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ORIGINAL RESEARCH ARTICLE

The Women's Soccer Health Study: From Head to Toe

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Abstract

Objectives Women are under-represented in the sports literature despite increasing rates of sports participation. Our objective was to investigate the risks and benefits of an elite women's soccer career in five health domains: general, musculoskeletal, reproductive endocrinology, post-concussion, and mental.

Methods An online survey was distributed to retired US college, semi-professional, professional, and national team soccer players using personal networks, email, and social media. Short validated questionnaires were used to evaluate the health domains, including the Patient-Reported Outcomes Measurement Information System (PROMIS), Single Assessment Numerical Evaluation (SANE), Post-Concussion Symptom Scale (PCSS), and Patient Health Questionnaire (PHQ).

Results A total of 560 eligible players responded to the survey over a 1-year period. The highest competitive levels were 73% college, 16% semi-professional, 8% professional, and 4% national team. The mean number of years since retirement was 12 (SD = 9), and 17.0% retired for involuntary reasons. The mean SANE scores (0–100 scale as percentage of normal) were knee = 75% (SD = 23), hip = 83% (SD = 23), and shoulder = 87% (SD = 21). The majority (63%) reported that their current activity level included participation in impact sports. A substantial proportion of players reported menstrual irregularities during their careers: 40% had fewer periods with increasing exercise and 22% had no periods for ≥ 3 months. The players ($n = 44$) who felt that post-concussion symptoms were due to soccer reported more time-loss concussions ($F[2] = 6.80$, $p = 0.002$) and symptom severity ($F[2] = 30.26$, $p < 0.0001$). Players who recently retired (0–5 years) reported the highest anxiety/depression scores and lowest satisfaction rates compared with those who retired 19+ years ago.

Conclusion Health concerns include musculoskeletal injuries, post-concussion symptoms, and lower mental health in the early years following retirement. This comprehensive survey provides initial results that will lay the foundation for further analyses and prioritize research studies that can help all female athletes.

Key Points

Despite the rising participation of girls and women in sports, female athletes are under-represented in the sport and exercise medicine literature.

This study investigates both the current and past health of former women's soccer players in five health domains to obtain a better clinical picture of the lifetime risks and benefits of playing at an elite level.

Our cohort of elite soccer players reported an average career length of 5 years, one soccer-related surgery, one time-loss concussion, and were only somewhat satisfied with their careers.

These results can be used to promote wellness, identify risks that may be preventable, and develop interventions that will help protect future generations of women's soccer players and other female athletes.

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1 Introduction

The principles of public health are based on prevention, protection, and promotion that apply regardless of the population. There is a long history of epidemiologic studies in public health, notably the Framingham Heart Study to investigate the etiology of coronary heart disease [1] and the Nurses' Health Study on the development of chronic diseases in women [2–4]. In the sports literature, prospective cohort studies have also been performed. The National Football League (NFL) Players Health Study enrolls retired NFL players who have played in the league since 1960 and evaluates their general, cardiovascular, neurocognitive, musculoskeletal, and sleep-related health [5]. The Drake Football (Soccer) Study aims to recruit professional football players in Europe and follow them in the transitioning years pre- and post-retirement [6]. Of note, the protocol for the Drake Football Study, published in 2019, included only male footballers and has since been expanded to include female footballers.

There is ample evidence that women are under-represented in the sports medicine and exercise literature. In a review of articles published in three top journals—*British Journal of Sports Medicine, American Journal of Sports Medicine,* and *Medicine and Science in Sport and Exercise*—there were 1382 articles published over a 3-year period, in which 61% of participants were male and only 39% were female [7]. This disparity was statistically significant and did not differ across journals. While the majority of articles included participants of both sexes, those involving only male participants ranged from 18 to 34% across journals. This sex and gender disparity does not align with the rise of female athlete participation, which has increased from 2% for the 1900 Paris Olympics to almost 50% for the 2021 Tokyo Olympics [8].

It is well known that soccer is a high-risk sport for women. They are more likely to suffer both musculoskeletal injuries [9] and concussions [10] compared with their male counterparts. Two of our meta-analyses found that women had higher risk than men for both initial and recurrent concussions in soccer across various sex-comparable sports [10, 11]. While the association between knee injuries, particularly anterior cruciate ligament (ACL) tears, and premature osteoarthritis has been well studied [12], the relationship between concussions and neurocognitive or mental health in female athletes has not been explored. There is limited data on the effects of the reproductive hormones, estrogen and progesterone, on health outcomes, performance parameters [13], and injury risk [14, 15]. Furthermore, the impact of the Female Athlete Triad (low energy availability, hormonal disruption, and poor bone health) on long-term physical and reproductive health has not been well researched [16–18]. A systematic review in elite athletes found that there was very low- or low-quality evidence on postpartum outcomes such as return to sports, injury risk, and performance [19]. With increasing numbers of female athletes competing during and after pregnancy, a better understanding of the impact of elite sports across the lifespan is necessary. More recently, the Triad has been expanded to Relative Energy Deficiency in Sport (RED-S), which recognizes the deleterious effects that low energy availability can have on bodily systems, including the metabolic, immunological, and cardiovascular systems [20].

To address the sex and gender gap in the literature and build upon the long history of public health studies, this study aims to evaluate the health impact, both adverse and beneficial, of a playing career dedicated to elite-level women's soccer in five health domains from head to toe: general, musculoskeletal, reproductive endocrinology, post-concussion, and mental. These domains were chosen based on the protocol for the Drake Football Study [6]. Our study differs by including a general health (including physical status) domain and excluding cardiovascular and neurocognitive testing, which could not be accomplished with an online survey. However, we evaluate post-concussion symptoms using a common validated scale [21].

2 Methods

2.1 Eligibility Criteria

Players were eligible if they retired from competing at the elite level, defined as College (at least 1 year at a National Collegiate Athletic Association [NCAA] institution [Divisions I–III]), Semi-Professional (at least one season in a semi-professional league), Professional (at least one season in a US professional league or top division overseas), and Senior National Team (at least one appearance for any country). In addition, the players needed to be located in the US to comply with Health Insurance Portability and Accountability Act (HIPAA) regulations and be ≤ 70 years of age (to coincide with the passage of Title IX in 1972). Players were asked to complete an anonymous survey on REDCap (REDCap Consortium, Vanderbilt University, Nashville, Tennessee, USA), a secure online platform. The survey was distributed by contacting the professional networks of study investigators, NCAA institutions, soccer alumni groups, and using social media. Since REDCap keeps all records, duplicate records (i.e. respondent started the survey then completed another on a later day) were checked using date of birth and player profile information.

Players were asked about demographics and playing history. The questions included the age at which they starting playing organized sports and when they specialized in soccer. They were asked to report their competitive levels, the number of years/seasons, and the most frequent field position at each level. Finally, the players were asked for their

year and reason for retirement. The number of years since retirement was categorized into quartiles based on the data distribution: 0–5, 6–10,11–18, and 19+ years.

2.2 General Health

The Patient-Reported Outcomes Measurement Information System (PROMIS)-10 Global Health scale, is a commonly used questionnaire containing 10 items that was developed by the National Institutes of Health [22]. T-scores ranging from 0 to 100, which are the outputs of the PROMIS-10, are provided for both physical and mental health, with T-scores of 50 (SD = 10) representing the mean for the US general population. Higher scores indicate better health. In addition, the University of California, Los Angeles (UCLA) Activity Score consists of one question to determine current physical activity level [23].

2.3 Musculoskeletal Health

Retired players were asked about the number and location of soccer-related surgeries during and after their careers. We focused on surgery (as opposed to injury) since they are more severe, result in time loss from practices or games, and may be less subject to poor recall. We also used the Single Assessment Numerical Evaluation (SANE) score, which is one question, to rate their shoulder, hip, and knee function as a percentage of normal (0% to 100% with 100% being normal) [24].

2.4 Reproductive Endocrinology Health

Players were asked questions on menstruation, nutrition, and bone health from various Female Athlete Triad screening tools that have been developed [25, 26]. Eleven questions on the three components of the Triad were included from the 2014 Female Athlete Triad Coalition Consensus Statement [25]. Five questions on hormonal contraceptive use and six questions on menstrual function were included from the Low Energy Availability in Females (LEAF) questionnaire [26]. Questions relate to menstrual dysfunction, hormonal contraceptive use, pregnancy, disordered eating (subclinical conditions without fully meeting the criteria for an eating disorder) and eating disorders [25, 27], as well as the number and location of stress fractures during and after the career.

2.5 Post-Concussion Health

Players were asked to report the number of soccer-related concussions during their careers and the number of concussions that led to missed practices and games. Players who reported at least one time-loss concussion were then asked to complete the Post-Concussion Symptom Scale (PCSS), which is a validated symptom measurement tool for post-concussion syndrome [21]. The PCSS consists of 22 symptoms with scoring based on severity (0–6), with higher scores indicating greater severity. For those who reported the presence of any symptoms, they were asked whether they felt that the symptoms were due to soccer-related concussions.

2.6 Mental Health

The General Anxiety Disorder (GAD)-7 is a well-known scale that has been used to assess for anxiety [28]. The Patient Health Questionnaire (PHQ)-4 has been validated as a brief questionnaire for combined anxiety and depression and consists of the first two questions from both the GAD-7 and PHQ-9, which is used to evaluate for depression [29]. Additional questions were used to distinguish mental health symptoms, encompassing emotional, psychological, and social well-being, that may be due to loss of athletic identity during retirement from the possible sequelae of concussions. Soccer career and post-career satisfaction were measured on a Likert scale. In addition, players were asked whether they were still involved in soccer and to respond with true/false to the question "If I could go back in time, I would choose again to become an elite soccer player".

An overview of the validated questionnaires for each of the five health domains is provided in Table 1. The online survey was pilot-tested by co-investigators and research assistants, some of whom were college-level athletes (including soccer), for clarity, flow, and timing.

2.7 Statistical Analysis

Descriptive statistics were reported, including the mean, standard deviation (SD), and range. Results were also compared across highest competitive level, field position at the highest level, and category for years since retirement using the one-way ANOVA test and pairwise comparisons. The χ^2 test was used for categorical variables with the same comparisons. Statistical significance was set at the alpha = 0.05 level. All analyses were conducted using Stata 17 (StataCorp, College Station, TX, USA).

3 Results

3.1 Player Profiles

A total of 656 players started the online survey, and 33 did not meet eligibility criteria. There were 46 records with only

the consent page completed, and 17 duplicate records were excluded. Thus, the analysis included data for 560 players from February to December 2021. For those who played in college, the levels were Division I (76.2%), II (8.0%), and III (15.9%). For players on the national team, the number of appearances ranged from 1 to 190+. A total of 89 (16.0%) players had played for a youth national team (Table 2).

The most common reason for retirement was graduation/expired eligibility (61.3%), while 17.0% retired for involuntary reasons (COVID-related, coach decision, injury/illness, or league folded/unavailable). There was no difference in the proportion of players who reported involuntary retirement across competitive levels ($\chi^2[3] = 5.88$, $p = 0.12$). The mean age at start of playing organized sports was 6 years (SD = 3, range 2–20) with an average of three (SD = 2, range 0–11) sports played. The most frequent sports were basketball (60.2%), track and field (40.9%), softball (31.8%), volleyball (19.1%), and baseball (4.3%). A total of 35 (6.3%) players reported playing no other sports. The mean age for specializing in soccer was 14 years (SD = 3, range 4–23). Players with the greatest number of years since retirement (19+ years) reported the oldest age of playing organized sports (8 years; $p < 0.0001$), age of specializing in soccer (15 years; $p < 0.0001$), and number of sports played (3; $p = 0.03$).

3.2 General Health

The vast majority of players reported excellent ($n = 213$, 38.1%), very good ($n = 228$, 40.8%), or good ($n = 108$, 19.3%) general health on the PROMIS-10. For the physical health component, the mean T-score was 54.3 (SD = 6.7, range 32.9–67.7), while that for the mental health component was 52.0 (SD = 7.9, range 31.6–67.6). Most players reported that their current activity level included participating in impact sports, either regularly ($n = 182$, 33.4%) or sometimes ($n = 160$, 29.4%). This pattern of mostly excellent/very good health and participation in impact sports was seen regardless of the level, position, or years since retirement.

3.3 Musculoskeletal Health

Data on soccer-related surgical procedures are shown in Table 3. The most frequent locations, all lower extremity, were similar during and after the playing career. More surgical procedures were reported during the career with higher levels of competition ($F[3] = 4.82$; $p = 0.003$). The biggest differences were seen comparing college players versus professional (difference = 0.7 [95% CI 0.1–1.4]; $p = 0.02$) and national team players (difference = 0.8 [95% CI −0.1 to 1.8]; $p = 0.09$). There was also a gradient of greater number of post-career surgeries with years since retirement ($F[3] = 12.12$; $p < 0.0001$). On the SANE scale, the knee was the worst-affected joint (mean = 75, SD = 23), followed by hip (mean = 83, SD = 23) and shoulder (mean = 87, SD = 21). There was a significant difference on the SANE knee score by field position ($F[3] = 2.94$; $p = 0.03$). Goalkeepers had better perceived knee function than forwards (difference = 9.8 [95% CI 0.6–19.0]; $p = 0.03$).

Table 1 Overview of the validated questionnaires used in each of the five health domains

Health domain	Questionnaire	Validation	# Items	Range
General	Patient-Reported Outcomes Measurement Information System (PROMIS) Global Health [22]	General population/healthy people and people with various chronic conditions	10	T-score of 0–100, with 50 the average (SD 10) for the general population of the US. Higher scores indicate better health
	University of California, Los Angeles (UCLA) Activity Scale [23]	Orthopedic patients	1	1–10 with higher score indicating more physical activity
Musculoskeletal	Single Assessment Numerical Evaluation (SANE) [24]	Orthopedic patients	1	0 (worst) to 100 (normal)
Reproductive endocrinology	Triad Consensus Panel Screening Questions [25]	Part of consensus statement, not validated	11	n/a
	Low Energy Availability in Females (LEAF) [26] (hormonal contraceptives and menstrual function)	Female athletes	11	
Post-concussion	Post-Concussion Symptom Scale (PCSS) [21]	Post-concussion patients	22	0–132 with higher score indicating worse symptoms
Mental	Patient Health Questionnaire (PHQ) [29]	General population	4	0–12 with higher score indicating worse depression
	General Anxiety Disorder (GAD) [28]	General population	7	0–21 with higher score indicating worse anxiety

Table 2 Player profiles of 560 survey respondents

Characteristic	Frequency (%) or mean [SD, range]
Age, years	34 [9, 20–60]
Race	
White or Caucasian	514 (92.1)
More than one race	22 (3.9)
Black or African American	7 (1.3)
Asian	5 (0.9)
Native Hawaiian/Other Pacific Islander	3 (0.5)
American Indian or Alaska Native	2 (0.4)
Prefer not to answer	5 (0.9)
Ethnicity	
Not Hispanic or Latino	489 (87.3)
Hispanic or Latino	30 (5.4)
Prefer not to answer	8 (1.4)
Unknown/missing	33 (5.9)
BMI, current	23.4 [2.9, 17.2–34.4]
BMI, end of career	22.6 [1.9, 18.3–31.2]
Highest level played	
College	407 (72.7)
Semi-professional	90 (16.1)
Professional	42 (7.5)
National team	21 (3.8)
Years of elite soccer	5 [1–24]
Field position at highest level	
Midfielder	201 (36.0)
Defender	163 (29.2)
Forward	119 (21.3)
Goalkeeper	75 (13.4)
Age at retirement	22 [3, 18–40]
Years since retirement	
0–5	147 (26.3)
6–10	135 (24.1)
11–18	139 (24.8)
19+	139 (24.8)
Main reason for retirement	
Graduation/eligibility expired	342 (61.3)
Injury	67 (12.0)
Pursue another career	49 (8.8)
Burnout	34 (6.1)
Personal or family	25 (4.5)
Coach decision	10 (1.8)
League folded or unavailable	10 (1.8)
Issues with coach	11 (2.0)
COVID-related	6 (1.1)
Other	4 (0.7)

Table 3 Soccer-related surgical procedures during and after the playing career

	Frequency (%) or mean [SD, range]
Surgeries during career	1 [0–15]
Most frequent locations (not mutually exclusive)	
Knee ligament	94 (16.8)
Meniscus	69 (12.3)
Foot or ankle	42 (7.5)
Knee cartilage	36 (6.4)
Surgeries after career	0.5 [0–10]
Most frequent locations (not mutually exclusive)	
Meniscus	47 (8.4)
Knee ligament	44 (7.9)
Knee cartilage	26 (4.6)
Foot or ankle	21 (3.8)

3.4 Reproductive Endocrinology Health

The mean age at menarche was 13 years (SD = 2, range 8–21). A substantial proportion of players had irregular menstruation during their careers: 211 players (39.7%) reported having fewer/no periods with increasing exercise and 115 (21.7%) had no periods for ≥ 3 consecutive months. The majority of players ($n = 343$, 64.5%) reported use of hormonal contraceptives during their playing careers, and the mean age at start of use was 18 years (SD = 2, range 12–32). The most frequent type was oral contraceptives (94.5%), with birth control (55.7%) as the most common reason for use (Table 4).

A total of 239 (44.9%) players reported trying to become pregnant. From this group, 225 (94.1%) reported successful pregnancy and 53 (22.2%) sought fertility assistance. The most common types were intra-uterine insemination (50.9%), medications (49.1%), and in-vitro fertilization (43.4%). A total of 117 (20.9%) players reported an eating disorder or disordered eating during their career, and 85 (15.2%) players reported one after their career. A similar number of players answered that they worried about their weight while playing ($n = 328$, 61.8%) and about their current weight ($n = 326$, 61.3%). The mean number of career stress fractures was 0.4 (SD = 0.9, range 0–5), and the most frequent locations were metatarsals ($n = 44$, 7.9%) and tibia ($n = 37$, 6.6%). The mean number of post-career stress fractures was 0.1 (SD = 0.5, range 0–4), and the most frequent locations were metatarsals ($n = 26$, 4.6%) and shin ($n = 12$, 2.1%).

3.5 Post-Concussion Health

The mean number of soccer-related concussions was one ($n = 320$, SD = 2, range 0–10). The mean number of time-loss concussions was one (SD = 1, range 0–10). There was a significant difference in soccer-related concussions by position ($F[3] = 4.84$; $p = 0.003$), with defenders and

goalkeepers experiencing more concussions compared with forwards and midfielders. Concussions also varied by competitive level ($F[3] = 6.51$; $p = 0.0003$), with more concussions at the professional (difference = 0.88 [95% CI 0.03–1.73]; $p = 0.04$) and semi-professional (difference = 0.94 [95% CI 0.32–1.56]; $p = 0.001$) levels compared with the college level. There was a significant difference in number of time-loss concussions over time ($F[3] = 5.42$; $p = 0.001$), as players in the 19+ years category reported fewer concussions compared with those in the 0–5 years category (difference = − 0.43 [95% CI − 0.86 to 0.01]; $p = 0.06$) and 6–10 years category (difference = − 0.69 [95% CI − 1.13 to − 0.24]; $p < 0.001$).

The mean PCSS score was 20 (SD = 23, range 0–116). For the 198 players (35.4%) who reported any time-loss concussions, the most frequent symptoms were fatigue, headache, and nervousness/anxiousness. Among the 168 (30%) players who reported any symptoms, when asked whether they felt the symptoms were due to soccer-related concussions, 44 (26.2%) players answered yes, 67 (39.9%) no, and 57 (33.9%) were unsure. Players who answered yes reported a higher number of concussions ($F[2] = 12.94$; $p < 0.0001$), time-loss concussions ($F[2] = 6.80$; $p = 0.002$), and PCSS scores ($F[2] = 30.26$; $p < 0.0001$) (Fig. 1).

Table 4 Types of hormonal contraceptives and reasons for use in 343 players

	Frequency (%)
Type of contraceptive (not mutually exclusive)	
Oral contraceptives	324 (94.5)
Intra-uterine device/coil	29 (8.5)
Hormonal ring	15 (4.4)
Injections	4 (1.2)
Hormonal implant	4 (1.2)
Hormonal patch	3 (1.0)
Primary reason	
Birth control	191 (55.7)
Reduce menstrual symptoms	70 (20.4)
Regulate the menstrual cycle in relation to performance	30 (8.8)
Reduce acne	20 (5.8)
Reduce bleeding	17 (5.0)
Menstruation stops otherwise	7 (2.0)
Treatment for polycystic ovarian syndrome	6 (1.8)
Other	2 (0.6)
Secondary reasons (not mutually exclusive)	
None	100 (29.2)
Birth control	73 (21.3)
Reduce menstrual symptoms	74 (21.6)
Regulate the menstrual cycle in relation to performance	32 (9.3)
Reduce acne	26 (7.6)
Reduce bleeding	25 (7.3)
Menstruation stops otherwise	9 (2.6)
Treatment for polycystic ovarian syndrome	1 (0.3)
Other	3 (0.9)

3.6 Mental Health

The mean GAD-7 score was 4 (SD = 4, range 0–21), indicating an overall minimal level of anxiety. The mean PHQ-4 score for combined anxiety and depression was 2 (SD = 2, range 0–12), indicating normal levels of anxiety and depression. There were no significant differences when comparing GAD-7 and PHQ-4 scores across levels and positions. However, there was a dose response with fewer mental health symptoms with greater years since retirement: GAD-7 ($F[3] = 4.44$; $p = 0.004$) and PHQ-4 ($F[3] = 5.31$; $p = 0.001$). On both scales, the biggest differences were seen comparing players who retired 19+ years earlier with those who had more recently retired (0–5 years and 6–10 years) (Fig. 2).

The most common answer for soccer career satisfaction was somewhat satisfied ($n = 259$, 49.4%), followed by very satisfied ($n = 179$, 34.2%) and somewhat dissatisfied ($n = 55$, 10.5%). For post-career satisfaction, the most common answer was very satisfied ($n = 293$, 55.9%) and somewhat satisfied ($n = 190$, 36.3%). Players in the 0–5 years retirement category reported the lowest rates of being very/somewhat satisfied on both career ($\chi^2[12]$; $p = 0.02$] and post-career satisfaction ($\chi^2[40.5]$; $p < 0.001$). A total of 293 players (55.9%) reported continued involvement in soccer after retirement, with significant differences by level ($\chi^2[3] = 11.8$; $p = 0.008$). College players showed the lowest involvement ($n = 198$, 51.7%), while the national team players reported the highest

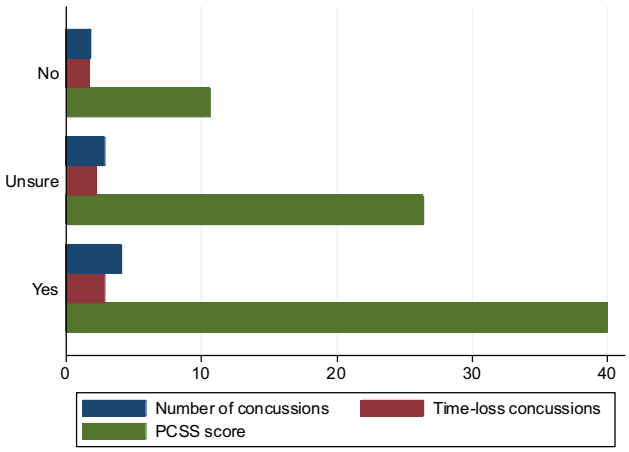

Fig. 1 Mean number of concussions, time-loss concussions, and Post-Concussion Symptom Scale (PCSS) score by response to the question "If you checked off any symptoms, do you feel that they are due to soccer-related concussions?"

involvement ($n=16$, 80%). When presented with the option of being an elite soccer player again, the vast majority ($n=499$, 95.4%) players responded true. Again, there was a significant difference in the proportions who answered true by years since retirement ($\chi^2[3]=11.8$; $p=0.004$], with the lowest proportion in the 0–5 years category ($n=121$, 90.3%) and the highest in the 19+ years category ($n=128$, 97%).

4 Discussion

The findings from this study provide data on the prevalence of health outcomes in elite female athletes who play soccer, the most popular sport in the world. In the US alone, where this study was based, there are an estimated 18 million soccer players, with 40% in the women's game [30]. At the NCAA level, women's soccer has the greatest number of athletes [31]. Unlike most studies that investigate one area, we covered five health domains from head to toe. This cohort of elite soccer players reported an average career length of 5 years, one soccer-related surgery, one time-loss concussion, and were only somewhat satisfied with their careers. Our results were further compared by competitive level, field position, and years since retirement. Players with the most years since retirement were older on both the age of playing organized sports and sport specialization and reported the greatest number of sports played. This finding agrees with growing concerns around early or over-specialization in youth sports [32]. Our data also suggest that women's soccer may be changing over time, with more time-loss concussions reported by players who had retired more recently. While this result could be due to the increasing competitiveness of the game, it can also be attributed to growing awareness for diagnosing concussions.

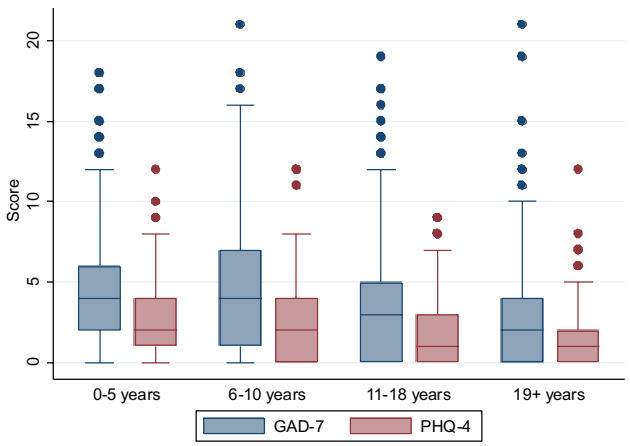

Fig. 2 Mean GAD-7 and PHQ-4 scores by years since retirement. The biggest differences were seen comparing the 19+ years category with the 0–5 years and 6–10 years categories on both scales. The box contains the interquartile range (25th to 75th percentile of data), with the horizontal line representing the median (50th percentile). The lines below and above the box represent the minimum and maximum values, respectively. The dots represent any outliers. *GAD-7* General Anxiety Disorder-7, *PHQ-4* Patient Health Questionnaire-4

There was a difference in number of concussions by field position, with goalkeepers and defenders reporting the highest numbers. In a meta-analysis of sex-comparable sports conducted by our study team that evaluated the concussion-causing activity in soccer, we found that female players had higher risk when heading and goalkeeping compared with male players [33]. While goalkeepers do not engage in heading, they undertake high levels of risk to defend the goal, which can lead to reckless collisions and concussions [34]. In addition, since balls are often kicked forcefully at close range, goalkeepers are more likely to sustain head impact [35].

Much attention has been paid to the neurocognitive health of NFL players. In a study of 3500 former players, those who reported more concussion symptoms during their careers were more likely to report cognitive impairment, anxiety, and depression after retirement [36]. One study has shown that concussion rates are even higher in women's soccer compared with American football [37]. Still, research on the long-term effects of repeated heading in women's soccer players is lacking and urgently needed. The players in our study who felt that their symptoms were due to soccer reported the most concussions and severe symptoms.

While soccer is a team sport with wide-ranging effects on physical fitness and mental well-being [38], the impact of participation at the elite level is unclear. Several studies have shown that sports participation leads to improved quality of life [39–41]. However, other studies report that competing at the NCAA level can have adverse effects on long-term physical health [42–44]. This study found that former women's soccer players reported mostly excellent or very good health, with physical and mental T-scores comparable to the general US population. In addition, there were high rates of continued participation in impact sports. We found a higher number of post-career surgeries with increasing years since retirement. While this finding may be due to more time to have surgery, the locations of the career and post-career surgeries were similar, suggesting long-term musculoskeletal damage to the lower extremities, particularly the knee.

The wide-ranging conditions associated with low energy availability and their impact on overall health is also an emerging area of research. In a study of 220 women's soccer players at the youth, collegiate, and professional levels, 19% reported menstrual dysfunction. A greater number of players who had intermediate risk of disordered eating reported a history of menstrual dysfunction [45]. In our study with higher competitive levels, menstrual irregularities and disordered eating/eating disorders were even bigger health issues.

Almost 40% reported fewer periods with increasing exercise, and 22% had no periods for at least 3 months. While 62% worried about their weight while playing, this proportion remained nearly the same (61%) after retiring. These results were unexpected, as soccer does not have weight requirements and is not generally considered a sport with high risk of disordering eating/eating disorders compared with lean and aesthetic sports. Athletes may generally have an increased risk, with one article showing that the prevalence of disordered eating is 20% higher in athletes compared with non-athletes [16]. However, this perception may be based largely on lean/aesthetic sports, and one article focusing on soccer players found that non-athlete female controls had a higher prevalence of disordered eating compared with elite female soccer players [46].

In the last domain, mental health, there was a clear trend with players who had recently retired experiencing the most mental health symptoms. This group reported the highest anxiety and depression scores, lowest satisfaction rates, and lowest proportion of wanting to be an elite soccer player again. These findings provide a clear message that better counseling and support structures are sorely needed for young players as they transition out of their athletic identity. More resources have to be provided, particularly in light of earlier soccer specialization. While we cannot rule out that these trends are due to the changing game of women's soccer or generational differences, former players may be able to expect that symptoms will decrease over time as they gradually transition into life after their soccer career. One recent article that evaluated female sports participation and long-term quality of life found that anxiety but not depression was associated with being a college athlete, after adjusting for age. This study included Division III alumnae from universities in one region of the US [44]. A systematic review and meta-analysis published in 2019 also evaluated quality of life and life satisfaction in former collegiate and professional athletes across multiple sports. It found that athletes had better mental health than the general population but there were few studies on life satisfaction in former athletes. In addition, 9 of the 17 studies that were included in this review (52%) consisted of only male participants [39].

4.1 Limitations

Our sample of 560 players in 1 year is an under-representation of all eligible women's soccer players given the sport's popularity. The study population was not balanced in terms of level, as most respondents competed at the collegiate level. In addition, there was a lack of racial diversity. We intend to expand the study globally to help with external validity. The respondents were balanced for field position, including goalkeepers, and we used the data distribution to categorize years since retirement, which was an important factor for many findings. There were other limitations related to survey design. The semi-professional level and number of soccer-related concussions (not just time-loss concussions) were added based on early player comments. The years of playing at the elite level may be underestimated if only the highest level was selected. In addition, the number of career and post-career surgeries spanned a broad range. It is possible that players responded with the number of injuries. Improvements and clarifications will be made to future versions of the survey. Furthermore, there is the possibility of poor recall on the part of players to remember information from their playing career.

The GAD-7 and PHQ-4 scales asked questions to assess anxiety and depression over the last 2 weeks. The players' answers may have been affected by the COVID-19 pandemic or other life events that were unrelated to soccer. While the majority of respondents (64%) reported minimal anxiety, 25% reported mild levels. Similarly, post-concussion symptoms were assessed over the past 2 weeks. A recent study has shown that individuals with mild traumatic brain injury had high symptom burden even at 8 years post-concussion [47]. The same study also reported a sex difference, with women experiencing more symptoms. Since the symptoms on the PCSS are not very specific, players were asked if they felt symptoms were related to soccer-related concussions. Their answers were subjective, and it remains difficult to determine definitively whether any symptoms are due to prior concussions.

Despite these limitations, this study has several strengths. We have administered short, validated questionnaires that are commonly used in the literature to facilitate cross-study comparisons. We can use historical controls from well-established cohorts such as the Nurses' Health Study or make comparisons with the general population. We have also established a baseline cohort for prospective studies and more advanced epidemiologic study designs, such as the nested case–control study [48, 49]. While these first findings are descriptive and cross-sectional, we acknowledge that the five health domains are likely related and should not be evaluated in isolation. These results build the foundation for multiple research studies based on the wide-ranging data.

For instance, the Female Athlete Triad has been shown to be associated with musculoskeletal injuries [18, 50]. In a large survey study of collegiate female athletes, injectable contraceptives were more associated with history of stress fractures compared with oral contraceptives [51]. In another study of retired collegiate gymnasts, those with disordered eating reported worse physical function and higher rates of infertility [52]. At the professional level, NFL players who sustained an ACL tear during their careers were at increased risk of cardiovascular disease, indicating that career injuries can hinder active lifestyles later in retirement [53]. A history of concussions has also been shown to be associated with

musculoskeletal injuries, particularly of the lower extremity [54, 55]. This increased risk may be due to neuromuscular control deficits that persist after the concussion [52]. A recent systematic review found that worse quality of life in former athletes was associated with factors such as concussion history, involuntary retirement, and musculoskeletal issues [39].

5 Conclusions

The long-term health of elite athletes has not been studied extensively, and the gap is even more pronounced in female athletes despite the rising participation of girls and women in sports. Given the sex and gender disparity, this study focusing on women's soccer can serve as a precedent for other sports with similar health risks and benefits. Health concerns include musculoskeletal injuries, post-concussion symptoms, and lower mental health in the early years following retirement. Future studies will focus on interventions to improve joint dysfunction and the potential association between long-term heading and mental health symptoms in women's soccer. Former players have the power of hindsight, which will be used to look ahead to prevent injuries, protect future generations, and promote a lifetime of sports participation.

Declarations

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Conflict of interest All authors declare that they have no conflict of interest.

Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval This study was approved by the Hospital for Special Surgery Institutional Review Board (#2020-1747) and performed in accordance with the ethical standards in the Declaration of Helsinki.

Consent to participate Informed consent was obtained from all individual participants included in the study.

Consent to publish Not applicable.

Code availability Not applicable.

Author contributions DL conceived the study idea, designed the study, performed the analysis, and wrote the first draft of the manuscript. JH, HP, HS, TC, PD, CL, and EC provided clinical expertise and input on the study design, player recruitment, and data collection process. All authors have read and approved the final version of this manuscript.

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