Investigating the Perceived Effectiveness of Digital Technology for Elite Athlete Support in Golf

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Abstract: Digital technologies have enabled vast and varied amounts of data to be captured on elite athletes. The data is intended for use by athletes, coaches and support team e.g. physiotherapists, sports scientists for many purposes including performance development or injury prevention. However, the usefulness of such digital technologies and the information gathered is only beneficial if deemed effective by all those involved. The purpose of this study was to investigate the effectiveness of digital technology for elite athletes' development and support from athlete, coach and support team perspective in golf. Interviews were conducted with athletes, coaches and support team for a sport where digital technologies were used to facilitate training. The results of the study uncovered four categories that helped to understand how effectiveness was perceived which were "The Influence on Psychological Well-being and Proprioception", "Measurement Uncertainty", "Environment" and "Type, Ease and Frequency of Use". Exploring these categories provided insight into the best practices for digital technology integration into elite athlete support and ultimately can help shape future developments of digital technologies.

1 INTRODUCTION

For an athlete to reach the pinnacle of their sport, such as competing at the Olympic Games, there is often an organizational and management system put in place to support the athlete (Cruickshank et al., 2014). Part of this system includes the provision for a multidisciplinary support team made up of coaches, sport scientists and medical personnel responsible for supporting an athlete's performance or prevent injury.

An important role for the athlete support team is the analysis of elite athletes' technique to help improve and produce stable performances, particularly in individual sports such as golf (Buttifield et al., 2009). Support teams are required to observe and provide feedback of the performer's movement patterns or physical conditioning and subsequently amend coaching interventions to bring about a change in performance (Sherman et al., 2001). It is also acknowledged that precise qualitative or quantitative feedback may be more beneficial for elite athletes who require accurate information to detect errors in an already proficient performance (Smith and Loschner, 2002). Biomechanics analysis is well suited to provide this detailed feedback and understanding about technique and is reliant on digital technology. Advances in digital technology (defined as any type of electronic device or application that relies on recording, measuring and processing information in a binary form (i.e. as digits 0 and 1)) have made it possible to provide this augmented feedback to athletes (Liebermann et al., 2002), yet the perceived effectiveness of technology is often not addressed.

Digital technologies have been integrated into many aspects of daily life which has resulted in a growth in social sciences research. An impetus for the research is a desire to understand the consequences the technology has on social, emotional, mental, intellectual or physical development. Effective implementation of digital technologies offers the chance to augment knowledge in a given situation and provide evidence to make informed decisions, which in sport could be a decision about an elite athlete's technique. The technology itself does not automatically improve or augment human understanding and for it to be useful it must firstly be integrated into meaningful situations (Price et al., 2013). Secondly, the technology must be viewed as effective by all users and often is the measure of a new technological innovation success

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(Ratten, 2019). For example, the effectiveness of current or future sport technology innovations, must be judged worthwhile by all involved from the athlete to the support team.

Golf is an individual sport which was reintroduced as an Olympic sport in Rio 2016. In golf, athletes are required to perform a variety of shots to successfully displace the golf ball accurately and a given distance in as few shots as possible. Golf performance is objectively measured by the number of shots required to complete a round and is not reliant on digital technology for officiating purposes. Digital technology is now readily used in elite golf to provide feedback on golfer (Evans et al., 2012) or club (Leach et al., 2017) movement, yet there is limited understanding of how effective these technologies are for their intended purpose.

The overall purpose of this study was to investigate the effectiveness of digital technologies for elite athlete support from the athlete, coach and support team perspective. Three research questions were proposed:

1. What and how had digital technologies been implemented as part of elite athletes' support?
2. What were the perceived benefits and limitations of digital technologies as part of elite athlete support from the athlete, coach and support team perspective?
3. How was the effectiveness of digital technologies in elite athlete support perceived and measured by athletes, coaches and support team?

The results of the study could provide recommendations for the implementation and development of future technologies for supporting elite athletes.

2 METHODS

This study is based on the phenomenological belief that the effectiveness of digital technology for elite athlete support is perceived differently by athletes, coaches and support team member and is best understood from capturing individual first-hand accounts. Given this belief, an interview was deemed the most suitable qualitative research method. An interview allowed themes and detailed descriptions about the effectiveness of digital technology to be explored based on the experience of coaches, athletes and support team member using their own terminology. The study was approved by Loughborough University ethics advisory committee and prior to the interview participants were asked to sign a consent form.

2.1 Participants

Qualitative data collection methods typically rely on relatively small samples of participants who are selected based on the purpose of the research (Patton, 2002). Patton (2002) described these purposefully sampled participants as 'information-rich cases' from which, the researcher can gather in-depth information related specifically to the purpose of the research. A critical case purposeful sampling strategy was employed to ensure that participants met the following criteria: elite athletes competing internationally in their chosen sport and actively engaged with digital technology for biomechanics analysis. Three male golfers (Golfer One, Two and Three), aged 34.3 ± 13.5 years, two experienced golf coaches (Golf Coach One and Two) and one physiotherapist/strength and conditioning coach took part in the study.

2.2 Data Collection

Interviews were conducted at the start of the competitive golf season by the lead author who has a background in biomechanics research. The interviews were scheduled, where possible, to coincide with a biomechanics analysis measurement session which utilized digital technology to quantify athletes and equipment biomechanics. An overview of each measurement session including the technology used are presented to show examples of how technology is used and help to set the context when interpreting the outcomes of the interviews.

2.2.1 Digital Technology

The example biomechanics measurement session involved the use of three-dimensional (3D) motion analysis, force plates and launch monitor. The launch monitor provides objective measures of club and ball variables such as clubhead velocity and ball velocity which are considered key determinants of shot displacement. The combined use of 3D motion analysis and forces plates allow golfer kinematics and kinetics to be computed and reported. Retro-reflective markers were attached to the golfer to create a model of the golfer from which biomechanics variables were computed and shared through a report containing graphs and tables of data.

2.2.2 Interviews

The interview was divided into three sections: (i) digital technology and biomechanics analysis (ii) benefits and limitations of digital technology and (iii)

effectiveness of digital technology. Each section began with an open-ended question followed by several detail -oriented or clarification questions which were re-worded based on the interviewee's responses. The interviews with athletes and support team member were conducted at the same location as the biomechanics measurement session. The interviews with coaches were carried out at their coaching venue. The interviews lasted between 30 - 45 minutes and were recorded an Olympus DS-5000 dictaphone from which typed transcripts were produced for data analysis. Field notes were also taken during the interview.

2.3 Data Analysis

Interviews were transcribed verbatim using the qualitative analysis software QSR NVivo 12 (QSR International). Subsequent analysis was also carried out using NVivo.

An interpretative phenomenological analysis (IPA) was carried out on the interview transcripts. The goal of the IPA was to understand the concerns of participants and to consider their claims based on real-life experiences (Sparkes and Smith, 2014). The IPA guidelines offered by Sparkes and Smith (2014) were followed. A single analyst coded the transcripts. Initially, transcripts were read several times to become familiar with the accounts. Basic annotations were made on the transcripts to highlight and summarize areas of interest (i.e. coding). The purpose of the initial coding was to capture descriptive, linguistic or conceptual aspects of each participants account. The initial coding was then transformed into several themes which reflected the participants perceptions. Connections between themes were made and those which shared similar concepts were clustered into categories. If company names were used by participants when referring to technology these were replaced with the type of measurement technology.

3 RESULTS

3.1 Overview

Overall, mainly positive language was used by athletes, coaches and support team members when discussing technology with phrases such as, "*extremely important*", and "*it's big*" used to answer the question as to how important technology was to the support provided to elite athletes. This view is not surprising given successful elite athlete support systems emphasise the provision of sport science/coaching services and facilities that include technology.

Athletes, coaches and the support team member agreed that each member of the team would judge the effectiveness of technology in the same way. However, given each participant had different experiences and understanding of the technology, alternative perceptions were provided. As Golfer Two notes:

… if we didn't all agree then we wouldn't use it, but we definitely know that it's massive for helping us improve. [My coach]… knows more about the [launch monitor] or [my support team member] might know more about the biomechanics but when it all comes together we have all the information that we need, everything from physical to on-the-course stuff, so it's massive and it does definitely help.

3.2 Perceived Effectiveness of Digital Technology

In-depth analysis of the participants responses uncovered four categories that helped to understand how the effectiveness of digital technology for elite athlete support was perceived. The categories were: "The Influence on Psychological Well-being and Proprioception", "Measurement Uncertainty", "Environment", "Type, Ease and Frequency of Use" (Figure 1).

3.2.1 The Influence on Psychological Well-being and Proprioception

All participants recognized that the use of technology had the potential to influence feelings or emotions. The positive feelings which technology provided included increasing feelings of confidence or preparedness which led to wanting to continue to use the technology in future instances particularly for Golfer Two:

If you've used either the [launch monitor] or the biomechanics and seen that there has been an improvement from either last week or six months ago or twelve months ago, then, obviously that's going to give you a boost that you know what you're doing is leading in the right direction. So you're going to want to continue to work on those and use the same information or the same technology for the further years as well.

Negative feelings could also be experienced, which included the use of terms such as "*dependent*" or a sense the technology hindered confidence. The feeling that technology sometimes hindered confidence was experienced by Golf Coach One and

they believed that it could undermine their thoughts or view of a situation when working with a golfer. This feeling was exasperated when the coach had a strong sense of uncertainty about the technology which will be presented in further detail in the next section. As Golf Coach One explains:

If I just had my camera and just responded to what the golf ball is doing, I think I might come across as more confident, rather than trying to interprate something that might even be wrong.

In instances where the data had been used to change specific kinematic variables, Golf Coach One expressed concern about the external focus of golf being forgotten (i.e. hit the ball towards a pre-defined target). It appeared that although the data could identify a flaw in technique and used simple coding systems to try and directly change this for a player, it was deemed detrimental and the feedback provided by the technology should instead be communicated through the coach with support from those who were knowledgeable about the technology:

Personally, I've used [biomechanics analysis] in my own golf and whether I interpreted the information poorly or wasn't guided well enough after but I really struggled with it because I was trying to change a red light to a green…I kind of lost the ball, stick, target side of it. I spoke with a new pupil I've taken on the european tour and he'd spent 6 months working with someone who specialises in biomechancis and he said he just lost the target completely. So he now is thinking really internal and I think most golfers learnt the game externally.

3.2.2 Measurement Uncertainty

Thoughts and concerns about the accuracy of the technology also influenced their perceived effectiveness of technology. Uncertainty about measurement accuracy was a concern for all participants. Golfer One expressed doubts over some features of launch monitor technology which ultimately influenced their use of the technology:

Category	Conceptual Themes	Example Quotes		
		Athlete	Coach	Support Team
Influence on psychological feelings or proprioception	Confidence Preparedness Peer Pressure Feel vs. Real Obsession Dependence Individual feelings	*"If you've used either the [launch monitor] or the biomechanics and seen that there has been an improvement… obviously that's going to give you a boost that you know what you're doing is leading in the right direction."*	*"If I just had my camera and just responded to what the golf ball is doing, I think I might come across as more confident, rather than trying to interpret something that might even be wrong."*	*"…golfers are spending more time competing and practicing on the technical stuff that I'm using technology to almost just back myself, and can I say this is what I've measured and I can use it to help us inform where we need to go."*
Measurement Uncertainty	Accuracy Variability Comparison to other technology Cost-accuracy trade-off	*"…The more I learn about how…inaccurate it is, just to an nth degree that I don't look at some of the numbers"*	*"…sometimes the type of grass that you're hitting off, If it's sand based, the spin rate can be a bit different, or the performance can be out. So sometimes you have to make a judgement and go with what you're seeing…if you're not 100% sure on the data that you're getting from the [launch monitor]."*	*"I would be using ball speed as a very simple outcome measure, because it fluctuates, but I don't know whether that's the technology that fluctuates or whether that's actually happening."*
Environment	Replicate competition environment	*"… going through all the clubs in the golf bag, rather than just the driver, because you're obviously going to swing certain clubs differently and want to do stuff with your swing differently with different clubs"*	*"You can get too much of it. You can stand there and try and make yourself too perfect and then you know, golf is a game, it's a problem solving game played in an ever changing environment."*	*"…how the altitude effects the air flow in the bed and I've gone back to those competitions and looked at that data to see if air times were affected so yeah, we do go back but it's less of a systematic thing, more as we need to"*
Type, Ease and Frequency of Use	Combination of technology Prevalence of use	*"… I don't see how just using a [launch monitor] can help you because you need to know what that next course is going to be, so this is how I relate it with the data…to get the data from The [statistical analysis company]"*	*"I think probably the best way to interpret it is how often do you use it? If myself or a player go to use it, then I think it's probably effective."*	*So technology has to be portable, and that's why everyone's just using mobile phones, because it's easier isn't it, everyone's got one. So portable, how quick it's reported, how easy is it to understand, but ultimately it needs to be accurate as well.*

Figure 1: Four categories relating to the effectiveness of digital technology for elite athlete support from athlete, coach and support team member perspective in golf.

The more I learn about how…inaccurate it is, just to an nth degree that I don't look at some of the numbers on a [launch monitor], but what I do know is that the ball data, and especially with distances is such a key part of golf that I use it every single week when I go away so at the start of the week I would use it for gauging, we could be at altitude, different temperatures, how it affects the ball.

Golf Coach Two described how they would compare the results of two types of technology to check the quality of data and it appears that the cost of the equipment had influenced their decision as which was the most accurate. The need for coaches to carry out such testing does raise question as to whether there needs to be a legislative body or requirement for companies to be more transparent about measurement uncertainty. Golf Coach Two explained:

the fact it is expensive for a reason, because it's the highest quality, it's got the most research behind it, it's got the best people behind it, it's the best made etc. So therefore it costs quite a lot. I've done some testing of different technologies against each other. So I did [launch monitor 1] against [launch monitor 2] for example and [launch monitor 1] came out pretty good to be honest but the fact I'm measuring it against [launch monitor 2] …is the benchmark kind of says a lot really…some of the key data was very similar, almost identical but the angle of attack data was very different. But I will trust [launch monitor 2] rather than [launch monitor 1] and more people use it.

The support team member also commented on the cost-effectiveness trade-of which it came to judge the measurement uncertainty:

… I have to question the technology because I know how much things are to be really good, to produce really good data. For example the electromagnetics stuff, I'd be thinking 'how good is it,' but then it's so practical. [Launch monitor] you stand it up, you switch it on, you set it up, 'that's amazing' and 'yeah that data must be great' but then in the big picture, it's thousands of pounds worth, it's £16,000…I'd be thinking 'yeah, but force plates are way more than that,' and so it's the perception, that value

3.2.3 Environment

Technology was seen to be disconnected from the competitive environment, which for Golfer Three was a concern for new golfers on the professional tours:

I think the only thing that's a downside really, especially with this generation of young kids is that I mean because when you do use technology, it's off the perfect lie, a set lie, whereas you've got to go out there…golf it's a forever changing environment, so, with downhill lies and stuff like that. So the young generation are too dependant on it I think, on this stuff. They need to back away and just play golf. Obviously combine the both, you know combine your own talent with science but I think it's all about getting the ball in the hole in the least possible shots is the most important thing.

This recognized limitation of technology by the golfer did not fully compromise the perceived effectiveness of technology for golf coaches. For one coach, it was not an expectation for the technology to be able to replicate on-course conditions. The decision of when and how to use the technology appeared to be driven by the coach and if the coach had a good appreciation for the limitation of technology then necessary changes to the implementation of technology were made. Golf Coach Two summarised how they handle this limitation of technology in golf:

You can stand there and try and make yourself too perfect and then you know, golf is a game, it's a problem solving game played in an ever changing environment. So you have to practise that skill. You know, the technology helps me with the technical stuff which will help me to control the ball…Once you've got ball control, which is what technology is helping us do, then you need to get out in that ever changing environment and make it work. So that's where you withdraw the technology or slowly ween them off it. You might take [launch monitor] out for a session, then you might have a session without it and then you are going to go on the golf course with no [launch monitor] and you're going to put the artistic side of the game together. But it's all made easier because you've used technology to control the ball and get the right physics in the ball, the right efficiency in you body, the right sequence in your golf swing and so by the time we do get out there it makes life a lot easier.

Golf Coach One and the Support Team member supported the notion that future technology should have the ability to emulate on-course or competition surroundings:

Where as the [launch monitor], biomechanics and the force plate, that isn't going to give me data on how [the golfer] or anyone performed on the first tee or the 67th hole, with 5 to go in a major. That's the kind of information we need to find out.

So technologogy has to be portable, and that's why everyone's just using mobile phones, because it's easier isn't it, everyone's got one. So portable, how quick it's reported, how easy is it to understand, but ultimately it needs to be accurate as well.

3.2.4 Type, Ease and Frequency of Use

The frequency of use was another suggested metric as to how effective digital technology was as part of elite athlete support. Golf Coach One stated:

I think probably the best way to interperate it is how often do you use it? If myself or a player go to use it, then I think it's probably effective.

The frequency with which technology was used was also related to the ease of set-up. A technology that was easy to set-up was beneficial for all groups of participants particularly when travelling to tournaments around the world. Video technology was often still seen as the most useful type of technology due to its ease of set-up. Golf Coach One commented:

The one thing that we'll use all the time is video and a slo-mo video off an iPad. I try to be very consistent with the height that I film at…While biomechanics can tell me how much the lead wrist is in flexion , I can see a huge amount of where it is with pressure trace mats and things like that. I just think that the most usable piece of technology is still video. You'll probably get shot down by somebody who is a biomechanist or somebody who likes pressure mats but as a coach, you're travelling from place to place, performer to performer, the one thing that's really consistent is the camera and whether you want to draw lines or just view it. View it in slo-mo, view it at full speed, just to get the rhythm of the thing, I just still think it's the best. I think I probably could do my job just with that.

4 DISCUSSION

The aim of this study was to investigate the effectiveness of digital technologies for elite athlete support from athlete, coach and support team member perspectives. Based on an interpretative phenomenological analysis of interviews, predominantly positive views were expressed with regards to the use of technology for analysing athlete performance. Four main categories relating to the perceived effectiveness of technology were found: "The Influence on Psychological Well-being and Proprioception", "Measurement Uncertainty", "Environment", "Type, Ease and Frequency of Use". The interpretations of first-hand accounts can be used to provide suggestions of how to judge the effectiveness of existing or future technologies and help with decisions relating to implementation or investment in digital technology.

All participants described instances where the use of digital technology had influenced their psychological well-being in mainly positive but sometimes negative ways. Technology was an effective tool for encouraging positive feelings such as improving confidence, increasing a sense of preparedness and alleviating negative moods (Figure 1). Healthcare technologies have been promoted as ways to help treat major health problems such as obesity (Pagoto et al., 2013; Solbrig et al., 2017) or managing cancer treatments (Bender et al., 2013). Online and mobile applications (apps) have been developed to help manage weight loss programmes for example, but apps that failed to acknowledge psychological well-being of users were not rated favourably (Bender et al., 2013). Apps which provided motivational support rather than simple quantification of calories for example were seen to be more effective by users (Solbrig et al., 2017). There is a similarity with athletes' perceptions whereby technology was deemed effectives if it influenced their confidence. Therefore, future technologies could further encourage the motivational nature of digital technology through presentation of data as opposed to just presenting quantitative results. Mental health is an important concern for the International Olympic Committee (IOC) with the latest consensus statement published (Reardon et al. 2019). The consensus recognized several factors that may influence an elite athlete's mental health by considering the wider social environment of the elite athlete and how an environment can be created that supports mental well-being and resilience. In the consensus, coaches were encouraged to de-emphasize achievements and outcomes and instead develop a growth, effort and improvement mindset in athletes (Reardon et al., 2019). This study has shown that the use of technology can influence feelings, which for the athletes in this study, were predominantly positive, but it does still suggest that technology can be a potential source of stress. Therefore, it may be beneficial for strategies for the implementation of digital technology to be decided within a support team to avoid causing unnecessary stress. For example, a strategy may include gradual introduction of technology for athletes starting within an elite athlete support programme. Furthermore, if not already provided, coach education courses could incorporate information about the social sciences view of the role and use of technology in elite sport as suggested by Taylor et al., (2017).

Concerns were raised when the technology provided individualized feedback about specific kinematic variables without considering the wider

context of the feedback. Recommendations for measurement of elite athletes has emphasized the need for individualized measurement as it may provide better understanding and evidence-based support for athlete performance (Sands et al., 2019). Golfers, for example, show inter-individual differences in their movement patterns even for similar clubhead–ball impact parameters (Smith et al., 2017). The recommendation for future studies is that data analysis methods must provide interpretation and understanding of this individualized, multidimensional movement (Lamb and Pataky, 2018). Analysis methods that can provide this type of interpretation are of interest to include in analysis systems aimed at providing quantitative feedback to coaches about the athlete's technique which help inform personalized coaching interventions for performance enhancement or injury prevention.

Coaches and support team members who felt undermined by technology remarked about the accuracy of the technology. Measurement errors are impossible to avoid and therefore it is wrong to assume that a measurement technology gives the exact value of a variable of interest (Morris and Langari, 2012). Errors can be reduced through good data collection methods, appropriate analysis and processing yet there will always be some level of uncertainty. The coach-athlete relationship is very important and for elite coaches having a good rapport with athletes was perceived as the most important need for elite coaching practice (Williams and Kendall, 2007). If the coach feels undermined by the technology, it may start to affect the rapport with the athlete. It is therefore important that coaches can provide sound knowledge of the measurement uncertainty of the technology being used (Sands et al., 2019). Some of this responsibility may also fall with technology manufacturers by educating users about the technology's limitations, the measurement uncertainty particularly in applied settings and openly sharing validation procedures. One example where measurement uncertainty has caused confusion is Hawk-eye technologies used for officiating tennis tournaments (Collins and Evans, 2008). Collins and Evans (2008) argued that Hawk-eye's presentation of line calls in tennis were overestimating the ability of the technology because measurement uncertainty was not clearly shown to television audiences or athletes during the competition. Hence, more could be done by technology manufacturers to encourage a sense of trustworthiness in the data amongst users. Unless this occurs, independent studies comparing and reviewing commercially available technologies will continue to be conducted and published to help users appreciate their inherent strengths and limitations (Evans et al. 2012; Leach et al., 2017).

The cost of technology and popularity of a technology amongst peers appeared to influence judgments about effectiveness. Some of the technologies available on the market have a high cost and therefore it is anticipated there would need to be a cost-effectiveness trade-off. A technology with a higher cost was presumed to be more accurate and have the most research and development which it is unclear whether this can be proven unless companies or systems are willing to share details and the research and development. This can cause some ethical questions relating to availability of funds to purchase such technology, for example for elite athletes in developing countries. Once more, companies could do more to justify the costs of the technology. Coach education courses could also provide unbiased reviews and insights into different technologies to help coaches or support teams make better informed decisions about the most appropriate technology.

5 CONCLUSIONS

In summary, mainly positive language was used by athletes, coaches and support team when discussing the effectiveness of digital technologies. Athletes, coaches and support team members were in strong agreement about the effectiveness of technology. Digital technology did have the potential to influence psychological well-being and proprioception but with effective coaching strategies to implement technologies these feelings could be managed. Measurement uncertainty is an aspect of technology that influences the feelings of each member of the support team. Technology innovators and companies providing more transparent information about the measurement technology could help improve feelings of trustworthiness amongst users who often pay large amounts for the technology.

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