual athletes and teams during competition has been made available by a myriad of technological progressions over the past two decades. Sports scientists across chief disciplines have requisitioned hardware and software innovations in order to specifically develop better tools and improve methods to capture and process player performance data. These advances have allowed researchers and applied sports scientists to more readily measure key aspects of performance in the field setting, which were often previously constrained to the laboratory.

The fundamental benefit of this change is that it has increased the capabilities to collect information in an ecologically valid setting, without undue pressure on analysts. Perhaps one of the most notable progressions in the area of data collection and processing methods, involves computer vision. Computer vision uses algorithms to detect identifying features within video footage such as pattern or colour differences (Perš & Kovačič, 2000). This technique has gained interest in the areas of performance analysis and biomechanical assessment because of the ability to semi-automate the analysis of team or individual player movement, without affecting the players' environment. Examples of this type of technology can be seen in performance analysis systems such as Prozone (STATS, Northbrook, Illinois), used widely in soccer in England and European countries, SportsVU (STATS, Northbrook, Illinois), used in the National Basketball League in North America, and Hawk-eye (Hawk-Eye Innovations Ltd., Basingstoke, Hampshire, United Kingdom).

Computer vision systems typically require multiple cameras to be placed around the sports ground, and can require manual input of game events (Moeslund, Thomas, & Hilton, 2014). Whilst some game instances can be fully automated, challenges in the use of computer vision technologies to automate the capture of player movements are still present (Barris & Button, 2008). For example, capturing accurate player tracking data can be problematic when multiple players are gathered in a small area (Barros et al., 2007). Additionally, computer algorithms typically expect smooth movement, yet the dynamic nature of sports means players often change direction quickly and also frequently collide with other players. The combination of machine learning with computer vision to improve automatic identification of motion or game events will be highly influential to performance analysis in sports in the future.

Computer vision technology has also played a role in markerless motion capture developments in biomechanics and other sports sub-disciplines, with products such as the Microsoft KinectTM used as a low cost solution for motion tracking (e.g. Choppin & Wheat, 2013). Traditionally, three-dimensional biomechanical evaluation requires many markers to be placed over the body to identify the pose of each body segment. This process can be time consuming and can result in the participant feeling restricted in his or her movements. With markerless motion capture, computer vision techniques are used to identify and calculate detailed estimations of position and orientation (pose) of segments (Rosenhahn et al., 2006). The primary benefit of this technique is that it allows the athlete(s) to move more freely, without movement restraints imposed through wearing markers and marker clusters. Applied scientists are subsequently benefited by the reduced time required for participant preparation. Elite Form (Elite Form, Lincoln, Nebraska) is one such example that uses the Microsoft KinectTM cameras to provide real-time feedback surrounding peak and average power in common strength-training exercises in the gym environment. Nonetheless, despite promise, markerless motion capture solutions still require development in order to progress to a more acceptable level of accuracy in comparison with marker-based methods (Ceseracciu, Sawacha, & Cobelli, 2014). Given the benefits associated with markerless procedures, it is likely that this area will continue to improve.

A great example of the progression that can occur in sports through the application of innovative technologies drawn from other science disciplines includes the use of drones (unmanned aerial vehicles, UAV) for the collection of aerial game or event footage (Natalizio, Surace, Loscri, Guerriero, & Melodia, 2012, 2013; Sa & Ahn, 2015). The flight path of drones can be controlled via remote or smart-device applications, giving them the potential to offer more flexible and less arduous solutions than placing multiple fixed cameras around a playing field (Hammell, 2015; Ferreira, Cardoso, & Oliveira, 2015). Furthermore, device capabilities, such as tracking through GPS or combined sonar, computer vision and computer learning technologies, available in consumer market drones (e.g. Hexo+, Hexoplus, Grenoble, France; Phantom 4, DJI, Shenzhen, China; Airdog, Helico Aerospace Industries, Palo Alto, USA) gives rise to the possibility of drones being used as more than 'play-toys' for the creation of self-trailed personal videos, but tracking tools for performance analysis and other analyses drawn from game vision.

Finally, one innovation group, now commonplace technology for Post-Millennials, includes smart devices (e.g. smart phones and tablets). The advent of the iPad in 2010 (Harrison & Neumayr, 2010) sparked the use of applications (or "Apps"), which often run complementary to computer software packages. These portable hand held interfaces have become a fundamental tool for many applied scientists and coaches to aid in the setup of equipment, collection of data and/or in the provision of feedback. There are a number of examples of this, including Swift Performance's SpeedLight App (Swift Performance, Wacol, Australia) application, which aids set up and the recording of data; Coda (Sportstec, Warriewood, Australia), which allows real-time game analysis to be performed using an iPad, rather than requiring the analyst to sit behind a computer; or Siliconcoach Live Mobile (The Tarn Group, Dunedin, New Zealand), allowing you to perform basic two dimensional biomechanical analysis on videos you have stored online, or have recorded on your device. Smart devices and applications may provide clear advantages over more traditional technologies and, at the very least anecdotally, have provided improved opportunities for data collection and utilisation by coaches and athletes.

The collection of individual athlete and team based performance data has become commonplace in professional and elite sport. In general, information on player movement and team formations has been considered helpful to aid in the design and structuring of practice, and the tracking of performance. However, whether such applications and technology improves performance is ultimately dependent on how the information gained is used.

The next section will discuss how smart device applications and technology provides benefits and challenges in the way feedback is provided to athletes.

Developments in data feedback

Historically, coaches would observe and then relay information; he or she would provide feedback gathered from visual observation of an athlete's skill, relying solely on his or her ability to perceive changes in movement and interpret the results. Today, many coaches are challenged with a wealth of options relating to the selection of a feedback mode; he or she must decide which is the most appropriate per individual case (visual, auditory, haptic, multimodal), in order to ultimately improve performance. Consequently, the mode and schedule of feedback are crucial elements requiring consideration for improving sports performance.

Augmented feedback, that is feedback provided by an external source, is generally believed to effectively enhance motor learning (Sigrist, Rauter, Riener, & Wolf, 2013). New technologies have made it possible for applied sports scientists and coaches to extract this information from performances and relay this information to athletes at a rapid rate. One leading example relating to the speed at which feedback could be returned to athletes involves the production of ClipCoach (Sheffield Hallam University, UK). ClipCoach was developed prior to the London Olympics in 2012 as part of an innovation project partnered with Olympic sports. The system uses a series of machine vision video cameras and force plates to record the motion of the diver. High-speed video feedback of the dive is available to the coach and athlete immediately post dive, allowing both slow-motion review and dive comparisons to be made. The ClipCoach system drastically changed the way in which feedback was provided to Great Britain's divers.

The timing of when feedback is provided is a key concept within motor learning. Feedback can be classified according to the time point of its provision, with concurrent feedback being provided during skill execution, while terminal feedback is provided after skill execution (Magill, 2007). One of the major trends in sports technology has been centred on real-time applications and devices that have the ability to provide athletes, coaches or scientists access to immediate data. The scheduling of augmented feedback is perhaps one of the most studied aspects of feedback, yet understanding the intricacies of scheduling feedback is a challenging task confounded by task complexity, skill level and salience of task intrinsic feedback (Magill & Anderson, 2012). Coaches are increasingly calling for sport scientists to deliver real-time feedback, however, given the relatively new nature of these concurrent methods, knowledge surrounding the effects of this mode and the optimum schedule of real-time feedback may still be required.

Research conducted in this area lends itself to the positive effects of real-time feedback. Examples indicative of this have been provided in activities such as rowing (e.g. real-time visual feedback on kinematics shown to increase the kinematic consistency when compared to no feedback, Anderson, Harrison & Lyons, 2007), netball shooting and running (e.g. concurrent or real-time feedback led to learning and performance improvements, (Crowell, Milner, Hamill, & Davis, 2010; Helmer, Farrow, Lucas, Higgerson, & Blanchonette, 2010). Nevertheless, given fundamental motor learning knowledge relating factors such as how too much feedback can be detrimental to performance (i.e. if it causes the athlete to become reliant on the information), we suggest that more evidence on the effects of real-time feedback is required in this area.

Despite the increased flexibility of feedback methods now available, applied scientists and coaches must remain diligent and focussed in what material is provided back to the athlete(s). Intensive datasets have been made increasingly possible to collect, offering the potential for coaches, analysts or scientists to become overwhelmed and lose sight of the key performance variables. Coaches should remain focussed on the critical factors influencing a given performance. Phillips and colleagues suggest that feedback should be provided based on the following principles: 1) the selected variable must be relevant to improved performance, 2) the variable must be able to be controlled by the athlete and 3) measurement of the desired variable must be able to be accurately and reliably measured by the system or device being used (Phillips, Farrow, Ball, & Helmer, 2013).

Advances in the way in which feedback can be provided, and the immediacy of feedback that can now be delivered challenges coaches to ensure such technology is used effectively without diminishing any intrinsic feedback naturally available to athletes and without creating a reliance on feedback (see Salmoni, Schmidt, & Walter, 1984).

Technology and the training environment

Another area that technology has influenced sports performance is training and strategy. There are many examples that stretch across a number of sub-disciplines of sports science (e.g. GPS technology informing strength and conditioning; kinematic analysis and biomechanical intervention; game analysis and data analytics informing tactical decision making programs). This section will focus on the simulated training environment.

Changes to the standard training environment to include simulation of "game like" scenarios via augmented reality have become increasingly more feasible through progressive technology. The purpose of simulation and virtual environments is to aid training. It allows a supplementary training environment, where those needing additional work or injured players who cannot fully train, are provided with the opportunity to improve perceptual cognitive and perceptual motor ability. Examples of these tools include video-based decision making tools, virtual reality environments and simulated batting environments. Video-based decision making tools can be cost effective for teams and allow the coaches to use any game vision they have and select the most desirable options (e.g. above real time training, Lorains, Ball, & MacMahon, 2013), providing a high degree of flexibility to suit any team. Tools such as the Elite Decisions and Elite Recall iPad applications (Decision Science, Shepparton, Australia), used by a number of Australian football and Rugby League teams provides the option for team athletes to undertake this form of training in any location.

More advanced virtual reality environments allow athletes to be fully immersed in an interactive environment. This type of technology has been highly adopted by teams in the National Football League to supplement traditional practice methods, where the utilisation of virtual reality allows players to train without high physical impact loads, which may otherwise be faced if running through particular 'plays' during training. For example, the Minnesota Viking's used virtual reality to train their young quarterback. The process allowed the coach to be immersed in the same environment as the quarterback in order to point out correct reads and indicate mistakes. Other teams such as the Tampa Bay Buccaneers have used virtual reality to trial their offensive formations against the defensive formations of upcoming opponents (Bennett, 2015).

ProBatter (ProBatter Sports, Connecticut, USA) provides yet another example of how technology has influenced training environment in sports such as baseball, softball and cricket. ProBatter provides athletes with the opportunity to work on perceptual motor ability, by pairing a projected high definition video of a pitch with a projected ball. The paired video of the pitcher with the ball projection provides more information than the ball flight of the pitching machine alone. This technology attempts to provide important spatial and temporal information components of the pitch, allowing the coupling of perception-action. The simulator can throw the majority of pitching combinations, making the training tool diverse, and allowing players to train up skills without placing additional load on other players.

While such technologies have been widely adopted in training scenarios, understanding the limitations regarding their effective use is paramount. The ProBatter system for instance is limited in the fact that release always occurs in the same position, which is not true of real world pitching movement. In addition, Mann, Farrow, Shuttleworth, and Hopwood (2009) showed that viewing perspective is an important consideration when examining perceptual-cognitive decision making skill, with decision making superior when viewing an aerial perspective compared to a "player" perspective, raising questions about appropriate viewing perspectives. Further, considerations include 'action fidelity', that is, ensuring that the task adequately captures the dynamic nature of sport (Mann, Williams, Ward, & Janelle, 2007). Research has shown that baseball players may rely on different perception-action coupling when facing a pitcher and swinging a bat compered to watching a video and pressing a button – a task used in laboratory settings (Mann et al., 2007). Additional research in baseball has shown players to use visual, tactile and auditory feedback when adjusting their swing. Some of the aforementioned technologies may remove available feedback, and again limit the effectiveness of training with such devices (Gray, 2009). Such research highlights the need to critically evaluate how such technologies are used in applied settings to ensure the task being trained is representative of the actual task.

Considerations for the use of technology in sport

There is no doubt that technology has and will continue to have an impact on sport. What remains in contention is the extent at which scientists, coaches and athletes can appropriately use and understand new technologies. When working with elite athletes, small changes most often need to be made in a relatively short amount of time. Thus, three key factors may play a role in the effectiveness of a new technology, a) validity and reliability of the data, b) meaningful data, and c) processing speed.

Typically, the outputs from technical systems such as forceplates, isokinetic dynamometers and three-dimensional motion capture systems, seen as the gold-standard equipment, can be data rich and very comprehensive. There is merit in using these methods in order to collect valid and reliable data, and extract in-depth, meaningful information. These systems, however, are often limited in their use because of requiring a great period of preparation, processing and analysis time. Nonetheless, systems that become used in standard practice (e.g. forceplate use in swimming and athletics at Australian Institute of Sport, Tor, Pease, & Ball, 2015) may become highly automated and close to real-time through the streamlining of data processing and standardised procedures.

The limitations of gold-standard equipment (cost, environmental restrictions, specific training required, see Figure 1) are likely factors that drive new commercial devices and applications to be made available for purchase. Unfortunately, not all devices are found to provide valid and reliable data and thus, if the rate at which technology is adopted exceeds the rate of validation, then scientists, need to carry out corrections to technique or training (Liebermann et al., 2002).

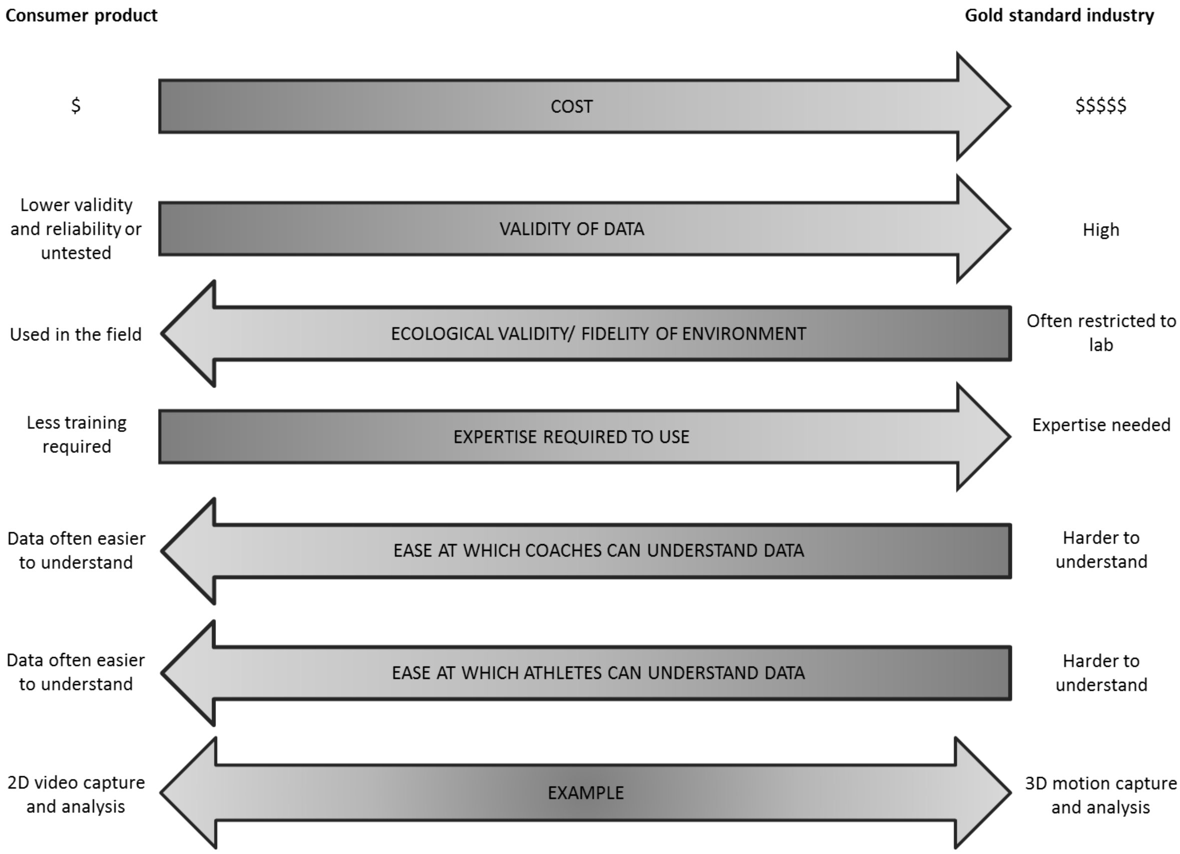

Figure 1. Trade-off of benefits and weaknesses between consumer and industry products.

coaches and athletes are at risk of using technology that has not been appropriately tested. Feedback or training interventions based on invalid and unreliable data may then be detrimental to performance.

Whether looking to implement changes toward short or long term goals, meaningful information is required in order for sports scientists and coaches to make informed decisions that affect the performance of his or her athletes. Thus, the ease at which information rich datasets can now be collected can be problematic if analysts are not focussed in their analysis. There is a risk that coaches, and more importantly athletes will become overloaded with the amount of information presented, which could be detrimental to learning or performance. ‘Paralysis by analysis’ or ‘choking’ is common outcome that results from conscious control of a movement that is typically automated, which is quite possibly brought about by an overabundance of information and continual monitoring (Ehrlenspiel, 2001). Furthermore, technology has shown great potential for monitoring performance in sport, but it can only be effective if the individual athlete is aware of the performance goal and if he or she perceives the

Finally, there is a trade-off between the usefulness of data to monitor and improve overall performance and duration of analysis when working with elite athletes. During competition, in order for athletes to implement any changes, there is a limited time to provide meaningful information. This necessitates the need for advanced tools with faster processing speeds such as the example of the ClipCoach system.

With the myriad of technology available that can be used to affect sport performances in both competition and training setting, we believe it is paramount for the sport scientist and coach to determine the goals and practical outcomes of using new technology. With new gadgets, widgets and applications being made available to the consumer market at a rapid rate, it is easy to get caught up in the “latest craze” without considering the practically of the systems used or output delivered. We encourage our applied colleagues to consider the potential benefits against any consequences or unknowns, prior to employing any new tool and before diving head first into purchasing unvalidated high-tech products.

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Research Profile

Georgia is a Performance Scientist at the Queensland Academy of Sport in Brisbane, Australia. She works with some of Australia's top athletes as they prepare for major benchmark events such as World Championships and Olympic Games. Georgia recently received her PhD from Victoria University, which she completed in collaboration with Tennis Australia. Georgia's research examined the capacity for coaches to perceive small changes in kinematics (technique) and the capability of athletes to implement specific kinematic feedback into their movement patterns.