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## SUPPLEMENT

# Head injuries in the female football player: incidence, mechanisms, risk factors and management

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Although all injuries in sports are a concern for participants, head injuries are particularly troublesome because of the potential for long-term cognitive deficits. To prevent any specific injury, it is important to understand the basic frequency and incidence of injury and then the mechanism of injury. Once these are established, prevention programmes can be tested to see if the rate of injury changes. A primary problem with head injuries is recognising that the injury has occurred. Many athletes are not aware of the seriousness of concussive injury, thus this type of injury is probably under-reported. Once the diagnosis of a concussion is made, the next difficult decision is when to return a player to the game. These two management issues dominate the continuing development of understanding of concussive head injury. This paper explores the known gender differences between head injuries and highlights the areas that need to be considered in future research.

Head injuries have been, and will continue to be, a concern for the football community. The use of the unprotected head to change the direction of the ball and to score goals is a key skill in football that places the player in an at-risk position for a variety of head injuries, including contusions, lacerations, fractures and concussions.

There is concern in the medical, football and lay communities that repeated concussions, and even subconcussive impacts, may have long-term adverse consequences. The current literature supports the contention that purposeful heading is safe in both the short and long term,<sup>1,2</sup> and that concussive injury is more commonly due to accidental contact with other hard surfaces (ie, opponent's elbow or head, ground, etc.).<sup>3,4</sup> Because of these and other concerns, some leagues have banned heading for their youngest players and the International Football Associations Board (IFAB) has given referees the authority to administer a red card for flagrant, injurious fouls such as an intentional elbow to the head.

Few studies comparing male and female injuries have examined football-related injury. Fuller *et al* examined all head injuries in Fédération Internationale de Football Association (FIFA) competitions (1998–2004) and found that there was a higher rate of head injury, a different spectrum of injury and different mechanism of injury in female compared with male footballers.<sup>3</sup> This paper explores the reasons for these differences.

## EPIDEMIOLOGY OF INJURY

The rates of injury in football vary depending on the age, level of play, skill and gender of the player. The lack of uniform methods in sports injury research makes direct comparisons a challenge.<sup>5</sup> In general, the overall rate of injury in football increases with age and level of play (tables 1 and 2), in some cases to over 50 injuries/1000 match hours in international men's tournaments. Injuries in recreational and schoolboy football are quite low whereas rates of injury in international championship events are high. There is a direct relationship between age and rates of injury in female players<sup>16,17</sup> (table 3). The overall rates of injury for low-skilled players are nearly twice those of similar-aged players with higher skill levels.<sup>18</sup> Although published data are limited, this finding seems to hold true for different skill levels in female and male footballers.<sup>13,14,17</sup>

## INJURY PATTERNS AND GENDER

A recent, interesting finding is that the patterns of football injury show notable gender-related differences. Fuller *et al* examined all head injuries from six years of FIFA competitions.<sup>3</sup> Of 1633 recorded injuries, 237 (14.5%) were to the head and 11 (0.7%) were to the neck. Of the 248 injuries to the head and neck, 194 (78.2%) were sustained by men and 54 (21.8%) by women. The overall incidence of head/neck injuries was 12.5 (95%CI 10.9 to 14.1) per 1000 player hours (men: 12.8, 95% CI 11.0 to 14.7; women: 11.5, 95% CI 8.4 to 14.6). The incidence of head/neck injuries leading to loss of time was 3.7 (95% CI 2.7 to 4.7) per 1000 player hours (men: 3.5, 95% CI 2.4 to 4.6; women: 4.1, 95% CI 2.1 to 6.1).

**Table 1** Published rates of injury for male football players

Country	Age	Level	Injuries/ 1000 match hours	Injuries/ 1000 training hours
World Cup <sup>6</sup>	Adult	Professional	51.0	
USA <sup>7</sup>	Adult	Professional	35.5	2.9
Iceland <sup>8</sup>	Adult	Professional	34.8	5.9
UK <sup>9</sup>	Adult	Professional	25.9	3.4
New Zealand <sup>10</sup>	Schoolboy	Non-professional	16.2	3.7
Sweden <sup>11</sup>	Adult	Division 1	21.8	4.6
		Division 2	18.7	5.1
		Division 4	16.9	7.6
		Division 6	14.6	7.5

**Table 2** Published rates of injury for female football players

Country	Age	Level	Injuries/1000 match hours	Injuries/1000 training hours
Sweden <sup>12</sup>	Adult	Professional	24.0	7.0
Germany <sup>13,14</sup>	Adult	Professional	23.3	2.8
Sweden <sup>15</sup>	Adult	Senior	14.3	3.7

**Table 3** Rates of injury among female football players by age

Country	Age	Injury rate/ 1000 player hours	Injuries/1000 match hours	Injuries/1000 training hours
USA <sup>16</sup>	7–18	1.1		
Sweden <sup>17</sup>	14–15	5.1		
	15–16	7.6		
	16–17	9.0		
	17–19	5.2		
	Overall		9.1	1.5

The most commonly diagnosed injury was a soft-tissue contusion (57% for men and 41% for women). The next most common injury in men was a laceration (21%), but for women, the next most common head injury was a concussion (22%). A concussion was the fourth most frequent injury in the men (8%). When concussions alone were considered, the incidence rate was 1.1/1000 player hours for men and 2.6/1000 player hours for women, a 2.4-fold higher rate. Delaney *et al* reported a similar, 2.5-fold greater, rate in women whereas Barnes *et al* stated a 2.2-fold greater rate in men.<sup>19–20</sup> The conclusions of the earlier studies were based on numbers of injuries recorded over fixed time periods rather than on exposure.

### MECHANISM OF HEAD INJURY IN FEMALE FOOTBALL PLAYERS

There are limited data on gender differences and injury mechanism, even though they are critical for designing prevention programmes. Fuller *et al* studied tackle-related injuries, looking for common factors associated with injuries.<sup>21–22</sup> The goal was to identify situations that place the player at risk of injury, in order to devise methods of prevention. From video recordings, the authors identified six factors leading to injury in matches: location on the pitch, possession status, direction of challenge, mode of challenge, action during challenge and intent to cause injury.

The same methods were applied to a project specifically focused on head injuries.<sup>3</sup> Heading is not like challenging for a ball while an opponent is in possession, so possession status is essentially a free ball. Heading challenges that lead to injury nearly always include jumping and the over intent is fair play with little intent to injure the opponent. Thus, the factors of interest can be reduced for analysis of head injury incidents. Table 4 shows the risk factors of injury according to diagnosis and gender. The common locations are the defensive or offensive outfield (between the penalty area and midfield line). A player jumps for the ball from the side (male player) or front (female player). A noticeable difference is that the point of contact to the head is the upper extremity in male players whereas it is a head-head impact for female players (table 4).

Fuller *et al* also noted that the distribution of injuries as a function of playing position was markedly different between

men and women. In men, head injuries predominantly occurred among the defenders (51 (40%)) followed by forwards (30 (23%)), midfielders (28 (22%)) and goalkeepers (19 (15%)), whereas in women the injuries was more evenly distributed, being fairly equal, among the defenders (12 (34%)), midfielders (10 (29%)) and the forwards (10 (29%)), with the goalkeepers (3 (9%)) being least often injured.<sup>3</sup> There were significant differences between men and women for possession status at the time of injury ( $p = 0.01$ ) and for intent ( $p = 0.009$ ). The distributions for the mode of approach to the injury event did not differ significantly ( $p = 0.05$ ). Match referees deemed that 30% of the incidents analysed that led to a head/neck injury were foul challenges with no significant differences noted by gender (men: 31%; women: 27%).

Data from experimental studies suggest there are differences between the responses of male and female head-neck segment kinematic and neuromuscular control variables to an external force; this may in part explain the differences noted in injury patterns.<sup>23</sup> Females showed considerably greater head-neck segment peak angular acceleration and displacement than males despite initiating muscle activity much earlier and using a greater percentage of their maximum head-neck segment muscle activity. The differences in head-neck segment angular acceleration may be because females had markedly lower isometric strength, neck girth, and head mass, resulting in lower levels of head-neck segment stiffness. The data suggest that there are intrinsic differences in the ability of female and male athletes to withstand equivalent blows to the head-neck complex.

### GENDER DIFFERENCES IN INJURY OUTCOME

Both clinical and experimental studies have shown gender differences in outcome following all forms of traumatic brain injury. A meta-analysis of eight studies concluded that traumatic brain injury outcome was worse in women than in men for 85% of the 20 measured variables, with an average effect size of  $-0.15$ .<sup>24</sup> The conclusions were limited by the small percentage of the total published reports on traumatic brain injury outcome that described outcome separately for men and women; nevertheless the authors highlighted an area of concern in injury management.

Gender has also been shown to be an independent predictor of survival following brain injury.<sup>25–28</sup> In these studies mortality following moderate to severe traumatic brain injury was found to be 1.28 times higher in females than males, with the greatest difference of 2.14 in deaths after discharge. Controlling for age, admission Glasgow Coma Score, penetrating versus blunt injury, and the presence of multiple trauma, females were 1.75 times more likely than males to die of their brain injury (95% CI 1.09–2.82). Furthermore, females were 1.57 times more likely to experience poor outcomes (eg, severe disability, persistent vegetative state) than males.<sup>25</sup>

With regard to sports-related concussion, in a study of 2340 male and female US high school and collegiate athletes, individuals who sustained sports-related concussions (155

**Table 4** Summary of common factors leading to head and neck injuries in FIFA-sponsored tournaments (adapted from Fuller *et al*<sup>3</sup>)

Head and neck injury category		Location on pitch	Direction of challenge	Action during challenge
By diagnosis	Contusion	Attacking outfield	From the side	Use of upper extremity
	Laceration/abrasion	Defensive outfield	From the side	Use of head/upper extremity
	Concussion	Attacking outfield	From the front	Use of head
By gender	Male	Defensive outfield	From the side	Use of upper extremity
	Female	Defensive outfield	From the front	Use of head

### What is already known on this topic

- There are few direct male–female comparisons of football-related injuries in general, and head injuries in particular. In FIFA competitions, a higher rate, spectrum and mechanism of injury has been found in female footballers compared with male footballers.

### What this study adds

- This review summarises the available data on the nature of head injuries in women. The literature indicates that symptoms, cognitive deficits and outcomes may be more severe in female football players, but this needs to be confirmed.
- Future work may lead to gender being considered as a specific factor influencing management decisions.

subjects) were evaluated by gender using standardised cognitive tests.<sup>29</sup> Female athletes had markedly greater declines in simple and complex reaction times relative to pre-season baseline levels, and they reported more post-concussion symptoms compared with age-matched male athletes. As a group, the female athletes were cognitively impaired approximately 1.7 times more frequently than male athletes following concussions. The authors stated that current return-to-play management must be made on an individual basis, including consideration of factors such as gender.

None of the current studies in football has analysed gender-specific symptom scores, physical signs, cognitive deficits or outcomes following concussive injury.

### SUMMARY

There is limited published literature on injuries in the female football player. What is known is that the nature and pattern of injuries differs from injuries to male footballers, at least at professional level, and that the risk of head injury is double that of males. The literature and experimental research on traumatic brain injury indicates that symptoms, cognitive deficits and outcomes may be much more severe in the female player, although this remains to be confirmed in football studies. This raises the issue whether current return-to-play guidelines need to take into account gender as a specific factor influencing management decisions.<sup>30 31</sup>

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