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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 2nd and 3rd 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.

340 **REFERENCE LIST**

- 341 1. UEFA (2022) the business case for women’s football.
342 [Httseditorialuefacomresources0278-15e121074702-C9be7dcd0a29-](https://editorial.uefa.com/resources/0278-15e121074702-C9be7dcd0a29-1000businesscaseforwomensfootball-Externalreport1.pdf)
343 [1000businesscaseforwomensfootball-Externalreport1.pdf](https://editorial.uefa.com/resources/0278-15e121074702-C9be7dcd0a29-1000businesscaseforwomensfootball-Externalreport1.pdf)
- 344 2. Benson E, Rajulu S (2009) Complexity of Sizing for Space Suit Applications. In: Duffy
345 VG (ed) *Digital Human Modeling*. Springer, Berlin, Heidelberg, pp 599–607
- 346 3. Kahlenberg B, Corroll D, Cristea O, et al (2021) Urologic Innovation in the Spaceflight
347 Environment: Challenges, Opportunities, and Future Directions. *Med Res Arch* 9:1–18
- 348 4. Ascott A, Crowest P, de Sausmarez E, et al (2021) Respiratory personal protective
349 equipment for healthcare workers: impact of sex differences on respirator fit test results.
350 *BJA Br J Anaesth* 126:e48–e49. <https://doi.org/10.1016/j.bja.2020.10.016>
- 351 5. Okholm Kryger K, Wang A, Mehta R, et al (2022) Can we evidence-base injury
352 prevention and management in women’s football? A scoping review. *Res Sports Med*
353 0:1–16. <https://doi.org/10.1080/15438627.2022.2038161>
- 354 6. Almulla J, Takiddin A, Househ M (2020) The use of technology in tracking soccer
355 players’ health performance: a scoping review. *BMC Med Inform Decis Mak* 20:184.
356 <https://doi.org/10.1186/s12911-020-01156-4>
- 357 7. Kulesa DJ, Gollhofer A, Gehring D (2017) The influence of football shoe characteristics
358 on athletic performance and injury risk – a review. *Footwear Sci* 9:49–63.
359 <https://doi.org/10.1080/19424280.2017.1284273>
- 360 8. Reilly T, Gilbourne D (2003) Science and football: a review of applied research in the
361 football codes. *J Sports Sci* 21:693–705. <https://doi.org/10.1080/0264041031000102105>
- 362 9. Garry T (2022) FA to consider white shorts U-turn after England’s women raise period
363 fears. *The Telegraph*
- 364 10. Kessel A (2018) If the boot doesn’t fit then female footballers should have an alternative.
365 *The Guardian*
- 366 11. Christenson M (2019) England women reveal bespoke new kit for 2019 World Cup. *The*
367 *Guardian*
- 368 12. Weaving C (2017) Breaking Down the Myth and Curse of Women Athletes: Enough is
369 Enough, Period. *Women Sport Phys Act J* 25:43–49.
370 <https://doi.org/10.1123/wspaj.2016-0010>
- 371 13. Findlay RJ, Macrae EHR, Whyte IY, et al (2020) How the menstrual cycle and
372 menstruation affect sporting performance: experiences and perceptions of elite female
373 rugby players. *Br J Sports Med* 54:1108–1113. [https://doi.org/10.1136/bjsports-2019-](https://doi.org/10.1136/bjsports-2019-101486)
374 [101486](https://doi.org/10.1136/bjsports-2019-101486)
- 375 14. Ahmad A (2011) British football: where are the Muslim female footballers? Exploring
376 the connections between gender, ethnicity and Islam. *Soccer Soc* 12:443–456.
377 <https://doi.org/10.1080/14660970.2011.568110>

- 378 15. Ryan CR (2012) The politics of FIFA and the Hijab. In: Foreign Policy.
 379 <https://foreignpolicy.com/2012/02/28/the-politics-of-fifa-and-the-hijab/>. Accessed 28
 380 Feb 2022
- 381 16. Prouse C (2015) Harnessing the hijab: the emergence of the Muslim Female Footballer
 382 through international sport governance. *Gend Place Cult* 22:20–36.
 383 <https://doi.org/10.1080/0966369X.2013.832664>
- 384 17. Al Saied N, Creedon P (2021) Chapter 4: Women’s Sports and Fashion in Arab Gulf
 385 Countries. In: Fuller LK (ed) *Sportswomen’s Apparel Around the World: Uniformly*
 386 *Discussed*. Springer International Publishing, Cham, pp 69–82
- 387 18. Hamzeh M (2017) FIFA’s double hijabophobia: A colonialist and Islamist alliance
 388 racializing Muslim women soccer players. *Womens Stud Int Forum* 63:11–16.
 389 <https://doi.org/10.1016/j.wsif.2017.06.003>
- 390 19. Shirazi F (2021) CHAPTER 7 Sportswear, Lingerie, and Accessories—the Islamic Way.
 391 In: CHAPTER 7 Sportswear, Lingerie, and Accessories—the Islamic Way. University
 392 of Texas Press, pp 175–198
- 393 20. Shivitz N (2001) Adaptation of vertical ground reaction force due to changes in breast
 394 support in running.
 395 https://ir.library.oregonstate.edu/concern/graduate_thesis_or_dissertations/9880vs96k
- 396 21. White JL, Scurr JC, Smith NA (2009) The effect of breast support on kinetics during
 397 overground running performance. *Ergonomics* 52:492–498.
 398 <https://doi.org/10.1080/00140130802707907>
- 399 22. Milligan A, Mills C, Corbett J, Scurr J (2015) The influence of breast support on torso,
 400 pelvis and arm kinematics during a five kilometer treadmill run. *Hum Mov Sci* 42:246–
 401 260. <https://doi.org/10.1016/j.humov.2015.05.008>
- 402 23. Milligan A, Mills C, Scurr J (2014) The effect of breast support on upper body muscle
 403 activity during 5 km treadmill running. *Hum Mov Sci* 38:74–83.
 404 <https://doi.org/10.1016/j.humov.2014.06.001>
- 405 24. White JL, Lunt H, Scurr J (2011) The effect of breast support on ventilation and breast
 406 comfort perception at the onset of exercise. In: *In Proceedings of the BASES annual*
 407 *conference*. p S75. Essex: BASES
- 408 25. McGhee DE, Steele JR (2020) Biomechanics of Breast Support for Active Women. *Exerc*
 409 *Sport Sci Rev* 48:99–109. <https://doi.org/10.1249/JES.0000000000000221>
- 410 26. Brisbane BR, Steele JR, Phillips EJ, McGhee DE (2020) Breast pain affects the
 411 performance of elite female athletes. *J Sports Sci* 38:528–533.
 412 <https://doi.org/10.1080/02640414.2020.1712016>
- 413 27. Brisbane B (2019) Breast pain and breast injuries experienced by female athletes. Univ
 414 Wollongong Thesis Collect 2017

- 415 28. Campbell TE, Munro BJ, Wallace GG, Steele JR (2007) Can fabric sensors monitor
416 breast motion. *J Biomech* 40:3056–3059.
417 <https://doi.org/10.1016/j.jbiomech.2007.01.020>
- 418 29. Geddes L (2021) 'They're not treating us a small men': Team GB women get the right
419 bras. *The Guardian*
- 420 30. Thomson A (2020) Same same, but different? Should football boot selection be a
421 consideration after ACLR. *Aspetar Sports Med J* 9:50–55
- 422 31. Kinchington MA, Ball KA, Naughton G (2011) Effects of footwear on comfort and injury
423 in professional rugby league. *J Sports Sci* 29:1407–1415.
424 <https://doi.org/10.1080/02640414.2011.593041>
- 425 32. Miller JE, Nigg BM, Liu W, et al (2000) Influence of foot, leg and shoe characteristics on
426 subjective comfort. *Foot Ankle Int Am Orthop Foot Ankle Soc Swiss Foot Ankle Soc*
427 21:759–767
- 428 33. Mündermann A, Stefanyshyn DJ, Nigg BM (2001) Relationship between footwear
429 comfort of shoe inserts and anthropometric and sensory factors. *Med Sci Sports Exerc*
430 33:1939–1945
- 431 34. Nigg BM, Nurse MA, Stefanyshyn DJ (1999) Shoe inserts and orthotics for sport and
432 physical activities. *Med Sci Sports Exerc* 31:S421-428
- 433 35. Williams AE, Nester CJ (2006) Patient perceptions of stock footwear design features.
434 *Prosthet Orthot Int* 30:61–71
- 435 36. Santos D, Carline T, Flynn L, et al (2001) Distribution of in-shoe dynamic plantar foot
436 pressures in professional football players. *The Foot* 11:10–14.
437 <https://doi.org/10.1054/foot.2000.0640>
- 438 37. Krauss I, Valiant G, Horstmann T, Grau S (2010) Comparison of female foot morphology
439 and last design in athletic footwear--are men's lasts appropriate for women? *Res Sports*
440 *Med Print* 18:140–156. <https://doi.org/10.1080/15438621003627216>
- 441 38. Krauss I, Grau S, Mauch M, et al (2008) Sex-related differences in foot shape.
442 *Ergonomics* 51:1693–1709. <https://doi.org/10.1080/00140130802376026>
- 443 39. Thomson A, Whiteley R, Bleakley C (2015) Higher shoe-surface interaction is associated
444 with doubling of lower extremity injury risk in football codes: a systematic review and
445 meta-analysis. *Br J Sports Med* 49:1245–1252. [https://doi.org/10.1136/bjsports-2014-](https://doi.org/10.1136/bjsports-2014-094478)
446 094478
- 447 40. Villwock MR, Meyer EG, Powell JW, et al (2009) Football playing surface and shoe
448 design affect rotational traction. *Am J Sports Med* 37:518–525.
449 <https://doi.org/10.1177/0363546508328108>
- 450 41. Lucarno S, Zago M, Buckthorpe M, et al (2021) Systematic Video Analysis of Anterior
451 Cruciate Ligament Injuries in Professional Female Soccer Players. *Am J Sports Med*
452 49:1794–1802

- 453 42. Bisciotti GN, Chamari K, Cena E, et al (2019) Anterior cruciate ligament injury risk
454 factors in football. *J Sports Med Phys Fitness* 59:1724–1738.
455 <https://doi.org/10.23736/S0022-4707.19.09563-X>
- 456 43. Garry T (2021) Why footwear gender gap must be tackled. In: *The Telegraph*.
457 <https://www.telegraph.co.uk/football/2021/04/23/footwear-gender-gap-must-tackled/>.
458 Accessed 4 Aug 2022
- 459 44. Mears AC, Osei-Owusu P, Harland AR, et al (2018) Perceived Links Between Playing
460 Surfaces and Injury: a Worldwide Study of Elite Association Football Players. *Sports*
461 *Med - Open* 4:40. <https://doi.org/10.1186/s40798-018-0155-y>
- 462 45. Geertsema C, Geertsema L, Farooq A, et al (2021) Injury prevention knowledge, beliefs
463 and strategies in elite female footballers at the FIFA Women’s World Cup France 2019.
464 *Br J Sports Med*. <https://doi.org/10.1136/bjsports-2020-103131>
- 465 46. Roberts JR, Osei-Owusu P, Mears AC, Harland AR (2020) Elite Players’ Perceptions of
466 Football Playing Surfaces: A Qualitative Study. *Res Q Exerc Sport* 91:239–251.
467 <https://doi.org/10.1080/02701367.2019.1660757>
- 468 47. Harris R (2019) FIFA will not allow artificial fields at 2023 Women’s WCup. In: AP
469 NEWS. <https://apnews.com/article/c54d2025b7c84ad982240d860b3a91dd>. Accessed 4
470 Aug 2022
- 471 48. Hill J (2014) Why FIFA Is Snubbing Its Top Women Stars. In: *ABC News*.
472 <https://abcnews.go.com/Sports/fifa-snubbing-top-women-stars/story?id=25948778>.
473 Accessed 4 Aug 2022
- 474 49. Alba M (2015) U.S. Soccer Star Abby Wambach: Playing on Turf a “Nightmare.” In:
475 *NBC News*. [https://www.nbcnews.com/storyline/artificial-turf-debate/us-soccer-star-](https://www.nbcnews.com/storyline/artificial-turf-debate/us-soccer-star-abby-wambach-playing-turf-nightmare-n371906)
476 [abby-wambach-playing-turf-nightmare-n371906](https://www.nbcnews.com/storyline/artificial-turf-debate/us-soccer-star-abby-wambach-playing-turf-nightmare-n371906). Accessed 4 Aug 2022
- 477 50. FIFPRO (2019) Playing surfaces in the professional football leagues in Scandinavia
- 478 51. James IT (2011) Advancing natural turf to meet tomorrow’s challenges. *Proc Inst Mech*
479 *Eng Part P J Sports Eng Technol* 225:115–129
- 480 52. Andersen TB, Krstrup P, Bendiksen M, et al (2016) Kicking Velocity and Effect on
481 Match Performance When using a Smaller, Lighter Ball in Women’s Football. *Int J*
482 *Sports Med* 37:966–972. <https://doi.org/10.1055/s-0042-109542>
- 483 53. Andersen TB, Bendiksen M, Pedersen JM, et al (2012) Kicking velocity and physical,
484 technical, tactical match performance for U18 female football players--effect of a new
485 ball. *Hum Mov Sci* 31:1624–1638. <https://doi.org/10.1016/j.humov.2012.07.003>
- 486 54. Dick RW (2009) Is there a gender difference in concussion incidence and outcomes? *Br J*
487 *Sports Med* 43:i46–i50. <https://doi.org/10.1136/bjsm.2009.058172>
- 488 55. Vedung F, Hänni S, Tegner Y, et al (2020) Concussion incidence and recovery in
489 Swedish elite soccer — Prolonged recovery in female players. *Scand J Med Sci Sports*
490 30:947–957. <https://doi.org/10.1111/sms.13644>

- 491 56. Rubin TG, Catenaccio E, Fleysler R, et al (2018) MRI-defined White Matter
492 Microstructural Alteration Associated with Soccer Heading Is More Extensive in
493 Women than Men. *Radiology* 289:478–486. <https://doi.org/10.1148/radiol.2018180217>
- 494 57. Harkness-Armstrong A, Till K, Datson N, et al (2022) A systematic review of match-play
495 characteristics in women’s soccer. *PLOS ONE* 17:e0268334.
496 <https://doi.org/10.1371/journal.pone.0268334>
- 497 58. FIFA (2019) Physical analysis of the FIFA Women’s World Cup France 2019™.
498 <https://img.fifa.com/image/upload/zijqly4oednqa5gffgaz.pdf>
- 499 59. Armour M, Parry KA, Steel K, Smith CA (2020) Australian female athlete perceptions of
500 the challenges associated with training and competing when menstrual symptoms are
501 present. *Int J Sports Sci Coach* 15:316–323. <https://doi.org/10.1177/1747954120916073>
- 502 60. Clarke A, Govus A, Donaldson A (2021) What male coaches want to know about the
503 menstrual cycle in women’s team sports: Performance, health, and communication. *Int J*
504 *Sports Sci Coach* 16:544–553. <https://doi.org/10.1177/1747954121989237>
- 505 61. Mkumbuzi NS, Dlamini SB, Chibhabha F, et al (2021) The menstrual cycle and football:
506 The experiences of female African football players. *Sci Med Footb* 0:null.
507 <https://doi.org/10.1080/24733938.2021.2005252>
- 508 62. UEFA (2019) Guide to minimum medical requirements 2019/20.
509 [https://www.uefa.com/MultimediaFiles/Download/uefaorg/Medical/02/61/67/19/261671](https://www.uefa.com/MultimediaFiles/Download/uefaorg/Medical/02/61/67/19/2616719_DOWNLOAD.pdf)
510 [9_DOWNLOAD.pdf](https://www.uefa.com/MultimediaFiles/Download/uefaorg/Medical/02/61/67/19/2616719_DOWNLOAD.pdf) 17–18
- 511 63. Bell KM, Frazier EC, Shively CM, et al (2009) Assessing range of motion to evaluate the
512 adverse effects of ill-fitting cervical orthoses. *Spine J* 9:225–231.
513 <https://doi.org/10.1016/j.spinee.2008.03.010>
- 514 64. FIFA (2021) Accelerate the growth of women’s football. [https://www.fifacom.com/womens-](https://www.fifacom.com/womens-Footb)
515 [Footb](https://www.fifacom.com/womens-Footb).
- 516 65. UEFA (2017) Women’s football across the national associations
- 517 66. Welford J (2015) Globalising Women’s Football: Europe, Migration and
518 Professionalization. *Int J Hist Sport* 32:726–728.
519 <https://doi.org/10.1080/09523367.2015.1004914>
- 520 67. FIFPRO (2020) Raising our game. Women’s Football Report. Accessed
521 [https://www.fifpro.org/media/vd1pbthj/fifpro-womens-report_eng-](https://www.fifpro.org/media/vd1pbthj/fifpro-womens-report_eng-lowres.pdf?fbclid=IwAR3925o7O74C14a3hQG7nYRthrHX6g9RyNPIXe1CGuKTsyD0KASKxIRDc4w)
522 [lowres.pdf?fbclid=IwAR3925o7O74C14a3hQG7nYRthrHX6g9RyNPIXe1CGuKTsyD](https://www.fifpro.org/media/vd1pbthj/fifpro-womens-report_eng-lowres.pdf?fbclid=IwAR3925o7O74C14a3hQG7nYRthrHX6g9RyNPIXe1CGuKTsyD0KASKxIRDc4w)
523 [0KASKxIRDc4w](https://www.fifpro.org/media/vd1pbthj/fifpro-womens-report_eng-lowres.pdf?fbclid=IwAR3925o7O74C14a3hQG7nYRthrHX6g9RyNPIXe1CGuKTsyD0KASKxIRDc4w)
- 524