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An Evaluation of a Low-Cost Virtual Reality Rehabilitation Tool in an Elite Soccer Environment

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ANNOTATION

Injuries in professional football (soccer) come at a significant financial, performance and personal cost to both the team and its players. Although recent research has supported the use of virtual reality (VR) as an effective rehabilitation tool [10] (Gumaa & Rehan Youssef, 2019), there is a lack of information available on how clinical staff in elite sporting organisations can use this technology effectively. The aim of this study was to analyse rehabilitation specialists' perceptions of the barriers and benefits of using VR technology to understand and improve the recovery journey of professional football players. Perceptions regarding the key barriers to VR's widespread adoption were the following: lack of foot tracking from the VR hardware used (Oculus Quest) and specificity of software to rehabilitate certain injuries (e.g., groin). Key benefits included better engagement from players, particularly in the early stages of rehabilitation following the prognosis of a long-term injury. In these cases, the VR technology presented an opportunity for players to start their rehabilitation journey in a more fun, gamified manner where the movements the players make to play the games are customised through the game settings to suit the current movement capabilities of each player. Additionally, the VR games employed a competitive scoring system where in-built algorithms calculated a score that reflected the quality of movements performed in the game [1]. These VR game scores were presented on a leader board, not only allowing players to track their own progress and recovery but also compete against their team-mates. One to one mapping between movement in the real world and movement in the virtual world allowed players, and the rehabilitation specialists to measure performance improvements which further enhanced the rehabilitation experience. In conclusion, VR games that analyse the quality of movement during game play to provide a meaningful score, have the potential to become a valuable supplement to current rehabilitation methods [2-4].

INTRODUCTION

Football (soccer) is a team sport with high physical demands (jumping, sprinting, heading, quick changes of direction, tackling) that puts its players at increased risk of both contact (e.g., concussion) and non-contact (e.g., Anterior Cruciate Ligament (ACL) injuries (López-Valenciano et al., 2020). Indeed, a professional football team with a squad of 25 players typically suffers about 50 injuries each season that result in substantial time-loss from play [5] (Ekstrand, Häggglund, & Waldén, 2011). This comes at a significant performance cost to a football organization where player availability has been found to correlate very

strongly ($r > 0.85$) with on-pitch success metrics such as games won, goals scored, total points and final league position [12] (Häggglund et al., 2013; Eirale et al., 2013).

Furthermore, injuries also pose a significant financial burden to football organizations. A recent study calculated that the cost of lost wages and lost prize money, means an English Premier League team could lose an average of £45 million per season as a consequence of injury-related decrements in performance (Eliakim, Morgulev, Lidor, Meckel, 2020) [6].

These findings provide professional football organizations with a strong economic and performative

incentive to invest in injury prevention and rehabilitation programs and technologies. One emerging technology that is being proposed as a method of augmenting traditional rehabilitation practices for both head [23] (Santos, Yamaguchi, Buckley, & Caccese, 2020) and musculoskeletal (Vogt, Skjæret-Maroni, Neuhaus, & Baumeister, 2019) injuries is Virtual Reality (VR). Through a head-mounted display (HMD), an immersive virtual environment can be presented where there is one-to-one mapping between movement in the real world and movement in the virtual world. This direct correspondence between how a person feels their movement in the real world and sees their movement in VR is critical for optimising rehabilitation and training. Preserving this behavioural realism ensures that the virtual environment (VE) allows users to interact with 3D generated models in real time while using their natural senses and skills (Craig, 2013) [13].

Indeed, since the beginning of the 21st century, the use of VR as an augmentative tool has shown utility in many domains including surgery [11] (Gurusamy, Aggarwal, Palanivelu, & Davidson, 2008), sport [8] (Gray, 2017; Neumann et al., 2018) and education [7] (Falah, 2014). As the technology has become increasingly accessible and the hardware components have become more powerful, sports performance has emerged as a key area of interest. For physiotherapists, one major opportunity has been created by the significant advancements in VR hardware, both in terms of performance and reduced cost. The Oculus Quest 2, currently retailing at £299, uses inside out movement tracking that has levels of precision (c. 0.18mm) that are comparable to other sophisticated, high-cost light-based motion capture systems such as Qualisys or Vicon [14] (Holzwarth, Gisler, Hirt, & Kunz, 2021). As a result, motion data can be easily captured, analyzed and presented back to the user in real-time with high levels of accuracy.

What's more, the power of virtual reality to create a perceptual context (through visual and auditory content) that invites certain kinds of game play interactions (e.g., moving to pop a ball) offers physiotherapists the opportunity to change these contexts (customise the games) to encourage different forms of movement. By using the power of game play, the user's attention is drawn away from the types of movements they are making and more towards the goal-directed nature of the interactions needed to successfully play the game. Customised VR games will encourage the appropriate level of movement, while VR motion sensors will record the quality of these interactions to produce game scores that objectively reflect where the player is on their recovery journey. Indeed, a recent study has shown that motion data collected from the sensors embedded in the Oculus Quest headset can be used to measure postural

sway and quantify improvements in stability rather than the physiotherapist relying solely on the power of observation [21] (Masoner et al., 2020).

VR can enhance physiotherapy by transforming rehabilitation exercises from a decoupled task – such as standing on one leg and asking the player to open and close their eyes - to a coupled task where the player is interacting in real time with moving objects in their surrounding environment in a more naturalistic way. For example, the visual scene in Virtual Reality can be subtly changed to give the perception of forward and/or lateral movement [2] (Burcal & Grooms, 2021). In keeping with Lee & Aronson's moving room experiments from the 1970s [18] (Lee & Aronson, 1974), perturbations to the virtual optic flow will force adjustments to the balance system to accommodate these. This ability to easily change visual input means that more natural perception-action couplings will be maintained, similar to what is encountered in real life. For instance, by promoting the down-weighting of visual inputs during balance exercises, athletes are being better prepared for the demands of the visually dynamic sporting environment where they are constantly required to monitor the reliability of sensory inputs rather than adapting to the static conditions of eyes open and/or eyes closed.

Another major advantage of VR technology when implementing a rehabilitation plan, is the ability to advance the athlete through progressively more difficult exercises. All-or-nothing approaches are limited because they either eliminate (e.g., eyes closed) or alter (e.g., foam pad) inputs from a sensory system. For example, such manipulations have been shown to be ineffective in reducing reliance on visual cues, as they are not challenging the role of visual perception in a granular way but are rather removing visual input altogether [25] (Song, Rhodes, & Wikstrom, 2018). VR therefore offers a promising new method for physiotherapists to offer more posturally challenging exercises that dynamically adjust the extent to which visual perturbations invoke balance readjustments through proprioceptive input, particularly at later stages of rehabilitation.

There are also important potential barriers to integrating VR into clinical practice. In an interview with several elite football coaches, Thatcher, Ivanov, Szerovay, & Mills (2020) attributed many coaches' negative perceptions of VR to the notion that the technology is relatively unproven in a football environment leading to early scepticism of the added value VR brings. Indeed, coaches were quoted as describing the technology as "gimmicky" and the technology must provide a clear indication that it holds more value than these existing methods. However, in a recent survey with

professional football staff, Greenhough, Barrett, Towlson, & Abt (2021) found that while there was no consensus on whether VR should be used as a talent identification tool, 73% of practitioners agreed that VR could be used in a professional football setting for rehabilitation.

Despite these opinions and proposed benefits, few physiotherapists and rehabilitation specialists in elite football use VR as part of their day-to-day practice. The aims of this study are i) to explore the perceived benefits and barriers to the adoption of VR technology to rehabilitate players in elite football following a trial period of usage and ii) provide a list of recommendations to support the design of virtual reality sessions aimed at rehabilitation in sport, but also outline the practical implications for using VR technology in a professional football setting, such as staff time constraints and player buy-in.

Method

Participants

Due to the well-known challenges of recruiting participants in professional football, purposeful sampling was adopted [26] (Thatcher et al., 2020). We identified and contacted two clinical staff (CS1, CS2) working within an elite professional football club in England who agreed to take part in this evaluative research. The clinical staffs' job titles were as follows: Sport Rehabilitation Therapist (CS1) and Senior First Team Physiotherapist and Injury Prevention Lead (CS2). The clinical staff have over 15 years' experience designing and delivering rehabilitation programmes for injured players.

Five elite football players from the same English Championship team agreed to participate in the user-testing study. The injured players (IP1, IP2, IP3, IP4 and IP5) were aged between 20 and 28 years ($M = 23.4$, $SD = 3.21$). IP1 and IP3 were recovering from knee injuries, IP4 and IP5 were recovering from ankle injuries, and IP2 was recovering from a quadricep injury at the time of testing [15].

Design

This exploratory research aims to assess the barriers and benefits of using VR technology to help rehabilitate injured players. Qualitative data will be collected through semi-structured interviews carried out with clinical staff and questionnaires [16] (adapted VRNQ; Kourtesis et al, 2019) administered to injured players. The methodology is comprised of two parts i) an initial phase of players and clinical staff using rehabilitation specific VR technology with injured elite footballers and ii) evaluating the technology through semi-structured interviews and questionnaires administered to staff and players, respectively.

VR Technology

The VR technology used was the MOVIR platform designed and developed by INCISIV Ltd. According to the product description, the platform has been designed from an affordance perspective where the VR games can be customised so they can be adapted to the user's action capabilities (Awad et al, 2014) [1]. The games also use competitive game play as a key feature where game scores reflect the quality of movement captured by the movement controllers during game play (Whyatt et al, 2016) [27]. Scores are then presented on leader boards that compare the user's previous scores to the current score and to that of other players.

The games used were called Ball Pop, Bounce & Catch, pick up & Throw and Standing Still (see figure 1). A description of each test and the respective rehabilitation goals are included in Table 1.

Procedure

An Oculus headset and two hand controllers with the MOVIR software pre-installed was provided. Two members of clinical staff were shown how to create new users, customise the games so they were specific to that user and cast the images presented within the headset onto the screen of a tablet. This was an important step that would allow the therapist to see what the player was seeing in the virtual reality headset [5].

Staff used the software amongst themselves so they could identify the rehabilitation aims associated with each game (see Table 1) and adopt the technology as part of an injured player's rehabilitation programme. The user-testing phase with injured players ran for 3 months. During this time, five injured players played a range of VR games as part of their initial recovery programme. As it was difficult to anticipate if, and indeed when, players would get injured, a period of three months was deemed sufficient to allow enough time for clinical staff and players to use the technology multiple times and evaluate its utility as part of the rehabilitation programme.

From a number of informal discussions with clinical staff during the user testing phase several VR themes emerged. Combining these initial VR themes with existing academic research, three VR concepts were developed and explored in semi-structured interviews (see Table 2) [6].

Data Collection

The data collection method for this research consisted of a semi-structured interview to assess the clinical staff's perception and an adapted version of the VRNQ

Table 1:

Game	Description of Game Mechanics	Identified Rehabilitation Aims
Standing Still	A balance game where the user must stand as still as possible looking at a fixed target on a wall.	<ul style="list-style-type: none"> Improve Ankle stability and balance
	Customisation includes:	<ul style="list-style-type: none"> Work and strengthen the intrinsic muscles of the foot when performed with shoes off
	<ul style="list-style-type: none"> Trial duration 	<ul style="list-style-type: none"> Improve general balance skills when manipulating visual input
	<ul style="list-style-type: none"> Visual field manipulations (no visual input, tilting room, side to side, forward/back and diagonal movement) 	<ul style="list-style-type: none"> Use as an activation drill for the other more challenging balance games
	<ul style="list-style-type: none"> Stance type (single, double, tandem) 	
	<ul style="list-style-type: none"> Surface type (mat, foam, hard) 	
Ball Pop	An interception game where the goal is to pop as many balls as possible.	<ul style="list-style-type: none"> Functional and transferable movements when used for goalkeeper rehabilitation
	Customisation includes:	<ul style="list-style-type: none"> Improves Motor control and reaction skills while adding in a cognitive load
	<ul style="list-style-type: none"> Ball arrival position 	<ul style="list-style-type: none"> Introduces dynamic and unpredictable movements to the rehabilitation process
	<ul style="list-style-type: none"> Ball speed 	
	<ul style="list-style-type: none"> Ball frequency 	
	<ul style="list-style-type: none"> Ball size 	
	<ul style="list-style-type: none"> Target ball type 	
Bounce and Catch	A balance game where the user can adopt a particular stance (e.g., single leg, double or tandem) on different types of surface (hard, mat, foam) and throws a ball at a target trying to catch it again.	<ul style="list-style-type: none"> Improve ankle Proprioception and stability
	Scores reflect points scored from hitting target and quality of postural control.	<ul style="list-style-type: none"> Activation of the gluteal muscle groups
	Customisation includes:	<ul style="list-style-type: none"> Adds in unpredictable movements and reactions that challenge balance and stability of lower limb joints (Ankle, Knee, Hip)
	<ul style="list-style-type: none"> Duration of task 	<ul style="list-style-type: none"> Added co-ordination and motor control skills
	<ul style="list-style-type: none"> Type of stance 	<ul style="list-style-type: none"> Can be used to progress from standing still balance drills (see above)
	<ul style="list-style-type: none"> Type of surface 	
Pick up and Throw	A balance game where the user must stand on one leg and lean down and pick up a stationary ball.	<ul style="list-style-type: none"> Improve ankle proprioception and stability
	The user then takes aim at one of 5 hoops. The size of the hoop changes with task success.	<ul style="list-style-type: none"> Decrease risk of re-injury to ankle
	Customisation includes:	<ul style="list-style-type: none"> Knee stability & quadricep function
	<ul style="list-style-type: none"> Duration of the game 	<ul style="list-style-type: none"> Trunk stability and balance
		<ul style="list-style-type: none"> Gluteal muscle group activation
		<ul style="list-style-type: none"> Hip ROM and stability
		<ul style="list-style-type: none"> Challenging balance in different planes of motion
		<ul style="list-style-type: none"> To improve dynamic single leg stability through different planes of motion as it is transferable to the sport of football

Table 2: VR Concepts identified following the user testing phase

CONCEPT		
Player Engagement	Charting the Recovery Journey	Goal-Directed Movements
Encouraged players to adhere to rehabilitation program through gamified experiences	Game scores provided players and clinical staff objective data on game performance	VR games were focused on functional movements
	"Players can see themselves improve"	Using visual cues to produce a context for the movement

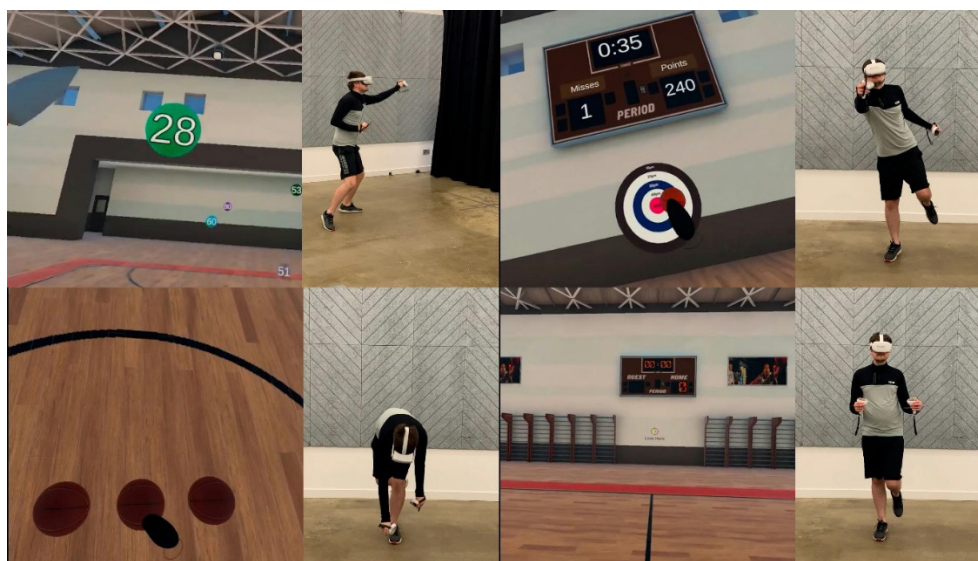


Figure 1: Images of the four games used with the elite footballers. The image presented top left illustrates the Ball Pop game, the image presented top right illustrates Bounce & Catch, the image bottom left indicates Pick up & Throw, and the bottom right image illustrates Standing Still.

questionnaire (Kourtesis et al, 2019) to assess the injured player's experiences using the VR technology. For the semi-structured interview, the clinical staff were asked several questions around the three concepts identified in the pilot phase, as well as more general questions surrounding the benefits and barriers of the VR rehabilitation application. The use of a semi-structured interview can be justified as the most appropriate method for data collection as the topic area is relatively unexplored, and it was challenging to anticipate how the interviewees would respond to the questions (Hirsjärvi & Hurme, 2008) [13]. This method allowed the interviewer to ask further questions that derived from the participant's responses, as new themes emerged (Saunders & Lewis, 2012) [24]. The adapted version of the VRNQ allowed players to give their feedback by rating their user experience, game mechanics and any other VR induced symptoms that they may have experienced as part of game play. Although 5 players completed the user testing, only four were able to complete the VRNQ [12].

RESULTS AND DISCUSSION

VRNQ – Players

The results from the adapted VRNQ can be found

below in Table 3. The questionnaire measures (on a 7-point scale) the quality of the VR experience both from a user interaction and game mechanics (7 being the best score) perspective but also takes into account any negative effects (induced symptoms) a VR experience can have (e.g., nausea, disorientation) (0 being the best score (i.e., symptom was absent)). The average scores can be found in Table 3. The scores show that all the players really enjoyed the VR experience (mean=6.5; median=7) and reported that the quality of graphics and sound to be of a very high standard (mean=6; median 6.5). They also felt that the level of immersion was high (mean 5.5: median=6) and the VR technology was comfortable to wear and use (mean=6; median=6) [8].

In terms of game mechanics, the players found it very easy to interact with the virtual environment (all scored it a 7) and the games were very intuitive to play (mean=6.3; median=6). As with any use of VR, it is important to understand if there are any adverse VR induced symptoms that may arise from the experience. The main negative experience is usually nausea which in this study was scored at 0 (absent) by all participants. The main negative

Table 3: The summary scores for each of the domains and questions presented in the adapted VRNQ. For the user experience the questions were scored on a scale of 0 (extremely low) to 7 (extremely high). For the game mechanics a score of 1 meant the game play was extremely difficult whereas 7 was extremely easy. Finally, for the VR induced symptoms 7 represented an extremely intense feeling while 0 meant those symptoms were absent. The median and mode scores are also presented.

User Experience	Mean Score (sd)	Median	Mode
Level of immersion	5.5 (1.7)	6	6
Enjoyment	6.5 (1.0)	7	7
Quality of graphics	6.0 (1.4)	6.5	7
Quality of sound	5.9 (0.8)	6	-
Comfort of technology	6.0 (0.7)	6	6
Game Mechanics			
Intuitive gameplay	6.3 (0.5)	6	6
Ease of VR interaction	7.0 (-)	7	7
VR Induced Symptoms			
Nauseousness	0.0 (-)	0	0
Disorientation	0.8 (0.9)	0.5	0
Dizziness	0.5 (0.5)	0.5	-
Fatigue	0.8 (0.9)	0.5	0
Instability	2.0 (2.2)	1.5	-

symptom participants did experience, though it was mild (mean=2), was instability. This was hardly surprising as the clinical staff used the VR games (such as the moving room manipulation in Standing Still) to test the reliance on visual information to maintain good balance. Others reported very mild (mean=0.5) effects of dizziness and disorientation (mean=0.75) and 2 out of 4 participants said they felt some fatigue (mean=0.8). Again, this was to be expected as the clinical staff were encouraging them to perform exercises that required different levels of physical effort [9].

Overall, the players appeared to enjoy the experience, felt the games were easy to use and did not suffer any

adverse effects. In fact, IP1 concluded that it was a “great piece of kit” [7].

Semi-Structured Interviews – Clinical Staff

The results from the semi-structured interviews can be deconstructed into clinical staff’s perceptions of the key benefits and barriers of adopting VR technology as part of a rehabilitation programme in elite football. This section discusses these findings and draws conclusions about how such perceptions may be formed, as well as the implications VR usage may have on clinical practice in professional football.

BENEFITS TO USING VR TECHNOLOGY

A key benefit to using VR technology when rehabilitating injured players in elite football is how it provides an engaging way for professional footballers to participate in rehabilitation. CS1 explained: “I think the key is that it’s offering variety, long term rehab can get boring at times for players, so you want to try and keep things as fresh as possible and keep them on their toes by giving them something new. It definitely adds something on the engagement.”

This observation suggests that a major challenge for rehabilitation specialists, when faced with long-term injury, is ensuring that a rehabilitation program does not become too repetitive and boring for a player. The fact that the VR technology was able to provide exercises that are similar to what they would do in real-life but disguised as games, helped with player adherence to the programme. CS2 reinforced CS1’s statement: “The fact he’s doing something different rather than using the same equipment within the same four walls we were able to say “right we’re going into the marquee to do VR now” before or after training changing the week up a bit that’s how you get the buy in from the players”.

CS2 went on to explain why ‘buy in’ from the players is such an important part of the rehabilitation journey:

“It’s really important, especially for the likes of IP2 who is going to be out 12 weeks and has never been out for that long before, the longer you can keep him engaged in this phase, means you got a better chance of having a successful outcome whereas if you go through the first 3 weeks and the player goes “I’m not doing this everyday” you lose a 3-week block and lose time the more you can keep them involved in the process the better”.

Indeed, other research has reported how VR exercises appear to be more enjoyable than generic rehabilitation programs as they tend to be more visually stimulating and enable the player to become more involved in the rehabilitation process through the dynamic interaction with

the 3D generated content (Laver, George, Thomas, Deutsch, & Crotty, 2012) [17].

Another benefit that emerged throughout the interview process is the quantification of the recovery journey through game scores. The MOVIR platform uses Oculus's motion tracking capabilities to produce game scores that also reflect the quality of the player's movement responses whilst playing the game. For example, the 'standing still' module required participants to keep their head and hands as still as possible [18]. Any wobbles or movements of the hands and head are captured by the motion controllers and are used to calculate a score that reflects the amount of postural sway. For example, if the player moved a lot, indicating a lack of postural control, they would receive a lower score in-game. CS1 also noted that these scores became very important to the players: "The players really like to see that [the scores] and the players have told me 'I'm not coming out of this until I beat my score'...."

By introducing scores based on movement quality, VR is uniquely placed to tap into the competitive nature of professional football by using leader boards to motivate the injured players to perform at their best when playing the customised games and to beat their teammates' scores. Although this was promising, the general view was the use of VR would lead to even better outcomes if the VR games reflected skills used by footballers on the pitch (e.g., ball skills, decision-making). Unfortunately, the limitations of the current VR technology mean any interactions with game content are limited to the hands and the head and which restricts direct applications to the game of football (see points below under Barriers to using VR technology) [19].

Despite this, the clinical staff interviewed did see direct benefits for some players. IP2 suffered a musculoskeletal injury that meant he was unable to train as normal. This was a source of extreme frustration for the player. CS2 noted that one of MOVIR's game modes (ball pop) focused on agility and decision making and allowed the player to practice interceptive movements in a controlled environment where the clinical staff could control the amplitude of movement he had to make. This ability to control the environment (i.e., frequency and location of ball arrival) allowed the player to keep his decision-making skills sharp whilst protecting him from the potential dangers of doing this out on the pitch, where it is more difficult to control ball flight and ball arrival position: "It's been good, he's enjoyed it, he's desperate to be getting out and catch balls so it was nice for him to do something different particularly around hand eye coordination in a controlled environment as we can't trust him when out on the grass not to dive for a ball that I hit at him. Even though MOVIR isn't really designed for

his specific injury, it's been something a bit different for his position" [20].

BARRIERS TO USING VR TECHNOLOGY

An issue facing VR rehabilitation technologies in professional football is the specificity of the VR games. The present technology uses an inside out light-based motion tracking system (Oculus Quest 2). While this technology offers key benefits in the form of ease-of-use, portability, and no external hardware (e.g., a PC, monitors, keyboards, etc.), it is limited to three motion controllers (the HMD and two hand controllers). This prevents the players from being able to use their feet to interact with the 3D virtual environment, like they would on an actual pitch. CS1 noted: "Having something for the feet, like the single leg balance drill but replicating passing. Particularly with footballers, especially with ankle injuries, balancing on one leg and making air passes and air volleys. For pick up and throw, we'd be keen to have a volley into a target. I've sent videos [to the researchers] about the players on an airex [exercise mat] and will play volley work back to the feeder and to replicate that in the VR would be great" [21].

Additionally, the clinical staff noted that while the VR was useful for certain types of injuries, the technology was not suitable for all circumstances and that the increased engagement could potentially increase risk if not carefully managed. CS2 pointed out:

"I don't think I'd use it for that [quad injuries], the only thing I can think of using it for is jumping but I'd be worried about [players] always wanting to beat their scores and I want to limit their jumps rather than going for max reach and we have technology to track max jump heights anyway and I'd be unlikely to change it" [22].

[2] Burcal and Grooms (2021) note that prior to using VR with patients, it is important that clinicians become familiar with what the VR system offers and how it can add value to their current practice. They claimed that when determining which specific test or application to use, it is important to first ask, "What do I want to accomplish with my patient?". Therefore, it should be noted that VR is not a one-stop-shop for rehabilitation and should be considered on a case-by-case basis factoring in the nature of the injury and the player's temperament [23].

LIMITATIONS

Although these preliminary outcomes sound promising for the introduction of VR into rehabilitation programs for elite football, there are several limitations to our study that should be noted. Firstly, most of the variables presented in this study were assessed using qualitative research methods. To truly measure and understand the benefits

of the VR technology, future research should include an objective evaluation of the rehabilitation tests scores that are calculated using the motion capture data collected from the Oculus Quest 2 sensors. This will allow for a more systematic investigation into whether VR can really augment rehabilitation by reducing recovery times, but also tracking progress through the game scores, thus providing valuable feedback about where the player is on their recovery journey [24].

Secondly, the footballer's perceptions of the technology were evaluated after using the technology for a short time (over the course of a week). Current investigations are underway to investigate an athlete's perceptions of the technology when it is being used for longer term injuries where the VR technology is embedded in as part of the rehabilitation programme and scheduled for use over several weeks.

CONCLUSIONS AND RECOMMENDATIONS

This paper has assessed clinical staff and elite players' perceptions of the benefits and barriers regarding the wider adoption of VR technology for rehabilitation purposes in professional football. Our findings illustrate how VR holds value as a rehabilitation tool by increasing engagement, quantifying recovery through game scores, and providing a context for more goal-directed movements in a rehabilitation program. On the flip side, it was also recognised that VR rehabilitation tools should not be used for all injuries without prior consideration for how the technology is adding value. Indeed, some of its benefits (e.g., increased engagement) can come at risk of downsides (e.g., players over-committing and risking aggravating their injury in an attempt to 'beat their score'). As a result, clinical staff need time to develop a level of expertise on when and how to introduce the VR rehabilitation exercises. Secondly, the benefits of low-cost VR hardware in terms of accessibility reduce the specificity of the recovery programs by preventing footballers from using their feet inside the virtual environment. To understand this, future research should investigate the trade-off between the benefits that external-based motion tracking headsets bring to VR physiotherapy (i.e., full body tracking, ability to use feet in VR, rehabilitation exercises specific to football) compared to the downsides they bring (i.e., reduced portability, longer set up times, tenfold increase in equipment costs) to see which method of VR rehabilitation is better suited to an organisation's needs and budgets.

COMPETING INTERESTS

This research did not receive any external funding. DW, AJ, & NW declare no conflicts of interest. JS is an employee of INCISIV Ltd that created the MOVIR technology used

for the present study. CC is a professor of Experimental Psychology at Ulster University and contributed to the design of the MOVIR technology used for the present study. This study concerned the perceptions of using VR technology in an applied setting with none of the authors set to gain financially from the results.

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