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Ten questions in Sports Engineering: Technology in elite women's football

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# **Ten questions in Sports Engineering: Technology in elite women's football**

## **ABSTRACT**

Use of technology in football is increasing, though, products predominantly focus on men's football in performance, safety, comfort, and fit considerations. A recent scoping review identified just 32 published scientific articles on technology in women's football, despite demands of those playing/working in the women's game increasing. We wish to highlight the progressions made so far and barriers remaining in elite women's football technology to shed a light on this topic and prod researchers and manufacturers to help support the evolution of women's-football-focussed technological considerations. The ten questions presented in this paper address the generic question on whether women's specific tailoring is needed (Question 1) as well as addressing specific questions on football technology and engineering such as the progressions made and ongoing issues in the following areas: football kits, religious considerations (hijab designs), sports bras, football boots, balls, football pitches, performance tracking devices, menstrual cycle tracking devices (Question 2-10). It is evidence that certain areas have received more attention than others and with these ten questions we hope to steer readers towards research and engineering gaps for future work.

**Keywords:** Soccer, female, design, manufacturing, pitch, cleats

21 **Introduction**

22 The field of sports engineering and technology is broad and diverse. The engineering and  
23 technology required in football is similarly vast with new technologies frequently introduced  
24 on the market. However, technology and engineering focus in football have and still are heavily  
25 targeting men's football. The women's side of the game is currently taking momentum in  
26 growth and professionalisation [1], which has changed the football technology and engineering  
27 demands of players and staff in elite women's football.

28 As a diverse author group composed of researchers, staff, and a player from elite women's  
29 football, we wish to highlight the progressions made so far and barriers remaining to shed a  
30 light on this topic and prod researchers and manufacturers to help support the evolution of  
31 women's-football-focussed technological considerations. The ten questions presented in this  
32 paper address the generic question on whether women's specific tailoring is needed (Question  
33 1) as well as addressing specific questions on football technology and engineering such as the  
34 progressions made and ongoing issues in the following areas: football kits, sports bras, football  
35 boots, football pitches, tracking devices, menstrual cycle tracking devices and other more  
36 overlooked areas (Question 2-10).

37

38 **Question 1 – Why do we need tailored technology designed for women in football?**

39 Use of technology in football is increasing. Most products are still predominantly designed for  
40 men's football. This is not an issue specific to football. Similar issues have been addressed in  
41 e.g., the space industry where space suits previously did not fit women astronauts [2] and toilets  
42 used in space were not designed for women's bodily functions causing issues with leakage [3].  
43 Similarly, respiratory personal protective equipment (PPE) for healthcare workers during the  
44 COVID-19 pandemic was designed for men, which left women at risk of contamination [4].  
45 Highlighting the sex-biased issues in football is important to steer research and the industry to  
46 address these, similarly to the cases mentioned, and now addressed, in the aeronautical and  
47 healthcare world.

48 A recent review scoped just 32 scientific articles on technology in women's football [5],  
49 indicating that little attention has been given and hence little is known about the technological  
50 requirements of women's football. Development of products and research on the men's side  
51 of the game has progressed for decades [6–8]. In the meantime, women were left to use these  
52 technologies and equipment designed predominantly for men, such as balls, kits, and boots.

53 Staff and players in the elite women's football have voiced concerns on social media platforms  
54 about multiple issues such as kit colour [9] and football boot fit issues [10] yet these issues are

55 not backed by evidence to date. We, therefore, hope readers will take these concerns and  
56 observations as guidance on where research on technology is needed to ensure evidence-based  
57 practice in women's football.

58 The demands and views of those playing/working in the elite women's game are changing.  
59 Previously, gratitude was high for any gifted garment/equipment/device. Today, focus has  
60 shifted to constructive collaborations and player/staff demands for change towards woman  
61 specificity. Changes have started but more attention is still needed to ensure the kit meets the  
62 requirements and desires of players.

63

#### 64 **Question 2 – How should football kits be designed to meet elite women footballers' needs?**

65 Bespoke women's fitted kits were not available until the FIFA 2019 Women's World Cup  
66 (WWC) [11]. Designing optimal kits is an ongoing conversation; bra and skin exposure through  
67 the top have not been fully appreciated, causing distress in some players.

68 Short colour is a neglected subject. Both football players and staff question why kit colour must  
69 match teammates from the men's team. Fear of sweat marks and visible leakage during  
70 menstruation is a concern for many players, with staff reporting that players ask them to keep  
71 an eye on their shorts when playing in light colours. Some players even report lack of game  
72 focus due to concerns about exposing themselves on live streaming with visible blood stains  
73 on their shorts [9]. Similar concerns have been raised in other sports such as tennis [12]and  
74 rugby [13].

75 Women's football shorts are short and perceived by some players to be exposing and  
76 sexualising them compared to their counterparts from the men's teams. Players like wearing  
77 cycling shorts (tightly fitted shorts) under their football shorts for protection of both these  
78 concerns but not all kit providers currently offer these.

79 Until the FIFA 2019 WWC, socks were unisex (i.e., men's fit) leaving some players to choose  
80 between something that fit their foot/boot, or their leg length/width, causing secondary issues  
81 including rubbing/slipping in the boot due to increased bulk of material. Medical staff report  
82 this as a risk factor for ankle sprains as players felt they were slipping inside the boots due to  
83 excessive sock material. In response, players commonly cut their football socks to wear grip  
84 performance socks underneath. This trend is also seen in men's football which in turn brings  
85 sponsorship-agreement failure fines.

86 No research was identified on the kit design for comfort, fit or performance. There is therefore  
87 a clear gap in the research field to understand the player desires and kit requirements.

88

89 **Question 3 – How has religious inclusion been considered in football kit manufacturing**  
90 **for women?**

91 Women’s specific clothing for women who, due to religious reasons, wish to cover more body  
92 skin than the traditional kit is also worth a mention. Whilst long sleeved shirts and trousers are  
93 accepted in football, face and hair covering has received pushbacks from governing bodies.  
94 When first challenged in 2007, the FIFA chief executive officer stated that hijab did not fall  
95 within the basic equipment outlined in law four of the game [14]. The Iranian women’s football  
96 team in 2011 were forced to forfeit their qualification game for the 2012 Olympics against  
97 Jordan due to the FIFA decision to ban headscarves on the pitch [15]. This ban was active  
98 despite no empirical evidence of any reported incidences of athletes being injured due to hijabs  
99 [14, 16]. Lobbying, sports hijab research and development of sport-specific products from  
100 companies such as Capsters and ResportOn, designed with safety recommendations outlined  
101 by the International Football Association Board (IFAB; the decision-making body for the laws  
102 of the game), led to a FIFA lift of the ban in March 2014 [17–19]. It was announced that  
103 religious head coverings (including hijabs, turbans for Sikh men and kippahs for Jewish men)  
104 would be permitted on the pitch where these head coverings meet IFAB medical regulations.  
105 These considerations highlight the importance of testing and development of technological  
106 alterations to women’s football to allow for maximal participation in the game.

107

108 **Question 4 - How are sports bras designed to match elite women footballers’ needs?**

109 The first sports bra is thought to have been developed in 1977, by sewing two jockstraps  
110 together. The sports bra industry has diversified since then, offering elite athletes and  
111 recreational exercisers many advancements in sports bra design, with level of breast support  
112 worn influencing biomechanical [20–22] and physiological [23, 24] variables. However, most  
113 research to date has focused on breast motion during treadmill walking and running [25]. This  
114 breast movement is unlikely to represent the frequency and magnitude of breast motion  
115 experienced by athletes training at high intensity or long duration, or in sports where athletes  
116 rapidly change direction, such as football. This can be detrimental for athletes as excessive  
117 breast motion during exercise has been associated with breast pain, reported by 44% of elite  
118 women athletes [26]. Furthermore, at the elite level many athletes are required to wear branded  
119 sports bras by the kit sponsors, which can negatively impact the fit, support and comfort of the  
120 bra. It is common for players to wear two bras, suffer in the pre-defined ‘sponsor’ bra, or risk  
121 fines for visible competing logos.

122 Sports bra brands commonly market their products as low-, medium, or high-impact support,  
123 suitable for specific sports. However, there has been limited research exploring breast motion  
124 in specific sports to support these categorisations [27]. To inform optimal breast support design  
125 for women footballers, the measurement of three-dimensional torso and breast motion of  
126 women footballers during training and match environments are required. The use of intelligent  
127 fabrics that respond to changes in breast motion and adjust the level of support accordingly  
128 [25] could also improve sports bra efficacy in sporting environments. However, there are  
129 challenges to overcome with integrating this technology into sports bras, including how to  
130 produce a garment that is both comfortable and robust enough to be washed [28]. At the elite  
131 level, bespoke sports bra design informed by individual breast and torso dimensions and breast  
132 biomechanical assessment, could be considered, although this has cost implications. This  
133 approach was successfully adopted at the recent Tokyo 2020 Olympic Games, where several  
134 Team GB athletes across a range of different sports were provided with bespoke bras to address  
135 their specific breast issues [29].

136

#### 137 **Question 5 - Have football boots been designed to match elite women footballers' needs?**

138 There are multiple concerns that surround men's football boots worn by women. These  
139 concerns are current and relevant as none of the larger manufacturers of football boots have yet  
140 invested in women's football boot designs [30]. Proper fit is an important feature related to  
141 comfort of footwear but also injury risk, fatigue, mobility, performance, and alignment of the  
142 lower limb [31–35]. Unlike running shoes, cushioning support in football boots is minimal, the  
143 outsole studs distribute pressures differently and the latter are narrower. These alterations in  
144 footwear design create around 9% less plantar surface area and 35% higher forefoot plantar  
145 pressures when walking in football boots in comparison to walking in running shoes [36],  
146 though measured on a hard surface. An optimal football boot fit is, therefore, important to  
147 ensure comfort, stabilise the foot, prevent fatigue and optimise both mobility and alignment of  
148 the lower limb.

149 Women's feet differ from men's feet in shape and volume [37, 38]. Though not reported in  
150 the literature, staff from the elite side report concerns with the impact of poor fit and foot  
151 deformation, skin conditions (e.g., blisters) and overuse injuries (e.g., metatarsal stress  
152 fractures). Therefore, optimal fit requires sex-specific fit requirements, and these issues are not  
153 yet solved.

154 Injury and performance concerns extend beyond the fit. Outsole stud/cleat types (e.g., soft  
155 ground outsoles or hard ground outsoles) aim to match a specific playing surface to optimise

156 traction. These optimal traction ranges have been designed and defined for men. Not obtaining  
157 optimal traction is both a concern for injury risk and performance measures [39, 40]. It is  
158 evident that anterior cruciate ligament (ACL) injuries are a big concern and a key research  
159 topic in elite women's football [5]. A common mechanism of ACL injuries in elite women's  
160 football has been identified to be non-contact with load added to an external foot position  
161 planted on the ground (identified using systematic video analysis) [41]. This mechanism is  
162 associated with findings from previous studies suggesting that increased shoe-surface traction  
163 (the boot getting stuck in the surface) is an ACL injury risk factor [42]. Therefore, applying an  
164 outsole producing too high traction may increase women's risk of injury [30]. Currently, only  
165 a single women-specific boot design is available from a start-up company [43]. Many of the  
166 major manufacturers are developing women's specific boots that should be available for the  
167 FIFA WWC in 2023, however the lack of football boots available is a general concern by  
168 researchers, players and staff working in women's football.

169

170 **Question 6 – How well do football pitches in elite women's football meet the performance**  
171 **and safety requirements?**

172 In a worldwide study of 1129 elite football players (n=1018 men and 111 women), 91% of  
173 players believed the type or condition of the playing surface increased injury risk. Hard, bumpy,  
174 and inconsistent playing surfaces and high or low traction (grip) were some of the major  
175 concerns [44]. During the FIFA 2019 WWC, the international level players (n = 196) ranked  
176 poor pitch quality and artificial turf as the 2<sup>nd</sup> and 3<sup>rd</sup> most important risk factors, respectively,  
177 for sustaining an injury, after low muscle strength [45]. Clearly players are concerned about  
178 surface type and/or conditions. Elite women are critical of the old or poorly maintained  
179 artificial surfaces they are often offered to play on, and although there is little (published)  
180 evidence that artificial surfaces lead to more injuries overall, most players prefer to play on  
181 natural grass [46]. International women players have for years utilised media to show pictures  
182 of skin abrasions sustained on artificial playing surfaces [47–49]. These photos were often  
183 accompanied by the player expressing their dislike for artificial playing surfaces. However,  
184 skin abrasions, while uncomfortable, will likely not cause a player to miss a match and are  
185 therefore not recorded as a 'time loss' injury in scientific studies.

186 Preferences are geographically dependent. Women players in Scandinavia expressed a  
187 preference for artificial playing surfaces over grass pitches via a survey-based questionnaire in  
188 2019. However, the reason being that the natural grass pitches women were exposed to were  
189 of such poor quality that players felt artificial pitches were a superior option. This issue

190 complicates attitudes towards grass pitches. It was concluded that an obvious negative  
191 difference exists between the natural grass pitch quality used for women in Norway, Sweden,  
192 and Denmark play on compared to men's tournament pitches [50].

193 Funding to improve pitch quality is needed for integration of technologies such as hybrid pitch  
194 reinforcement and sub-soil vacuum systems that are commonplace in elite men's football [51].

195 A focus on preparation and maintenance of good quality natural grass pitches that have not  
196 been worn out by men's games the previous day (common in e.g., Women's Super League) or  
197 being allocated better quality neutral pitches (e.g., qualifying rounds for UEFA Champions  
198 League games) is paramount.

199

200 **Question 7 – Does it impact playing performance that women play with the same footballs**  
201 **as men?**

202 Women play with a ball with identical criteria set, such as size, pressure, and material, to those  
203 of men. No adjustments have been made, which contrasts with other sports such as basketball  
204 and handball, where women play with a smaller and lighter ball. Research has, however,  
205 previously investigated the impact of changing the ball size on the game for women [52, 53].

206 It was demonstrated that women players kick the ball faster and report lower muscular exertion  
207 during games played with a lighter, smaller ball, though locomotor activities, heart rate and  
208 overall technical-tactical game performance remained unaffected [52, 53]. Since these studies  
209 were conducted around 10 years ago, little questioning of ball size has been made in relation  
210 to performance. There has been no research on whether players prefer playing with the same  
211 size ball as men. On the contrary, some concerns have been flagged, though not researched in  
212 detail about the ball size and mass in relation to the current concerns about increased incidence  
213 and severity of concussion in women's football compared to men's football [54, 55]. This has  
214 been demonstrated further by women exhibiting higher microstructural white matter alteration  
215 than men when heading a football [56]. Despite these safety concerns and the previous research  
216 on performance impact of ball size, it is generally accepted that women can and will play with  
217 the same ball design in football.

218

219 **Question 8 – What requirements are needed from tracking devices to match elite women**  
220 **footballers' needs?**

221 Global Positioning System (GPS) and heart rate monitoring equipment often have sex-specific  
222 setups; however, the default setting is usually for men. For example, GPS software systems  
223 will customarily be pre-programmed with the common thresholds used to measure physical



224 performance in men's football. Whilst it is possible to alter these thresholds, there is currently  
225 a lack of uniformity in the published literature regarding standardised thresholds for female  
226 players [57]. This may be considered problematic as failure to use population-specific velocity  
227 thresholds may lead to erroneous interpretations of player's physical match/training data which  
228 has implications for match and training GPS monitoring. It is also important to note that any  
229 derived thresholds may need to be altered frequently as the women's game continues to evolve,  
230 as illustrated by increases in physical match performance [58].

231 Women's teams habitually experience difficulties with ill-fitting HR and GPS monitoring  
232 equipment. Smaller players often have issues with the fit due to wrist or chest size differences  
233 compared to the larger men, which this equipment was originally designed for. These  
234 adversities with fit can result in sub-optimal data collection due to missing data as well as issues  
235 with comfort. Consequently, a simple recommendation is to ensure both GPS and heart rate  
236 monitoring equipment are available in sizes which are appropriate to cater for women.

237 GPS devices were generally used in men's sports first and therefore a garment was needed to  
238 house the unit; however, for elite women there is scope to integrate GPS devices into sports  
239 bras already worn during training and matches. Some GPS companies sell pouches separately  
240 which can be ironed/sewn on to a sports bra to reduce the need to wear additional layers of  
241 clothing. Recent additions to the market also include sports bras with heart rate monitoring  
242 technology sewn directly into the fabric, as well as bras manufactured by GPS companies  
243 which incorporate the pouch to secure the GPS device. However, as discussed in question 3,  
244 development of such bespoke products may limit sports bra choice, which could impact the  
245 level of support offered and compromise fit. More widespread accommodation of these  
246 technologies within sports bra design is warranted

247 Whilst it appears tracking devices were designed for men at first, the customisable nature of  
248 software means that these devices can simply be reprogrammed to ensure women-specific  
249 settings. Continued consideration is needed to ensure tracking hardware (e.g., vests, straps, and  
250 watches) are provided in appropriate sizes for all players. The recent developments by some  
251 technology companies to create a more integrated use of the sports bra to house tracking  
252 devices is a positive step forwards in ensuring bespoke monitoring support for women.

253

254 **Question 9 – How can menstrual cycle tracking apps be employed to manage elite women**  
255 **footballers' wellbeing and performance?**

256 Wellness monitoring apps and medical record systems commonly used in elite football do not  
257 request women's health information such as menstrual cycle logging and symptomology, or

258 use of hormonal contraception. Instead, some teams additionally use specific menstrual cycle  
259 tracking apps, and then have to manually interpret these data. Recent literature highlighted that  
260 80-95% of athletes experience menstrual cycle symptoms [59, 60], with these typically  
261 occurring pre- or during menstruation. Further, athletes perceive that their menstrual cycle can  
262 adversely alter readiness, attributing this to symptoms such as heavy bleeding, mood changes,  
263 fatigue, a perceived reduction in strength and pain [13, 59]. With this in mind, better monitoring  
264 of the menstrual cycle and symptomology alongside robust screening and the provision of  
265 education and proactive management strategies is needed to best support players. Menstrual  
266 cycle tracking apps are an ideal tool for this. Further, particularly where dysfunction or  
267 irregularities are suspected, urinary ovulation testing and/serum hormonal measures could be  
268 considered.

269

270 **Question 10 - Are there other areas where we need to address elite female footballers’**  
271 **needs from a sports technology perspective?**

272 Larger and more commonly discussed areas of technology have been reviewed in questions 2  
273 to 8, however the sports technology market expands beyond these discussed elements, and  
274 some will be discussed in brief below.

275 The development of sports friendly sanitary products and leak-proof clothing are potential  
276 strategies to address the concern raised about visible leakage due to the colour of shorts.  
277 However, to the authors’ knowledge, currently no research has addressed this issue to date.  
278 Moreover, access to sanitary products – even at national team level - is not a given when  
279 assessed globally. A group of researchers conducted a survey in November 2020 on women’s  
280 national team players competing in the Council of Southern Africa Football Association  
281 (COSAFA) Women’s Championship. They found a low presence of access to sanitary  
282 products, with 33% expressing having used old rags and 2% expressing having used toilet paper  
283 as alternatives to sanitary products [61].

284 Finally, women’s specific emergency medical equipment is paramount. Clear guidance on  
285 emergency medical equipment exists for both elite men’s and women’s football [62]. However,  
286 concerns have been raised around assumptions that equipment bought and used for men’s teams  
287 can be safely used with the desired effect for the club or national women’s team without the  
288 risk of issues. An example highlighted by medical staff in elite football is the standard cervical  
289 spine collars. It has been noted that, when tested on a women’s team – a procedure outside the  
290 set training and planning requirements - a worryingly poor fit was observed in smaller women.  
291 Applying a poorly fitted spine collar in trauma settings increases neck motion and hence

292 decreases safety and may lead to malmanagement of spinal fractures [63]. Assessing and  
293 checking fit of equipment on the relevant population(s) should therefore be standard best  
294 practice.

295

## 296 **Discussion**

297 FIFA has identified women's football as the single biggest opportunity for growth in football  
298 [64]. With elite women's football demonstrating recent growth in popularity [65], the sport is  
299 on an upward trajectory in terms of development and investment. Building on recent  
300 investment and popularity, the elite women's game has become increasingly professional [66].  
301 Still, the Fédération Internationale des Associations de Footballeurs Professionnels (FIFPro;  
302 World Players Union) recently reported a need for more investment and support if the women's  
303 game is to develop to its full potential [67]. As such, women's football seems to hold a complex  
304 position with both opportunities and challenges on the horizon. Women footballers are still not  
305 facing a level playing field and this is also evident from the sports technology perspective.  
306 Manufacturers are acknowledging this and a positive shift in developing women's specific  
307 football technology is happening. Though, due to a lack of research (with data often being  
308 extrapolated from men to women) not enough is known about the specific challenges facing  
309 elite women football players, thus technology advancements are limited by the level of research  
310 conducted.

311 To overcome these challenges, more products based on an enhanced understanding of women's  
312 specific needs are required to optimise performance, safety, and the overall experience for  
313 women's footballers. Advancements are being made, but these are often reliant on anecdotal  
314 evidence (as highlighted from this paper). A concerted effort is therefore needed from a  
315 research perspective to establish an evidence base to inform development of technologies that  
316 optimise performance and health. The authors of this paper aimed to highlight essential gaps  
317 in research and production of technology for elite women's football, which can help steer the  
318 directions of women's football attention in sports engineering research and manufacturing.

319

## 320 **Conclusion**

321 Elite women's football keeps growing and so do the requirements for football technology and  
322 engineering designed for women. We hope this paper has provided researchers and  
323 manufacturers with inspiration and insight into the requirements desired from the elite  
324 women's football world. As addressed, this industry is in rapid development and there are  
325 multiple issues still to be tackled. Though as a final remark, a general appreciation for the

326 current efforts made and increase in attention from manufacturers and researchers can also be  
327 mentioned.

328

329 ***Compliance with ethical standards***

330 Not applicable.

331

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333 None.

334

335 ***Conflict of Interest***

336 Four authors have received funding from sports technology companies for research purposes.

337 Six authors are or have recently worked on elite women's football for teams sponsored by  
338 sports technology companies.

339 One author is a professional player and is sponsored by Nike.

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