

Topical collection on football research

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1 Executive Summary – Topical Collection 2023

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3 The symbiotic relationship between football, industry, and academia is deepening, creating
4 opportunities to develop every facet of the game. The combination of new technology, research-led
5 approaches, and football expertise is cultivating an environment where ideas can be developed,
6 assessed, and implemented faster than ever. It is important to ensure that the implementation of
7 these ideas benefit the world of football and are supported by evidence.

8
9 The Topical Collection on Football Research is a collaborative initiative that was launched to increase
10 awareness of ongoing research that is contributing to new technology developments in football. The
11 collection contains 15 papers that address: current challenges in football, game analysis and player
12 tracking technologies, officiating technologies, playing surface assessment, and football-surface, -
13 player and -environment interaction.

14 The collection includes an invited paper, which explores why women specific tailoring is needed in
15 football. The paper explores ten questions on football technology and engineering and covers similar
16 themes to the collection itself. It identifies the unique challenges that female players experience due
17 to the design and development of technology and football products around male players, as well as a
18 lack of research for female specific challenges. The paper identifies where focus is needed and calls
19 on industry, and academia to leverage new technologies and research methods to improve
20 performance and health for female players. The Sports Engineering community is keen to explore
21 ideas on how this topic can be further promoted across sport.

22 The use of player tracking data was a large theme within the collection. The collection addresses how
23 tracking data can be used, how it can be validated, and explores the accuracy behind emerging
24 technologies and techniques. A key paper on player tracking describes a novel algorithm to
25 automatically identify football events using player and ball tracking data. Currently event data,
26 including that captured in the FIFA World Cup 2022™ and FIFA Women's World Cup 2023™, is
27 collected manually. The lack of affordable data collection solutions can mean that access to accurate
28 event data is prohibited by cost. Research presented in the collection has the potential to be used by
29 competition organisers or governing bodies to provide event data where only broadcast cameras are
30 available.

31 The reliability and effectiveness of a model is inherently linked to the quality of the input data. The
32 relevance, the completeness and in particular the accuracy - amongst others. Research presented in
33 the collection demonstrates the validation of a tool that can be used for 'full pitch' validation of
34 player tracking data, generated by commercial technologies. The methodology demonstrated that the
35 tool can be used to establish concurrent validity for a range of Electronic Performance Tracking
36 Systems (EPTS) when used in large areas, with or without gold standard tools such as 3D motion
37 capture.

38 There are a vast number of player tracking providers used in the football industry, each with their
39 own benefits and challenges. Players will often have their data collected by a variety of different
40 systems. This might occur due to playing for different teams at the same time such as national and
41 club, or at different clubs over their career, or even when data is collected by the same team using
42 multiple systems. One paper in the collection presents a data clustering approach to quantify and
43 categorise the error of different EPTS systems against 3D motion capture. To improve the precision of

44 the data and the levels of agreement between different systems, multiple methods were explored to
45 decrease the error between the EPTS and the motion capture data. The study found that error
46 reduction of up to 60% could be induced and if applied correctly, practitioners could increase the
47 level of agreements between data from multiple systems.

48 A technical note presented research in which the researchers assessed the validity of an inertial
49 measurement unit-based approach to categorise physical demands of players into locomotion
50 categories. The paper assessed agreement of the algorithm for 41 players and found that it is
51 beneficial to establish individual calibration thresholds to improve the algorithm. Lastly, a study
52 presented within the collection assessed the validity of a LiDAR-based tracking system using three-
53 dimensional motion capture. Previous works have focussed on the validity of position and velocity
54 data; however, this paper also assessed the validity of acceleration data, providing useful information
55 for those working in field settings.

56 Technology is used heavily in football, from training and talent identification to fan engagement, but it
57 has only recently made its way into officiating. The earliest example of technology use for officiating
58 in football was Goal Line Technology at the FIFA World Cup 2014™. This was followed by the
59 introduction of Video Assistant Refereeing (VAR) at the FIFA World Cup 2018™. VAR is now deployed
60 in over 50 Member Associations across the world with many technology providers offering this
61 service to leagues and competition organisers. In response, work has been conducted to ensure that
62 systems being used by member associations are of a high quality and pass specific, evidence-based
63 assessments. Many of the VAR technology tests developed are based on the requirements of the end
64 users (e.g., Video Assistant Referees). The development and validation of these tests are described by
65 research presented in the collection, which sets out evidence-based pass or fail values. It is important
66 to ensure end users are consulted and involved in research of this nature where possible.

67 Reliably capturing player perception is important to help understand the player-turf interaction. One
68 study presents research demonstrating the development of a sensory panel to collect reliable player
69 perception data. Results show that targeted training can improve a player's ability to detect and
70 describe nuances between different playing surfaces, offering additional insights to traditional
71 mechanical testing. The agreement between results of the Rotational Traction Tester (RTT) and the
72 Advanced Artificial Athlete (AAA) were compared to player perceptions of various artificial turf
73 surfaces. Modifications were made to test equipment to improve agreement. For example, the RTT
74 was modified with additional instrumentation, allowing secondary stiffness as well as the operator's
75 rate of loading to be calculated. The AAA methodology used fewer drops and presents an amended
76 algorithm to estimate Vertical Deformation and Energy Restitution. Ongoing work will inform how the
77 new test equipment can be best implemented into requirements for playing surface assessment, and
78 ultimately drive products to better represent the needs of players.

79 It is important to understand the performance of playing surfaces and how characteristics change
80 when used. To address this, the collection showcases research exploring the short-term variability of
81 natural-grass surface characteristics during a high-usage tournament. The study identified
82 characteristics that were the most consistent, those with the largest and smallest variability, and
83 suggested that better monitoring for high areas of use could allow for improved targeting of surface
84 management applications.

85 The interaction between the players and the playing surface that they are performing on has an
86 impact on both the performance and the safety. The same can be said for the equipment that is used
87 in the game. Three studies conducted research on the football itself.

88 When the dynamics of the football and surface interaction are considered, it is important to establish
89 sensitive measurement tools to allow comparative assessments. The collection presents research
90 describing a method to reliably quantify impact forces associated with this dynamic interaction. The
91 study concluded that commercial force platforms could be used to detect subtle differences in
92 dynamic impact characteristics. In the future, this understanding could be used to better understand
93 the performance of different footballs, which could inform future strategies for football performance
94 and player safety.

95 An important factor when considering the player ball interaction is the action of heading. The
96 collection presents research on the effects of football inflation pressure during ball-to-head impacts.
97 Using anthropomorphic head and neck equipment, the study concluded that reducing the inflation
98 pressure of the football might reduce head accelerations during ball-to-head impacts. Further
99 investigation is required to understand whether findings are applicable to the full pressure range
100 described under the Laws of the Game, how reducing the pressure of the ball would affect other
101 impact characteristics, as well as performance and playability of the ball.

102 An important performance characteristic of a football is how it behaves aerodynamically. A study
103 presented in the collection explored the effect of surface features such as seam length and surface
104 roughness on aerodynamic properties through the assessment of 3D printed footballs with varying
105 surface features in a wind tunnel. The study developed novel methods designed to statistically
106 analyse the roughness of the ball and these were correlated against aerodynamic performance. The
107 findings can be used to inform evidence-based design decisions that improve the aerodynamic
108 behaviour of footballs.

109 The final theme of the collection highlights research that explores the factors that affect a player's
110 ability to score a goal. One study explored the football-boot interaction, where a protocol was
111 designed to measure the effect of football boot upper padding on shot accuracy and velocity. The
112 study found that additional padding of the boot's upper had a negative effect on shot accuracy and
113 no effect on the shot velocity. The protocol can be used in future research to inform boot design and
114 provides opportunities to gather empirical evidence for data-driven decisions for manufacturers in
115 the design process. Lastly, a modelling approach was used to explore how environmental factors such
116 as temperature, altitude, and humidity affects the scoring probability for a 25 m free kick. The
117 impacts of these were then modelled to illustrate how the trajectory of the free kick with the same
118 launch conditions would differ in five iconic stadiums.

119 The wide range of submissions published in the Topical Collection on Football Research demonstrates
120 the enormous impact that research can have to improve the game for the players, coaches,
121 competition organisers and fans. Further Topical Collections on Football Research will be launched to
122 build on what has been achieved so far. We would like to offer a big thank you to all those who have
123 taken part in the process and contributed to the collection's success and invite those who want to be
124 involved in the process and future collections to get in contact.

125 The conclusion of the Topical Collection on Football Research aligns strategically with the launch of
126 the FIFA Women's World Cup 2023™. The timing aims to capitalise on growing excitement
127 surrounding the biggest female football event in history and highlight ongoing research opportunities

128 that are available in football. The tournament will be hosted in 10 stadiums across Australia and New
129 Zealand and kicks-off on the 20th of July 2023. Under the banner of 'Beyond Greatness', the event
130 urges individuals to push beyond their comfort zones, overcome uncertainty, and break down
131 barriers – a philosophy that resonates strongly within the spheres of sport, industry and academia.