



Concussion incidence and recovery in Swedish elite soccer — Prolonged recovery in female players

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Objectives: Sport-related concussions are an increasingly recognized health problem. Soccer is the most popular sport in the world although recent studies on concussion incidence are scarce. Here, a nationwide prospective study on concussion incidence, symptom severity, risk factors, gender differences, and return-to-play after concussion was performed in 51 Swedish elite soccer teams during the 2017 season.

Methods: In the 1st and 2nd soccer leagues for men and women, a Sport Concussion Assessment Tool (SCAT)-based questionnaire study was performed at preseason (baseline) and from 48 hours to 3 months post-concussion.

Results: We followed 959 players (389 women, 570 men) for 25 146 player game hours (9867 hours for women, 15 279 hours for men). Concussion incidence ($n = 36$ concussions during the season) was 1.19/1000 player game hours (females 1.22/1000 hours, males 1.18/1000 hours; $P = .85$). Twenty-seven percent of all players (8% of females, 40% of males) continued to play immediately after the concussion. When compared to male players, female players had worse initial symptom severity scores (median and IQR 30 (17-50.5) vs 11 (4-26.25), $P = .02$) on SCAT and longer return-to-play ($P = .02$). Risk factors for concussion were baseline symptoms and previous concussion.

Conclusion: In Swedish elite soccer, the concussion incidence was 1.19/1000 without gender differences. Most players recovered to play within 4 weeks post-injury. Almost one third of players continued to play at time of concussion. Female players had worse initial symptoms and longer return-to-play time than males, and a prolonged recovery beyond 3 months was only observed among female players.

KEYWORDS

female, questionnaire, return-to-play, soccer, Sports Concussion Assessment Tool (SCAT), sports-related concussion

1 | INTRODUCTION

Sport-related concussions (SRCs) are common in contact sports such as American football, rugby, ice hockey, and soccer.¹ A concussion is defined as a traumatic brain injury initiating complex pathophysiologic processes that cause transient neurological symptoms.² The potential adverse effects of SRCs are increasingly recognized, and the accumulating effects of repetitive SRCs may lead to long-term persistent symptoms that result in premature termination of an athlete's career.^{3,4} An increasing number of studies suggest long-term physical and cognitive consequences of SRCs such as depression, cognitive impairment, and an earlier onset of Alzheimer's disease, in particular following repetitive injuries.⁵ Based on animal experiments, a concussion induces metabolic and vascular changes in the brain and during the early post-injury phase, an additional impact lead to exacerbation of the initial injury.^{2,6-8} Thus, it is mandatory that a concussed player is prevented from the risk of sustaining an additional head impact in the early post-injury days. This is the main reason for implementing the graduated return-to-play protocol⁹ adopted in most sports. Most players are expected to return-to-play after 10-12 days⁹ with markedly longer recovery times in more than 10% of them.⁴

Soccer, with an estimated 265 million licensed players in Fédération Internationale de Football Association's (FIFA's) member countries in 2006,¹⁰ is the most popular sport in the world. The incidence of SRC in European elite soccer was previously estimated to be ca 0.35-1.38¹¹⁻¹³ per 1000 hours of game play. Considering the large number of active players worldwide, these incidence figures indicate a very high annual number of concussed soccer players. The concussion incidence may also be higher in amateur players when compared to professional soccer players.¹⁴ Furthermore, although a steadily increasing concussion incidence has been observed over several years in ice hockey, recent concussion incidence studies in elite soccer are sparse.

Previously, many studies on SRC in sports, including soccer, have suggested a higher incidence and worse outcome in females.^{1,9,15,16} Although soccer is the most popular sport in the world for both males and females, only few studies describe gender differences in elite soccer players. Renewed prospective incidence studies, investigating symptoms longitudinally after concussion, are warranted.^{1,17}

In the present comprehensive nationwide study, we investigated 959 male and female elite Swedish soccer players during the 2017 season. We used a clear definition of SRC and evaluated concussion incidence, risk factors, initial management and symptoms as well as return-to-play duration.

2 | MATERIAL AND METHOD

2.1 | Ethics

The Regional Research Ethics Committee at Uppsala University granted permission for the research included in the present study. Written informed consent was obtained from all players at time of baseline inclusion and the research was conducted in accordance with the ethical standards given in the Helsinki Declaration of 1975, as revised in 2008.

2.2 | Recruitment

In Swedish elite soccer, 55 teams of 58 eligible teams were recruited and agreed to participate prior to the season of 2017. The teams received no financial or other forms of compensation. Players entered the study between the start of the Swedish national cup in February until the start of the regular season in April 2017. After the first game in each series no additional player was recruited. The included leagues were for men the 1st (Allsvenskan) and 2nd (Superettan) leagues, and for women the 1st (Damallsvenskan) and 2nd (Allettan) leagues. The 1st league for men is professional, the 2nd league for men and 1st league for women are semi-professional, whereas the 2nd league for women is an amateur league.

The players in each team completed a baseline questionnaire, based on concussion symptoms described by Lovell¹⁸ and later adopted into the Sport Concussion Assessment Tool (SCAT) 3 and, in 2017, the SCAT5. The self-reporting questionnaire also included information on concussion history, medication, headache/migraine, depression, and learning disabilities (including ADHD and ADD diagnoses). Data on numbers of players declining to fill out the baseline questionnaires was not acquired. When the baseline questionnaire was completed, the player was considered a study participant. Concussions were registered by a member of each medical team, most commonly a physiotherapist, between study inclusion and the last competition game of regular season 2017 in early November. When an included player sustained a concussion, the prospective questionnaire was completed by the medically responsible persons of each team and/or the concussed player. This questionnaire was divided in four parts, B1 and B2 to be completed within 48 hours (B1 filled out by the medical team and B2 filled out by the concussed player), B3 at 4 weeks, divided into two parts and filled out by both the player and the medically responsible person and B4 at 3 months post-concussion, filled out by the concussed player. After the season, an additional questionnaire (C) was sent to a member of the medical team as a summary of SRCs occurring during the 2017 season. The study protocol is described in Figure 1.

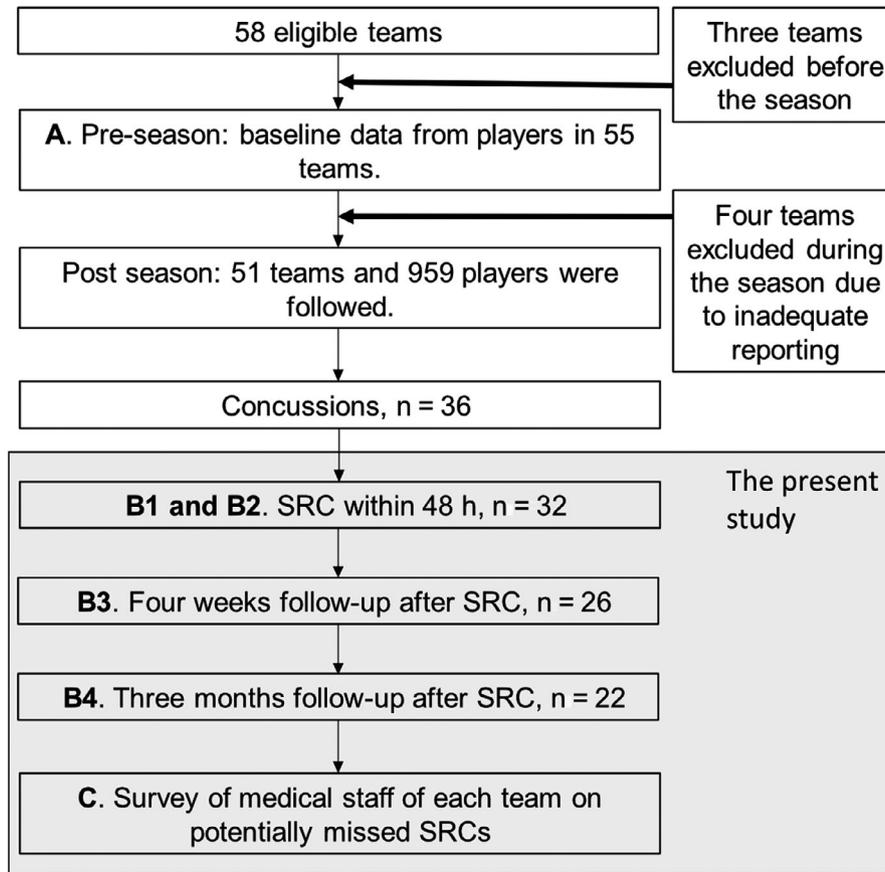


FIGURE 1 Summary of the study design. In total, 959 adult elite soccer players filled out the baseline questionnaire prior to season start and were followed during the 2017 season. Of these, 36 players sustained a concussion of which 32 players filled out the questionnaire by 48 h, 26 players by 4 wk and 22 players by 3 mo post-concussion. At all included time points the questionnaires were based on the symptoms evaluation part of SCAT. A, A Baseline questionnaire, completed by the player prior to the season, about previous concussions and baseline symptoms. B1: A questionnaire completed by member of the medical team immediately following the SRC (Sport-related concussion). B2: Questionnaire regarding concussion symptoms completed within 48 h after SRC by the player. B3: Questionnaire completed 4 wk after SRC regarding concussion symptoms and rehabilitation progress. One part was completed by the player and a second part completed by a member of the medical team. B4: Questionnaire to be completed by the player 3 mo after SRC regarding persistent concussion symptoms and return-to-play. C, Summary about how many SRCs each team sustained during the 2017 season, information obtained from a member of the medical team. The questionnaires are provided in Supplementary Information

2.3 | Concussion definition and initial management

A concussion was defined as transient neurological symptoms caused by an external force/trauma to the head, either direct or indirect, as based on the consensus meetings on concussion in sport held in Zurich 2012.¹⁹ Some examples of neurological symptoms are loss of consciousness, memory loss, blurred vision, dizziness, balance problems, and confusion. The player evaluation was made in accordance with this definition by the medically responsible team member of each participating team, who reported the mechanism of the SRC in the B1 questionnaire (Figure 1).

Our questionnaire also investigated whether removal from play and the graduated return-to-play protocol was implemented. If a concussion was suspected evaluation off-field should be initiated. When a concussion was diagnosed,

removal from play was strongly recommended. Then, the graduated return-to-play protocol is initiated by 24–48 hours of “brain rest” with minimal physical and mental activity, which is then followed by a gradual escalation of activity in six steps. The time between each step should be at least 24 hours. All Swedish teams have leaders educated in concussion management, according to the concussion consensus statements adopted by the Swedish Football Association (FA) and recommended by the Swedish Sport Medicine Society.^{9,20}

The symptom evaluation score, as originally described by Lovell et al.¹⁸ and adopted into the SCAT protocol part 3.3, lists 22 symptoms with a range of severity from 0 to 6 to be evaluated by the player. The symptom severity score (SSS) is the sum of all symptom severity scorings (range 0–132). The Number of Symptoms (NOS) is the sum of each symptom with a severity score between 1 and 6 (range 0–22).²¹

The number of competitive games was calculated by regular screening of the official homepage for Swedish football, <http://www.svenskfotboll.se>. Each game was approximated to 90 minutes, played by 11 × 2 players.

To minimize the risk of concussions not reported, each team was contacted regularly during the entire season, on average once per month, for updates. In addition, once every 2 weeks the internet was screened for information regarding concussions or head trauma in Swedish soccer. If information from these searches suggested that a concussion may have occurred, the medical teams were contacted for additional information. If it was implied that a player had sustained a concussion, the medical team was asked to ensure that the questionnaires were filled out. Finally, all medical teams were contacted (questionnaire C) at the end of the season for information on any concussions that may not have been reported during the season.

2.4 | Statistics

Statistical analyses were performed using Statistica (version 13, Dell Inc Tulsa, USA; 2016). Normality of data was decided using Shapiro-Wilk. Odds ratios were calculated by Fisher's exact test. The non-parametric Friedman's test was used to investigate differences between more than two paired groups, that is, NOS and SSS, which is analyzed at baseline, at 48 hours, at 2 weeks and at 3 months. The Wilcoxon signed rank test was used to calculate differences between two paired time points. The non-parametric Mann-Whitney U test was used to analyze gender differences in unpaired continuous data, whereas Chi-square test was used for dichotomized data. For assessment of risk factors, a set of pre-defined factors⁹ were included in a univariate analysis. No multivariate analysis was performed in view of the rather low number of cases. For comparison of return-to-play, Log-Rank was used. Mean and standard deviation was used for normally distributed data, medians, interquartile range (IQR), and/or range for non-normally distributed data. A *P*-value of < 0.05 was considered statistically significant.

3 | RESULTS

Of the 55 teams that were included before the season, four teams (two from the 1st league for men, one from the 2nd league for men and one team from the 2nd league for women) were excluded during the season due to inadequate and incomplete reporting (Figure 1). Thus, 51 out of 58 teams in Swedish elite football participated, including 959 players, 389 women (age 23 ± 4.2 years old), and 570 men (age 25 ± 4.6 years old). The players were followed for 25 146 game hours. Thirty concussions were reported during these competing games resulting in a concussion

TABLE 1 Presentation of different SRC incidence, presented as per 1000 h, per game, per player and per level of play

	Total	Women	Men	<i>P</i> -value
Game incidence (SRC/1000 h)	1.19	1.22	1.18	.99
SRC/Games	1/25	1/25	1/26	.99
SRC/Player	1/27	1/23	1/30	.39
Incidence 1st leagues (SRC/1000 h)	1.27	1.33	1.23	.99
SRC/Game 1st leagues	1/48	1/46	1/49	.99
SRC/Player 1st leagues	1/24	1/19	1/28	.47
Incidence 2st leagues (SRC/1000 h)	1.11	1.12	1.11	.99
SRC/Game 2st leagues	1/55	1/55	1/55	.99
SRC/Player 2st leagues	1/29	1/26	1/33	.62
Incidence S-P level (SRC/1000 h)	1.20	1.33	1.11	.79
SRC/Game S-P level	1/51	1/46	1/55	.79
SRC/Player S-P level	1/26	1/19	1/33	.32

Note: The SRC incidence metrics per player is provided in order to include SRCs occurring during practices.

Abbreviations: SRC, sports-related concussion. S-P, semi-professional level.

incidence of 1.19/1000 hours of game play, similar in men (1.18/1000 hours of game play) and women (1.22/1000 hours of game play; Table 1). During practice, an additional six concussions were reported. To include these in the incidence metrics, we calculated SRC/player in the study, resulting in one SRC per 23 female, and one SRC per 30 male players (Table 1). Thus, 36 concussions occurred during the 2017 season, of which 83% occurred during games. Two players sustained two concussions, and the 36 concussions were distributed on 34 players. Furthermore, to compare the SRC incidence between genders on the same level of play we compared the incidence in the female 1st league to the male 2nd league (females: 0.8/1000 hours of game play; males 0.9/1000 hours of game play; *P* = .79; Table 1). Of the 36 concussions, 22 completed each questionnaire. The number of concussed players who completed each questionnaire is outlined in Figure 1. Twenty-three teams out of 51 reported one or more SRCs. Of these 23 teams, six were from the first league for males, seven from the first league for females, five from the second league for males, and five from the second league for women.

3.1 | Concussion management

Of the 36 SRCs, data on immediate concussion management was available for 26. Of those 26, seven players (27%) continued to play/practice immediately after concussion, in

TABLE 2 Basic data and gender differences

	Total	Women	Men	P-value
Age (mean; SD)	24 ± 4.5	23 ± 4.2	25 ± 4.6	.22
# of player game hours	25 146	9867	15 279	
Total number of concussions	36	17	19	
Number of game concussions	30	12	18	
Previous SRC among those concussed in 2017	21/30	12/13	9/17	.40
Return-to-play (days; median (IQR))	12 (IQR: 7-21)	20 (IQR: 8.5-75)	10 (IQR: 7-13.5)	.02
Amnesia from SRC	9/29	3/13	6/16	.70
Unconsciousness from SRC	2/30	0/14	2/16	.49
Dizziness/seeing stars	9/27	7/13	2/14	.24
Continued to play immediately after concussion	7/26	1/12	6/14	.08
Recurrence of symptoms during rehabilitation	7/22	5/10	2/12	.39
SSS (baseline)	3 (IQR 0-14.5; n = 29)	7 (IQR 0-14; n = 13)	2.5 (IQR 0.25-14.75; n = 16)	.32
NOS (baseline)	3 (IQR 0-10; n = 29)	5 (IQR 0-9.5; n = 13)	2 (IQR 0.25-10; n = 16)	.59
SSS at 48 h	19 (IQR 5-40; n = 31)	30 (IQR 17-50.5; n = 13)	11 (IQR 4-26.25; n = 18)	.02
NOS at 48 h	10 (IQR 5-15; n = 31)	13 (IQR 6.5-18; n = 13)	7.5 (IQR 3.75-12.25; n = 18)	.02
SSS at 4 wk	2 (IQR 0-6.25; n = 26)	3 (IQR 0-13; n = 11)	2 (IQR 0-5; n = 15)	.46
NOS at 4 wk	1 (IQR 0-6.25; n = 26)	3 (IQR 0-6; n = 11)	1 (IQR 0-2.5; n = 15)	.54
SSS at 3 mo	1 (IQR 0-8; n = 21)	7 (IQR 1.5-19.5; n = 10)	0 (IQR 0-5; n = 11)	.01
NOS at 3 mo	1 (IQR 0-5; n = 21)	5.5 (IQR 0.75-10.25; n = 10)	0 (IQR 0-2.5; n = 11)	.005
SSS (baseline) — S-P level	3 (IQR 0-15; n = 13)	9.5 (IQR 0-27; n = 8)	0 (IQR 0-6; n = 5)	.57
NOS (baseline) — S-P level	2 (IQR 0-10; n = 13)	5 (IQR 0-12; n = 8)	0 (IQR 0-4.25; n = 5)	.63
SSS at 48 h — S-P level	23 (IQR 4-50; n = 15)	38.5 (IQR 17.75-50.75; n = 8)	9 (IQR 4-39; n = 7)	.23
NOS at 48 h — S-P level	12 (IQR 4-18; n = 15)	14.5 (IQR 8.25-18; n = 8)	7 (IQR 3-13; n = 7)	.16
SSS at 4 wk — S-P level	1 (IQR 0-6.25; n = 12)	2.5 (IQR 0-14.25; n = 6)	0.5 (IQR 0-3.25; n = 6)	.39
NOS at 4 wk — S-P level	1 (IQR 0-3.75; n = 12)	2.5 (IQR 0-6; n = 6)	0.5 (IQR 0-1.5; n = 6)	.27
SSS at 3 mo — S-P level	0 (IQR 0-8; n = 11)	8 (IQR 1-20; n = 5)	0 (IQR 0-0; n = 6)	.02
NOS at 3 mo — S-P level	0 (IQR 0-6; n = 11)	6 (IQR 1-10.5; n = 5)	0 (IQR 0-0; n = 6)	.02

Note: Symptoms were evaluated prior to the season (all data presented for those who sustained an SRC during the season), at 48 h, at 4 wk and at 3 mo post-concussion. Data for Symptom Severity Score (SSS) and Number of Symptoms (NOS) are presented as median and Inter Quartile Range (IQR). Denominators and n in the parenthesis indicate the number of available responses for each item in the questionnaires.

Abbreviations: SRC, Sport-Related Concussion; S-P, Semi-professional.

females 1 out of 12 (8%) and in males 6 out of 14 (40%) ($P = .08$; Table 2). During the graduated return-to-play protocol rehabilitation, 7 of the 22 players (32%) in whom data were available from either the 4 weeks or 3 months questionnaires (Figure 1) had set-backs, that is, return of symptoms. Return-to-play time was available in 29 players, of whom two had returned to play within 5 days, while 27 players needed a longer recovery period (IQR 7-21; range 3-270 days in those returning, one female player ended her soccer career; Figure 2, Table 2).

3.2 | Symptoms and their duration

Information on amnesia was available in 29 players, of whom nine (31%) experienced memory loss from the SRC. Of the 30 players who reported data, two (7%) lost consciousness at time of SRC. Data on “seeing stars/felt obtunded” was reported by 27 players, of whom nine (33%) experienced these symptoms (Table 2).

At the 48 h post-concussion assessment, a median of 10 (IQR 5-15; range 0-22) Number of Symptoms (NOS), and

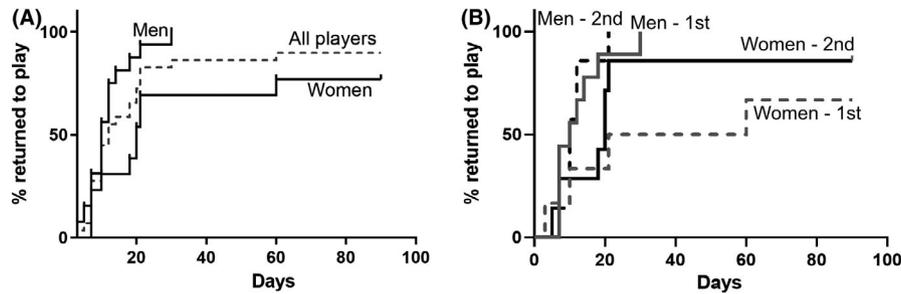


FIGURE 2 Cumulative incidence of return-to-play following SRC. A, Return-to-play, all players ($n = 29$; data missing for five players). Return-to-play gender differences in males ($n = 16$) and females ($n = 13$; $P = .02$). B, Return-to-play divided based on league; women 1st league ($n = 6$), women 2nd league ($n = 7$), men 1st league ($n = 9$) and men 2nd league ($n = 7$)

a median Symptom Severity Score (SSS) of 19 (IQR 5-40; range 0-88) were reported. By 4 weeks post-concussion, both the NOS and SSS had returned to baseline levels on a group level (Figure 3, Tables 2, and 3). However, of the 29 concussed players who reported data, three players had not returned to full contact play by 3 months, of whom all had at least one previous concussion and all were female (Figure 2). Of these three players, one ended her career, one returned to play after 9 months and the third returned to play shortly after 3 months. Median time to return-to-play was 12 days for all concussed players (IQR 7-21 days; Table 2).

3.3 | Gender differences

Females had worse initial symptoms as evaluated by the SSS (median 30; IQR 17-50.5; range 4-67; in males: median 11; IQR 4-26.25; range 0-88; $P = .02$), and a higher number of symptoms (NOS 13; IQR 6.5-18; range 4-22) when compared to males (NOS 7.5; IQR 3.75-12.25; range 0-20; $P = .02$) when assessed by the 48 h questionnaire. By 3 months, although not at 4 weeks post-concussion, females had worse symptoms as indicated by SSS (median 7; IQR 1.5-19.5; range 0-39) when compared to males (median 0; IQR 0-5; range 0-19; $P = .01$) and a higher number of symptoms (median NOS 5.5; IQR 0.75-10.25; range 0-16) when compared to males (median NOS 0; IQR 0-2.5; range 0-11; $P = .005$). The symptom difference did not reach statistical significance when the level of play, that is, the 2nd division male and the 1st division female leagues, was compared (Table 2). Return to full contact play occurred at a median of 20 days (IQR 8.5-75; range 3-270; one player did not return to soccer) for females and 10 (IQR 7-13.5; range 7-30) days for males ($P = .02$). All male players had returned to play after 30 days post-concussion, whereas 3 out of the 12 female players in whom data were available had not returned to play by 90 days (Table 2; Figure 2).

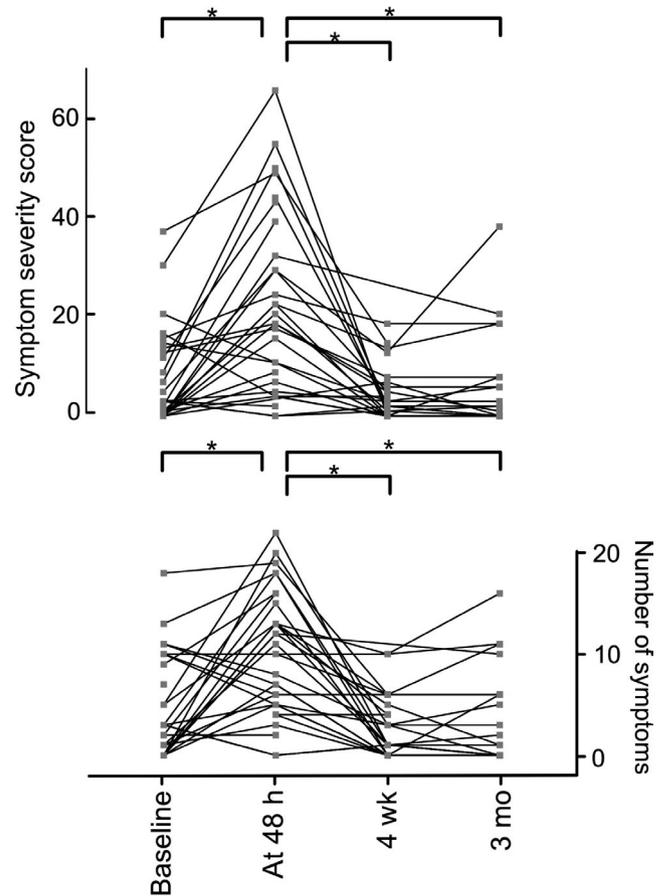


FIGURE 3 Longitudinal Symptom severity score (SSS) evaluated by the symptoms part of Sports Concussion Assessment Tool and Number of symptoms in each concussed player prior to season start (baseline), at 48 h, at 4 wk and at 3 mo post-concussion. $*P < .05$

3.4 | Concussion risk factors

Of the 959 players, 363 reported sustaining a previous concussion prior to inclusion of this study. Of these, 5.8% ($n = 21$ of 363) sustained a concussion during the 2017 soccer season, in contrast to 1.5% ($n = 9$ of 584) of players without any

TABLE 3 Percent of players with presence of the symptom, that is, symptom severity score (SSS) between 1 and 6 for all evaluated symptoms

	Baseline	at 48 h	at 4 wk	at 3 mo
Headache	33	81	15	23
"Pressure in head"	23	84	31	27
Neck pain	33	45	31	18
Nausea or vomiting	10	29	0	9
Dizziness	7	65	4	14
Blurred vision	20	26	12	14
Balance problems	7	29	0	5
Sensitivity to light	23	58	19	23
Sensitivity to sound	20	45	12	23
Feeling slowed down	17	48	8	9
Feeling like "in a fog"	10	32	4	14
"Don't feel right"	17	74	19	9
Difficulty concentrating	27	52	15	18
Difficulty remembering	23	42	8	14
Fatigue or low energy	57	71	35	32
Confused	10	26	4	18
Drowsiness	10	48	8	9
Trouble falling asleep	20	23	4	9
More emotional	17	26	0	18
Irritability	37	35	23	18
Sadness	10	39	15	18
Nervous or anxious	30	19	15	14

Note: These data indicate that the SSS returns to baseline at 4 wk where it remains by 3 mo in most players.

previous concussion, an odds ratio of 3.98 ($P < .001$). Of the players concussed during 2017, 21 of 30 (70%) in whom data were available had sustained a previous concussion. Thus, a previous concussion was associated with an increased risk of sustaining another concussion (Table 4).

In addition, the presence of 10 or more symptoms at baseline was associated with an increased risk of sustaining a concussion during the 2017 season (odds ratio 3.30; $P = .008$). However, players with a previous SRC also had more baseline symptoms. Six out of eight players with ≥ 10

TABLE 4 Risk factors for sustaining a soccer-related concussion

	Odds ratio	95% CI	P-value
Previous concussion	3.98	1.78-17.6	.0004
Baseline 10 or more symptoms	3.30	1.53-7.64	.008
Medication #	0.53	0.17-1.61	.46
Headache	1.28	0.60-2.87	.51
Learning disability	1.04	0.10-5.94	.99

Note: Previous concussion and 10 or more baseline symptoms were risk factors for sustaining a concussion during the 2017 soccer season, using a univariate analysis. Medication refers to whether the player consumes any prescription medicine regularly. In the concussed group, only treatment against asthma and allergy were used, and in no player against migraine or any psychiatric disorders. #, numbers.

baseline symptoms had suffered from a previous SRC and 6 out of 20 athletes with a previous SRC had ≥ 10 baseline symptoms.

Headache/migraines, depression, ADHD/learning problems or medications at time of SRC were not associated with increased risk of sustaining a concussion. At baseline, 15% of all players ($n = 1030$) had any prescription, and 9% of those with a previous concussion ($n = 395$). The most commonly prescribed medications, at baseline in all players, were contraceptives ($n = 24$) or against asthma ($n = 52$) and/or allergy ($n = 35$; Table 3).

3.5 | Mechanism, team level, and location of SRC in soccer

Player-player interaction was the most common cause of concussion during game play, and head to head impact was the most common subgroup (Table 5). During practice, two concussions occurred after being hit by the ball and one by heading the ball. No player-player interaction resulted in a concussion during practice. During games, concussions occurred over the entire soccer field with an increased incidence in the penalty zones. The location on the soccer field where the injury occurred is indicated in Figure S1.

In the first half of games, there were nine SRCs (female five, male four), while 12 (female five, male seven) occurred in the second half ($P = .66$). In the first leagues 21 SRCs (female 9, male 12) occurred, whereas 13 SRCs (female 5, male 8) in the second leagues ($P = .12$).

4 | DISCUSSION

The main finding of our comprehensive nationwide study of elite soccer players during the 2017 season was a concussion incidence of 1.19 per 1000 game player hours, similar in male and female players. In addition, almost one third of the

TABLE 5 Mechanism of concussion injury

	Total	Women	Men
Head to head	12	5	7
Head to knee/leg/ foot	4	1	3
Head to shoulder/ elbow/hand	6	3	3
Head to ground	0	0	0
Head to goal post	0	0	0
Heading	1	1	0
Hit by ball	4	2	2
Secondary head rotation ^a	1	0	1

Note: Player-player interactions were the most common cause of concussion, with head-to-head collisions the most frequent. Three of these concussions occurred during practices, of which two were hit by the ball and one from headed the ball.

^aRefers to an injury mechanism where the head rotates following impact to another body part than the head.

concussed players continued to play immediately after the concussion. The strongest risk factors for sustaining a concussion were a previous SRC, or ≥ 10 baseline symptoms on the SCAT evaluation. Female players had worse initial symptoms following concussion than males, and a longer recovery before returning to full contact play.

In a previous study of male elite soccer players in Norway and Iceland, a concussion incidence of 0.5/1000 hours¹³ was found, whereas recently the concussion incidence in the 2014 World Cup for men was 2.4/1000 hours of game play ($n = 5$ concussions).²² In a European study including 20 FIFA tournaments between 1998 and 2004 evaluating both male and female players, the concussion incidence was 1.38 /1000 hours.¹² In addition, a 2001-2010 survey of 26 European teams including 1401 players found a concussion incidence of only 0.06/1000 hours.¹¹ Concussion was not defined in any of these studies, and often reported as a subset of head and neck injuries.

In Sweden, to our knowledge, there are two prior soccer concussion incidence studies. During the 2000 season, the incidence of all types of head injury was 2.2/1000 hours of match play, of which 0.1/1000 hours was regarded as a concussion.²³ In the 2005 season, the injury pattern in the first leagues for females (12 teams, 228 players) and males (11 teams, 239 players) was evaluated and 13 concussions were identified. Of note, of these 13 only two players had a recovery > 1 week, and four returned to the game within 1-3 days.¹⁷ In neither of these studies was the term concussion defined.

These studies report a large difference in concussion incidence and emphasize the use of a strict definition of concussion. In a recent review article on the incidence of SRC in contact sports, 28 studies on concussion in elite soccer for

men and women were included and a concussion incidence of 0.44/1000 hours match play for men and 1.76/1000 hours match play for females was found.¹ The incidence in our present study was 1.18 and 1.22 for male and female elite soccer players, respectively. Thus, we observed no gender differences in contrast to previous studies. One recent 2006-2016 German study found that the soccer concussion incidence slightly increased over time,²⁴ in contrast to the total number of head injuries and the overall injury incidence that have remained constant over time.²⁵ Future studies need to use a clear definition of a soccer-related concussion to determine whether the concussion risk in elite soccer is increasing. Accordingly, we used the definition from the 2012 Zurich consensus conference. During the course of this study, an updated definition of concussion was published in 2017, based on the 2016 consensus meeting in Berlin. Here, symptoms developing up to the first hours following head impact were included in the definition of SRC. We did not alter our protocol according to this changed definition, and although we cannot exclude that some SRCs were not included this number is plausibly low based on information in available protocols. Furthermore, only a few previous studies evaluated both males and females using similar methods, making the comparisons to the previously reported gender differences uncertain. We also evaluated SRC incidence according to the level of play, comparing the semi-professional 1st female league and the 2nd male league. In view of the rather low number of SRCs, no significant sex difference in SRC incidence could be detected in those leagues.

In our recent retrospective study of this elite cohort of soccer players, approximately 10% of players reported sustaining a previous concussion during the 2016 season (Hänni et al, 2018).²⁶ These data are in contrast to our present 2017 prospective study, where 3.4% of the players sustained a concussion. This discrepancy might be due to recall errors and difficulties in concussion diagnosis²⁷ in the retrospective study, resulting in too liberal interpretation of a soccer-related concussion. More likely, there may be some underreporting in our present prospective results due to factors discussed below.

All concussions in our prospective study were identified from clinical features by the medical teams, trained in concussion recognition. We also contacted each team regularly for updates on concussion. Although these factors argue against an underestimation of the concussion incidence reported here, some concussions occurring during practice may have been unreported since the medical teams were not always present. Incorrect diagnosis or players not reporting symptoms at time of concussion may also have reduced the number of reported concussions. In addition, the medical teams in the second leagues were not always present during games which may have increased the risks of concussions being unreported. It should be noted that 28 of 51 participating teams did not

report a single SRC in 2017, which increases the suspicion that some concussions were unrecognized or not reported. Thus, despite our best efforts we cannot exclude that some concussions were not reported and that the true incidence in elite soccer is higher than what was reported here.

When a concussion occurs or is suspected, the player should immediately stop playing according to current Swedish and international soccer guidelines. If player symptoms, clinical observations and findings on examination suggest an SRC, initiation of a return-to-play protocol is mandated that includes 24–48 hours of “brain rest” followed by a stepwise escalation of activity during a minimum of approximately 5 days.^{9,19,28} If the play is continued there is a risk of additional injuries, as well as a delayed recovery.^{7,29} In our present study, almost one third of players continued to play following a concussion. In addition, a subset of players had a shorter time from concussion to game play than recommended by the graduated return-to-play protocol. Player attitude may play a role when refraining from adhering to current recommendations, as suggested by a study of male high school American football players. In addition, management by leaders and the medical teams may also contribute. SRC recognition by the referee, leaders, and medical teams is likely one key factor in the management of concussion and for removing the player from the field. Off-field tests such as King-Devick, ImPACT, SCAT-5, and the Concussion Recognition Tool (CRT)-5³⁰ might be additional aids in the identification of concussions. In September 2014, an effort to increase the removal of concussed players from the field was made by UEFA and FIFA by introducing a new rule, allowing the team physician to evaluate a player with suspected SRC for three minutes on the field (www.uefa.com). To adequately determine when to remove the player from the field remains a challenge.⁹ As stated in the most recent concussion in sports consensus document,⁹ any player with loss of consciousness, tonic posturing, balance disturbance, or suspected SRC, should immediately be removed from the sport and be assessed off-field. Our results imply that increased awareness of concussion and knowledge of their management among players and leaders is needed.

In this study the concussion symptoms, as originally described by Lovell and later adopted in SCAT 3 were used. Following the consensus meeting on concussion in Berlin SCAT 5 was adopted, however no changes in the symptoms part of SCAT were made and did not alter the results of our study. The symptom part of the SCAT is considered the most sensitive part to discriminate between concussed and non-concussed athletes.³¹

The duration of symptoms after an SRC is associated with concussion severity, number of symptoms, severity of symptoms, sex, depression, and a history of headache diagnosis such as migraine or tension headache.³² There may also be cumulative effects, with longer recovery period

for each additional concussion. In many previous studies summarized in the 2012 sports concussion consensus document, 80%–90% of all players had recovered by 7–10 days.¹⁹ However, in the more recent 2016 consensus meeting statement summary, the mean recovery time had increased to 14 days. The 2012 summary correspond well with our present results of the male players, who had a median of 10 days before return to full contact play, whereas female players had a median time of 20 days. A subset of concussed female players, 3 out of 17, had not returned to play after 90 days, all of whom had suffered from previous SRC. Although the symptom severity score (SSS) and number of symptoms (NOS) had returned to baseline levels or lower by 4 weeks after concussion in both male and female players on a group level, the SSS and NOS, considered the most important risk factors for prolonged symptoms,³³ were significantly higher in females at 48 h post-concussion. In contrast, male players suffered more from amnesia and loss of consciousness which are not, however, established risk factors for prolonged symptoms.³³ When only the semi-professional leagues (the 1st female and 2nd male leagues) were compared, the symptom scores in female players were significantly higher at 3 months, while not at the earlier evaluation time points (Table 2). The total number of concussed players in the semi-professional leagues was rather low, making statistical comparisons uncertain. Some concussed players had lower symptom scores at 4 weeks post-SRC than at baseline, presumably reflecting the normal fluctuation of symptoms in athletes as noted by rather high baseline symptom rating in some previous reports.³⁴

We found a history of previous concussion to be a significant risk factor for sustaining another SRC in the evaluated 2017 season. However, while the relative risk was increased, only a small percentage of players with a previously sustained SRC had an additional SRC in 2017, and thus the absolute risk increase was low. A previous SRC co-varied with the presence of the arbitrarily chosen cut-off of ≥ 10 baseline symptoms, which also was a significant risk factor for additional concussions. Only a univariate analysis was performed due to the low number of concussed athletes, and the number of baseline symptoms and previous SRC may co-vary. Of note, the evaluated players had a rather high SSS and NOS compared to other baseline symptom studies.²¹ We could not detect any correlation between current medication, headache or learning disabilities and a 2017 season SRC. In a previous review article only previous concussions and game play were consistently associated with increased concussion risk.³⁵ Our data did also imply game play as a risk factor, since only six concussions occurred during practice and 30 during game play. Due to incomplete reporting from the teams regarding practice hours, the relative risk during soccer practice could not be calculated.

Previous studies commonly report increased SRC incidence in female contact sports when compared to males,³⁶ which was not supported by our present data. In addition, females typically fare worse than males after SRC.³⁶⁻³⁸ Both initial symptoms and duration of symptom are commonly worse,³⁶ findings supported by our present study. The reasons for this gender difference are not established, although less neck muscle strength or biomechanical factors have been suggested.^{39,40} In view of the increasing popularity of women soccer worldwide, increased focus on the management of concussion in female players is warranted.

The strength of this study is that all included players were well characterized using a baseline questionnaire. In other studies, preseason symptoms as a risk factor for future concussion were inconsistently reported. Furthermore, the study population is large, resulting in the largest prospective, nationwide single season study to our knowledge and there was also a clearly defined start and end of the study inclusion period. We used established criteria for how to define a concussion. To avoid underestimations of concussion incidence, we had regular contacts with the medical teams, screened available media for concussions reports and collected summary reports from the teams post-season. The key limitation of our study is that the medical staff of each team consisted of different individuals with heterogeneous experience and background, which may have resulted in different interpretation of the definition of concussion despite our best efforts to educate each team on how to recognize and diagnose an SRC. Furthermore, the motivation to report concussions and to complete each questionnaire may have been inconsistent among both players and leaders leading to an underestimation of the true concussion incidence in Swedish elite soccer.

In summary, our present study of 959 elite soccer players over 25 146 game hours revealed a concussion incidence of 1.19/1000 hours, without gender differences. Almost one third of the concussed players continued to play immediately following the injury. In addition, female players had worse initial symptoms as well as longer duration of symptoms following concussions in Swedish elite soccer.

5 | PERSPECTIVE

In many sports, concussions are increasingly recognized as a medical problem with significant short- and long-term consequences. Soccer is the most popular sport in the world and information on concussion incidence is important for improving their prevention and management. Furthermore, in contrast to many previous reports we sought to use current definition of concussion to enable comparison to future studies. In view of the strict guidelines for acute concussion management adopted by recent guidelines and consensus

reports, it was surprising that 30% of players continued the game despite sustaining a concussion. These facts emphasize the continuous need for education of team leaders and medical staff, as well as strict enforcement of the guidelines and concussion management protocols. In our present study, we also evaluated both male and female players in contrast to most previous studies. The total number of registered female players is close to 5 million worldwide, a number expected to rapidly increase. Our findings of worse symptoms and longer recovery following a soccer-related concussion emphasize the need for focused studies of the pathophysiology and management of concussion in female soccer players.

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CONFLICT OF INTEREST

None reported.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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