Field Hockey

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Maria Tuca, Pía Franz, and Matías Sepulveda

4.1 Sports Modality

Field Hockey is called after the word "hocquet" (shepherd's crook in French) in reference to the shape of the players' stick. Historical evidence suggests that ancient variations of field hockey were first played 4000 years ago in Egypt, Ethiopia (1000 BC) and Irán (2000 BC). Modern hockey emerged in England in the mid-nineteenth century, spreading in popularity among the Commonwealth nations. Nowadays, field hockey has more than 30 million players worldwide, and 137 National Field Hockey Associations. It is an Olympic Sport since Amsterdam 1928 for men, and Moscow 1980 for women.

Hockey can be played on grass, synthetic or watered turf, as well as on indoor surfaces. Hockey field is rectangular (55 × 91.4 m), with an "area" comprising the first 23 m from the backline. The team is constituted by ten field players and one goalkeeper. All players use a stick, which can be made out of wood, carbon fiber, fiberglass, or a combination of these, to hit a hard-plastic round ball. The International Hockey Federation (FIH) represents and organizes hockey players around the world and is responsible for elaboration and register of the game rules that are constantly adapted in favor of the players' safety and sports show [1].

A cardinal game rule is that players are only allowed to hit the ball with the flat portion of the stick, whereas only goalkeepers can use any part of the stick and their whole-body surface. A game match is divided into four periods called "quarters," each of 15 min. The team that scores more goals during these periods wins the game. Penalties are granted when players break the rules. If a rule violation happens in the 23 m designated area, a "penalty hit" or a "penalty corner" will be granted to the opposing team. Most of the rules dictated by the FIH are designed for player safety, considering the risk that implies that hockey has the highest ball speed of swing sports (more than golf or baseball), with up to 103 mph. Thus, field players are allowed and encouraged to use hands, mouth, and shin protections during the match, and face masks or goggles during penalty corners (Figs. 4.1 and 4.2). Goalkeepers must wear protective equipment at all times, consisting at least of headgear, leg guards, and kickers. Players are not allowed to elevate the stick above the head height of their opponents and cannot intentionally raise the ball, with the exception of goal shooting or a flick. Players can raise the

M. Tuca (✉)
Universidad del Desarrollo – Clínica Alemana, Santiago, Chile

Hospital Clinico Mutual de Seguridad, Santiago, Chile

P. Franz
Universidad Austral de Chile, Valdivia, Chile

M. Sepulveda
Universidad Austral de Chile, Valdivia, Chile

Hospital Base Valdivia, Valdivia, Chile

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Fig. 4.1 Chile's National Female Field Hockey Team defending a penalty corner. Defenders are allowed to use face googles only during the penalty corner and must wear them off immediately after it ends. Goalkeeper is wearing specialized protective equipment designed to cover most of the body. (Courtesy of the Chilean Field Hockey Federation)

Fig. 4.2 Former captain of Chile's Female Field Hockey Team wearing hand, mouth and shin protections during a match. (Courtesy of the Chilean Field Hockey Federation)

ball with a *flick* provided it is not dangerous, meaning keeping 5 m distance or more from the opponent [1].

Field hockey is an intense, physically demanding sport, that occurs at high speed, requiring multiple skills. This makes a sport unique, exciting for everyone who practices or watches it. The Olympic Games and the World Cup, each held every 4 years, are the most important field hockey events around the globe.

4.2 Introduction

Field hockey is a high speed, intense continuous game. Because of this, the risk of fatigue injuries is high and requires for proper substitutions, which are unlimited. The absence of an "offside rule" leads to the presence of many players around the goal area, probably increasing the injury risk. However, most injuries are minor without consequences for the players [2]. Injury rates in field hockey are comparable to those in basketball [3], lacrosse [3], and softball [4], and lower compared to soccer and rugby [3–5].

The average injury rate per 1000 player hours varies depending on the competition level, 15 for amateurs [6], 33 for elite players [6], and <1 for children <12 years old [6, 7].

While field hockey is essentially a non-contact sport, players can suffer injuries from non-contact and direct contact mechanisms. It has been reported that field hockey players suffered 64% non-contact mechanism injuries and 36% direct contact injuries during training [8]. Among direct contact injuries, 14% are from contact with the ball, 10% with a stick, 7% with the field surface, and 5% with another player [8]. The same study reported that players are twice as likely to suffer an injury during season games than practice [8]. During games, 28% are non-contact injuries and 72% direct contact injuries. Among these, 29% are from contact with the ball, 18% with the stick, 14% with another player, and 9% with surface [8].

The injury incidence varies according to the player's position, with goalkeepers presenting the lowest rate (4–16%), probably for the fact of using more protective equipment, then the forwards and midfielders (22–37%), mainly due to high balls and defenders (24–36%), associated with penalty corners [6] (Fig. 4.3).

In relation to the location in the body, most injuries occur in the lower extremities (54%), upper extremities (13%), spine and pelvis (12%), face and eyes (9%), and concussions (7%) [6].

The most frequent injuries among field hockey players are ankle sprains, knee injuries, head and

Fig. 4.3 Goalkeeper wearing the protective equipment and catching a shot at goal. (Courtesy of the Chilean Field Hockey Federation)

face injuries, fractures of the hand and fingers and back pain. These top-five sports-related injuries of Field Hockey will be reviewed in detail throughout this chapter.

4.3 Ankle Sprains

Ankle ligamentous injuries are the most common sport-related injury [9]. Field hockey is not the exception, associated to cutting and pivoting maneuvers, and the risk of ankle-forced inversion when accidentally stepping over the ball or the opponent's stick.

Ankle sprains are classified as medial or lateral, high (syndesmal injury), or low (distal syndesmotic injury). The most common ankle sprain is lateral and low, affecting the anterior tibiofibular ligament and calcaneofibular ligament due to inversion mechanism on a plantarflexed foot [10].

The traditional classification system for ankle sprains includes three degrees: grade I, microscopic injury without ligament stretch at the macroscopic level, minimal bruising and swelling, no weight-bearing pain; grade II, stretching without rupture, moderate bruising and swelling, mild pain with weight-bearing; grade III, complete rupture, severe bruising and swelling, severe pain with weight-bearing [11]. Although its use is controversial, this classification is useful operationally.

Hootman [3] reported injuries for 15 collegiate sports (including field hockey) over a 16-year period, where ankle sprains accounted for 15% of all reported injuries [3].

Ankle sprain was the most common single injury (39.7%) in a cohort of female field hockey players [11]. First-time ankle injury has a rate of 0.9 injuries/1000 person-day, as reported by Beynnon et al. [12] A review from the National Collegiate Athletic Association (NCAA) Injury Surveillance Data for a period of 15 years shows that for women's field hockey there is twice the risk of sustaining an ankle sprain in a season game than during practice [8]. The ankle sprain accounts for 9.1% of severe injuries (at least 10 days loss of activity for hockey players) [8].

The mechanism of injury correlates to the sudden sprints and rapid direction changes that take place in field hockey [13]. A study proposed that poor peak dorsiflexor torque at the ankle was associated with increased risk for ankle sprains [14]. This is explained by the fact that an increased dorsiflexion strength can help the to prevent ankle inversion associated with lateral sprains [14]. When the ankle is in an inverted and plantar-flexed position, the everter and dorsiflexor muscles act eccentrically [14]. Weak dorsiflexor muscles allow excessive movement, putting additional stress on the lateral ligaments of the ankle joints [14].

General treatment for ankle sprains is rest, ice, compression, and elevation of the extremity. For grade I and II, initial immobilization is required for a short period (<1 week) in a walking boot. After swelling and pain have subsided, immobilization should be changed to a functional brace that limits inversion and eversion. Grade III sprains may benefit from 7 to 10 days of immobilization and non-weight-bearing [10].

Treatment strategy for ankle sprains in athletes has two key points: (1) early onset of rehabilitation to reduce the risk of new injuries and fast sport return [15]; (2) prevention of recurrent injury, by balance and neuromuscular training programs (3 months period usually), focusing on proprioceptive rehabilitation and prophylactic bracing for risk activities [16–18]. Evidence supports that neuromuscular and balance training programs and prophylactic bracing reduce the incidence of injury in up to 50% [19, 20].

It is important to prevent these injuries, avoiding injury recurrence and chronic ankle instability due to its long-term morbidity and disability since it represents a potential burden for athletes. Prevention strategies from other sports that point to different types of injuries are effective in preventing ankle injuries. The "Knee Injury Prevention Program," a neuromuscular warm-up program designed for prevention of anterior cruciate ligament injury, is a good example of a program reported to reduce both ankle and knee sprains, and gradual onset injuries of the lower extremities in female football and basketball players [21]. Other study proposed that the use of

the proprioceptive balance board program aimed at volleyball players was effective in preventing the recurrence of ankle sprains [22]. Since ankle sprain is the most frequent injury in field hockey, with a loss of an average of 4 days per lesion [23], prevention is of great importance [18].

Sports return depends on the grade of sprain, associated injuries, and compliance with rehabilitation programs. After a grade I–II ankle sprain, return to sports occurs on average 1–2 weeks after the injury, and after a grade III, up to 4 weeks. Complications such as pain and instability are described in up to 30% of cases, associated with non-diagnosed fractures, osteochondral lesions, impingement syndrome among others [10].

Considering the evidence backing up prophylactic bracing, balance and neuromuscular programs, there should be an ongoing support towards implementing these actions in field hockey teams. Acute injuries should be identified and treated early to reduce the risk of recurrence and chronic instabilities. To achieve this, players, coaches, and physical therapists should know the basic care of ankle sprains and follow strictly the recovery period, avoiding premature return to sports.

Ankle sprains should not be underestimated, and players should be evaluated by a specialist to obtain a precise diagnosis after a thorough study, ruling out associated injuries and initiating early rehabilitation for a prompt safe sports return, thus avoiding chronic instability and pain and decreasing the risk of re-injury.

4.4 Knee Injuries: ACL Tears

After ankle sprains, injuries around the knee are the second most frequent lesions among field hockey players, accounting for 18% of all injuries [8].

Panagodage [24] published a systematic review of injuries in female players competing in sports with stick use, and knee injuries were among the most common [24].

In relation to the severity of knee injuries, a prospective study that analyzed all injuries throughout the German Field Hockey Tournament season, reported that severe injuries (defined as absence of practice and games for more than 21 days) were 31.5% of the lesions, 17.6% corresponding to knee injuries [25]. Other study that accounted for injuries among college field hockey players through 15 years showed that 15% of the lesions were severe in-game injuries, with 23% of severe those being knee injuries, all of them related to a non-contact injury mechanism [8].

Considering gender differences, women are more likely to suffer knee injuries, with an increased risk of four times to have an anterior cruciate ligament (ACL) injury, compared to men [26].

ACL injuries in up to 78% of the cases occur after a non-contact mechanism [27]. Injuries are caused by abrupt movements when cutting or pivoting, sudden deceleration and external rotation of the tibia, associated with valgus and semiflexion of the knee.

Women's increased predisposition to injure the anterior cruciate ligament is multifactorial. This includes differences in conditioning level, femoral notch size, ACL dimensions, laxity, and Q angle, among others. However, landing biomechanics after jumping and neuromuscular activation patterns (quadriceps dominant) play the main role. Women tend to land from a jump in a more vertical position than men due to an insufficient knee and hip flexion, increasing the stress in the ACL [28]. Also, their movements involve more internal rotation of the hip along with external rotation at the tibia compared with men, leading to increased knee valgus [29].

Adequate muscular strength, along with appropriate muscle recruitment and timing, are key aspects of knee stability [30].

Factors that have been studied and incorporated into ACL prevention programs include muscle strengthening and recruitment patterns, landing and decelerating patterns, proprioception, and plyometrics [31].

There are no ACL prevention programs in literature specific for field hockey, but there are programs from other sports, mainly soccer, that have proven to be effective.

Caraffa [32] reported a significant reduction in ACL injuries with a proprioceptive training pro-

gram; however, subsequent studies have not shown a significant difference in injury reduction [32]. Balance and proprioceptive training may be useful to include in an ACL prevention programs, but they are not sufficient on their own. Neuromuscular and biomechanical adaptations need to be addressed [31].

In 2005, Mandelbaum [33] studied the effects of implementing the "Prevent Injury and Enhance Performance Program" (PEEP program) in a female soccer club. The intervention was a 20-min-specific exercises regimen, performed 2–3 times a week during 12 weeks of the season. The athletes watched an educational video on safe and unsafe landing patterns, and participated in team workouts for stretching, strengthening, plyometrics, and soccer-specific agility drills, which replaced the team's regular warm-up during soccer practice. They reported an 88% overall reduction for ACL injury rate in the intervention group [33].

In 2011, LaBella [21] studied the effects of a neuromuscular warm-up program on ACL injury rates in high school female soccer and basketball players. Intervention coaches went to a 2-h training session prior to the season and learned how to implement a 20-min warm-up program designed to reduce ACL injuries. The warm-up involved plyometrics, balance, progressive strengthening, and agility exercises, as well as instruction on how to avoid dynamic knee valgus and how to land from a jump with flexion of hips and knees. At the end of the season, there was a 56% reduction in total non-contact lower extremity injuries in the intervention group compared with the control group [21].

In 2018, Webster and Hewett [34] published a meta-analysis of ACL Prevention programs and concluded that ACL injury reduction programs decrease the risk of all ACL injuries by 50% and non-contact ACL injuries by 75% in female athletes, but there is insufficient data regarding effectiveness of ACL prevention programs in male athletes [34].

To prevent ACL injury in field hockey, it is important to consider the results of these interventions and train coaches to include these routines in their training programs.

The prevention of this injury is essential since affects the sports career of the player, considering the long postoperative rehabilitation period, associated with late sport return, usually with decreased performance.

4.5 Head and Face Injuries

Sports with stick use as field hockey present an increased risk of injuries because of the high-speed movement required to hit the ball with the stick [7], which can reach up to 80 km [1] (Fig. 4.4).

Field hockey is an intense, fast-paced sport, that has become even faster in the last decades. The elimination of the off-side rule (REF), increased dedication to physical conditioning, technique progression towards more powerful shots, better technology in sticks, and games being played more often in artificial turfs, has risen the game speed over the last few years. These changes make this sport more exciting, but also potential for high risk of injuries. Athletes that participate in sports with stick use, such as field hockey, ice hockey, and lacrosse, have an increased risk of trauma because of the high-speed stick movement required to hit a puck or a ball [35]. Field hockey players had a higher proportion of facial injuries (25% for males and 20% for females) compared with ice hockey (10% males and 18% females), and lacrosse (10% boys and 20% girls) [7, 35].

Women presented more head/face injuries than male players, according to an international field hockey injury study [36], and had the highest incidence of concussion [37]. Male players present more risk for orodental injuries compared to female players (OR: 1.4) [38].

Sport-related head and face injuries can be serious and are often underdiagnosed. Injuries resulting in neurological compromise or airway obstruction may be life threatening, but fortunately are extraordinary [39]. The National Center for Catastrophic Sport Injury Research reported two skull fractures in field hockey players from 1982 to 2006 [40].

Fig. 4.4 Chile's Female Field Hockey Team player performing a "slap hit," wearing hand and shin protections. (Courtesy of the Chilean Field Hockey Federation)

According to the fifth Concussion Consensus Conference (2016), the definition of "Sports Related Concussion" is "a traumatic brain injury that is defined as a complex pathophysiological process affecting the brain, induced by biomechanical forces with several common features that help define its nature" [41]. This definition is imminently clinical and there's not a standard to assess their diagnosis.

The main concern in relation to sports-concussions is that it may increase the likelihood of incurring a subsequent head or musculoskeletal injury, where repeated concussions have been associated with long-term consequences such as neurodegenerative disorders, depression, or persistent post-concussive symptoms [37]. This is specially relevant for field hockey since concussions account for 5% of severe game injuries, meaning 10 or more days lost to injury [8].

In one series, head and face injuries account for 34% in field hockey [11]. Gardner [39] reported 75.3% of head and face injuries, other than mouth, nose, and eyes, among US collegiate women's field hockey players [39]. The most common specific injury was concussion, with an incidence of 0.40 per 1000 athlete-exposures [39]. Dick [8] reported an incidence of 9.4% for concussions and concluded that a player had six times more risk of sustaining a concussion in a game than in practice [8]. This might be due to difference in the intensity of play during a game compared to practice, specifically, more frequent direct contact among players during games [8]. Field congestion, within 25 yd of the goal, has been implicated as a potential contributor to the frequent head and face injuries [11]. Also, midfielders and attacking forward players present more concussions than other positions [37].

The "red flags" for concussions are: decreased level of consciousness, absence of movement for more than 5 s, dizziness, nausea, amnesia, blank look, and clutching the head [42]. When a sport-related concussion is suspected, the athlete should be removed from the field immediately and assessed by a physician or other licensed health care professional next to the field and keep

the player under observation. In case of presenting any of the red flags, the player must be transferred to an emergency service and evaluated by a specialist. The physician who evaluates the player will carry out multiple serial evaluations, assess the need for neuroimaging, and define the sports return possibilities [42].

The most common post-concussion symptoms are headache and difficulties concentrating [37]. Depending on the severity of the concussion, the sports return varies between 48 h and 1-month [37].

It is important that the player, his family, and coach respect the resting time because of the risk of the second trauma syndrome. This syndrome takes place when the player suffers a new concussion before the previous one has resolved, producing a catastrophic brain edema, leading to loss of brain self-regulation [43]. This condition is known as traumatic encephalopathy syndrome which is a progressive neurodegenerative disease with a 50% mortality rate and disability at long term [44].

For dentofacial injuries, 56.5% are caused by hockey ball hit, 37.7% related to a hit with the hockey stick [8], with similar percentages were presented in numerous studies [2].

To prevent head and face injuries, face masks are permissible since 2007, but are not routinely worn by players [39]. Moreover, this protective gear is not allowed in international tournaments unless medically required [37]. For international competitions, face shields are only allowed for defensive players during penalty corners, but they must remove them once the short corner is over [1]. Perhaps a widespread use of face masks as part of the regulations of field hockey, could reduce the rate of craniofacial injuries, promoting their use from young ages to favor their routine use.

To prevent orodental injuries, mouth guards are effective. The use of mouth guards has increased from 27–36% in 1980s [45] to 77–91% in the late 2000s [46]. Injuries are less severe in athletes who were mouth guards than those who don't (OR = 2.1) [38]. Women had greater odds for regular wear of mouth guard during a match than males, and players who had experienced a dentofacial injury previously also had significantly higher odds to regularly wear a mouth guard [35]. There is a 55% of players who considered the mouth guard unnecessary despite the evidence available [35].

There are different mouth guards. Stock mouth guards provide inadequate protection and can cause breathing and talking problems. Mouth-moulded mouth guards provide better protection but can be too thin in prominent teeth exposing them to injury. Custom-made by dental technicians offer the better protection and aren't related to breathing or speaking problems, also last longer [35].

In a recent study regarding the use of mouth guards in field hockey in Holland, players complained less from custom-made than mouth-moulded mouth guards, and also reported that the use of mouth guards are related to lip cuts [38].

Other important aspect of the game is that the only player that wears a helmet is the goalkeeper because it is mandatory [1]. Some experts have suggested that helmets should become standard equipment for field hockey, but detractors consider that it would change the nature of the game, possibly increasing player-to-player contact, which could ultimately increase the injury rate [8, 11].

It is important to promote and regulate the use of mouth guards in hockey as it should be for all games since their mandatory use in other sports such as rugby and ice hockey have decreased orofacial injuries. More studies are needed to clarify the possible effects of the helmet in the game to recommend its widespread use.

4.6 Fractures of the Hand and Fingers

Murthaugh [11] described 14% of upper limb injuries among female field hockey players, placed in the third place of most prevalent injuries [11]. A recent study showed that upper extremities injuries account for 19.4% of all injuries, being the hand/finger the most affected location for contact injuries, also the most severe injuries [25].

During major international field hockey tournaments, the rate of upper limb injuries was 0.2 injuries per match, and 7.5 injuries per 1000 player match hours in men's tournaments [36].

Bowers [47] showed that collegiate field hockey players have significantly higher odds ratio of sustaining an upper limb injury. Hockey field players presented an injury rate of 0.48/1000 exposures, compared to 0.26/1000 in ice hockey players, 0.27/1000 men's lacrosse players, and 0.11/1000 in women's lacrosse players [47]. The odds of a hand injury (OR = 2.12), hand fracture (OR = 1.93), phalangeal injury (OR = 4.19), or phalangeal fracture (OR = 4.04) occurring in field hockey players were significantly higher than for gloved players [47] (Fig. 4.5).

The hand injuries are common due to the grasping position of the hand on the stick and the proximity of the stick and hands to the ground. The standard field hockey stick is 35–37 in. in length, with a short-curved toe that is flat on the striking surface and rounded on the backside. All field hockey sticks are designed to be held with the left hand at the top of it and the right hand distal to the left hand, typically halfway down to stick, closer to the ground, to effect fine control over the ball. As a result, the fingers and thumb, particularly of the right and frequently dominant hand, are quite vulnerable to injuries from contact with the ball or the opponent's stick [47].

According to a national surveillance of collegiate women's field hockey, finger and hand injuries accounted for 10% of all game injuries and for almost 15% of severe game injuries [8]. Most of these were caused by contact with the ball or the stick [8]. They also report that 68% of the injuries occurred when the player was near the goal or within the 25-yd line. The position associated with most injuries are back fielders (39% hand injuries) [8].

In field hockey, the bent-over posture is used for dribbling and shooting. This posture may place the player's hands closer to the ground, which may make it easier to sustain trauma from other players' sticks or cleats, or a ball during play. In areas of player congestion, such as in front or near the goal, players may easily have their hands crushed between two sticks, a player

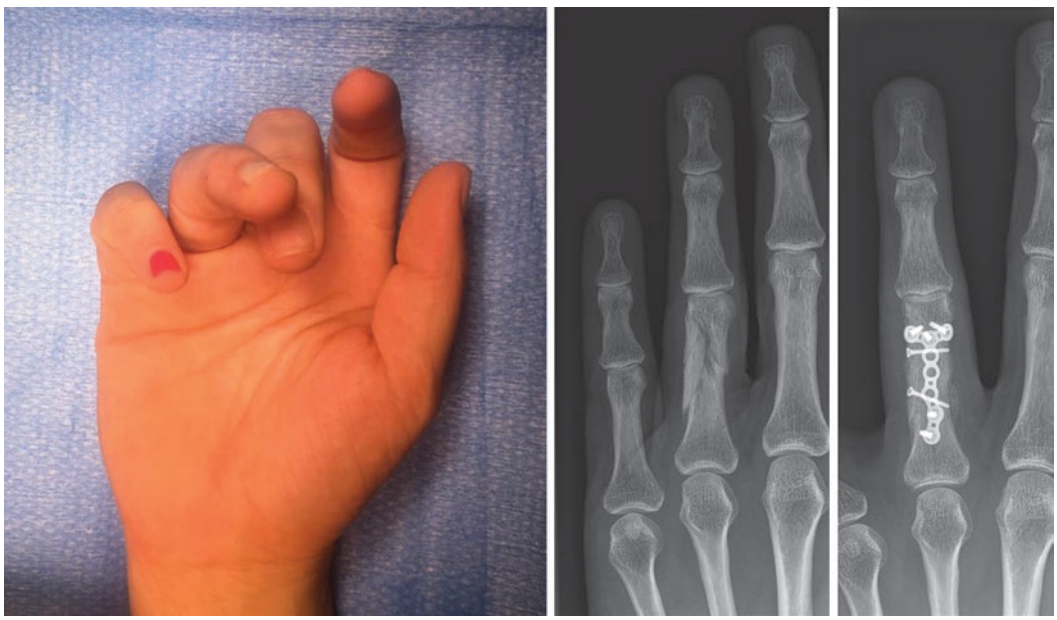

Fig. 4.5 Twenty-three-year-old amateur female hockey player that suffered an attrition of her ring finger between the ball and the stick at high speed, resulting in a comminuted fracture of the proximal phalanx that required open reduction and internal fixation with plate and screws. She was not wearing any hand protections at the moment of the injury. (Courtesy of the Chilean Field Hockey Federation)

and a stick, or a player and the ground. Before 2003, game rules required that during a penalty corner, the ball came to a complete stop outside the circle before a shot on goal, which led players to use the stick to "trap" the ball against the ground to stop it. This technique may still be used in other parts of the game and puts the hands and fingers at considerable potential for injury [8].

Field hockey-related injuries to the upper extremity can also be non-traumatic, but secondary to overuse or repetitive maneuvers. Broekstra [48] presented a cohort of 169 male field hockey players over 60 years old, matched with men from the general population of the same age. They observed Dupuytren's disease in 51.7% of field hockey players with an OR of 9.42. This is explained by the exposure of field hockey players to hand-arm vibration [48].

According to the current regulations of field hockey, the only player who needs to wear hand protection as mandatory is the goalkeeper [1]. It is important not to underestimate the injuries in terms of severity and potential sequelae. The burden of hand injuries is permanent loss of motion and function, osteoarthritis, among others [49]. Prevention of hand and finger injuries is of great importance for its short- and long-term implications. The use of protective gloves should be mandatory and guaranteed for all field hockey players, in all positions.

4.7 Back Pain

Prevalence of back pain among young elite athletes is 3–5 times higher compared to the general population [50]. The prevalence of back pain in athletes goes from 1% to 30% according to literature, and 10–15% of all sport injuries are low back injuries [51]. Serious pathology is present in less than 5% of the cases of low back pain [52]. According to literature [53], being too active might increase the risk of low back pain according to the U-shaped exposure response curve between physical activity and low back pain.

Even though back pain is not necessarily related to an acute trauma, it appeared to be a common complaint among hockey field players.

Murtaugh [11] conducted a questionnaire among high school, university, and national level female field hockey players. It found that 59% of athletes have experienced back pain at some point, and 50% reported that back pain affected them during the field hockey season [11]. The pain was serious enough to cause 12% of athletes to miss a field hockey game, time at school or work. In the same study, traumatic back injuries were only 1% [11].

Among collegiate women field hockey players, the back/trunk injuries account for 16.2% of the injuries during practice, in second place just below lower limb injuries [8].

The prevalence of lumbar flexion posture that accompany participation in field hockey renders the athletes susceptible to injuries of the lumbar spine at a rate significantly greater than general population [54]. The crouched playing position in hockey combined with side flexion and rotation may be contributing factors in the high incidence of low back problems [55].

Non-ergonomic position during field hockey practice has been related to the appearance of degenerative changes in the lumbar spine, according to Ogurkowska [56]. The excessive lumbar lordosis causes a higher load of the gravity force moment at the posterior aspect of the vertebral bodies, transforming them into a wedge shape [56]. Also, there are important changes in the intervertebral discs among field hockey players due to excessive overload. Repetition of a maximal forward bending over the years causes micro ruptures in the posterior part of the annulus fibrosus, which leads to a higher chance of having a hernia of nucleus pulposus in the lumbar segments [56].

In a prospective cohort study of elite field hockey players, 55% of all injuries were due to overuse, and lumbar pain accounted for 8% of this injuries [57].

The players exposed to increased risk of overuse injuries are the drag-flickers (OR: 1.564, compared to non-drag-flickers) [58]. The drag flick is the preferred method of scoring during a penalty corner in field hockey. During a drag flick, the player performs a run up, followed by a powerful "dragging" of the ball before releasing

the ball towards the goal with a flicking motion [58]. This may be related to the volume of skill-specific training required to develop and maintain expertise in drag flicking [58].

The key to avoid back pain among field hockey players is the implementation of preventive measures and early detection of symptoms for prompt treatment. Players should undergo prophylactic core strengthening [2] and muscle stretching to reduce the compression on posterior parts of vertebral bodies as well as exercises stabilizing lumbar spine [56]. Factors associated with a lower occurrence of low back pain are satisfaction with their own performance and with the coaching staff [50].

References

1. International Hockey Federation. Rules of hockey. http://www.fih.ch/inside-fih/our-official-documents/rules-of-hockey/. Accessed 1 Apr 2020.
2. Murtaugh K. Field hockey injuries. Curr Sports Med Rep. 2009;8(5):267–72.
3. Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. J Athl Train. 2007;42(2):311–9.
4. Rauh MJ, Macera CA, Ji M, Wiksten DL. Subsequent injury patterns in girls' high school sports. J Athl Train. 2007;42(4):486–94.
5. Powell JW, Barber-Foss KD. Injury patterns in selected high school sports: a review of the 1995–1997 seasons. J Athl Train. 1999;34(3):277–84.
6. Barboza SD, Joseph C, Nauta J, van Mechelen W, Verhagen E. Injuries in field hockey players: a systematic review. Sports Med. 2018;48(4):849–66.
7. Yard EE, Comstock RD. Injuries sustained by pediatric ice hockey, lacrosse, and field hockey athletes presenting to United States emergency departments, 1990–2003. J Athl Train. 2006;41(4):441–9.
8. Dick R, Hootman JM, Agel J, Vela L, Marshall SW, Messina R. Descriptive epidemiology of collegiate women's field hockey injuries: National Collegiate Athletic Association Injury Surveillance System, 1988–1989 through 2002–2003. J Athl Train. 2007;42(2):211–20.
9. Fong DT, Hong Y, Chan LK, Yung PS, Chan KM. A systematic review on ankle injury and ankle sprain in sports. Sports Med. 2007;37(1):73–94.
10. Scillia AJ, Pierce TP, Issa K, et al. Low ankle sprains: a current review of diagnosis and treatment. Surg Technol Int. 2017;30:411–4.
11. Murtaugh K. Injury patterns among female field hockey players. Med Sci Sports Exerc. 2001;33(2):201–7.
12. Beynnon BD, Vacek PM, Murphy D, Alosa D, Paller D. First-time inversion ankle ligament trauma: the effects of sex, level of competition, and sport on the incidence of injury. Am J Sports Med. 2005;33(10):1485–91.
13. Nelson AJ, Collins CL, Yard EE, Fields SK, Comstock RD. Ankle injuries among United States high school sports athletes, 2005–2006. J Athl Train. 2007;42(3):381–7.
14. Naicker M, McLean M, Esterhuizen TM, Peters-Futre EM. Poor peak dorsiflexor torque associated with incidence of ankle injury in elite field female hockey players. J Sci Med Sport. 2007;10(6):363–71.
15. Chinn L, Hertel J. Rehabilitation of ankle and foot injuries in athletes. Clin Sports Med. 2010;29(1):157–67. https://doi.org/10.1016/j.csm.2009.09.006.
16. Olmsted LC, Vela LI, Denegar CR, Hertel J. Prophylactic ankle taping and bracing: a numbers-needed-to-treat and cost-benefit analysis. J Athl Train. 2004;39(1):95–100.
17. Gross MT, Liu HY. The role of ankle bracing for prevention of ankle sprain injuries. J Orthop Sports Phys Ther. 2003;33(10):572–7.
18. Janssen KW, van Mechelen W, Verhagen EA. Bracing superior to neuromuscular training for the prevention of self-reported recurrent ankle sprains: a three-arm randomised controlled trial. Br J Sports Med. 2014;48(16):1235–9.
19. Handoll HH, Rowe BH, Quinn KM, de Bie R. Interventions for preventing ankle ligament injuries. Cochrane Database Syst Rev. 2001;(3):CD000018.
20. Kim E, Choi H, Cha JH, Park JC, Kim T. Effects of neuromuscular training on the rear-foot angle kinematics in elite women field hockey players with chronic ankle instability. J Sports Sci Med. 2017;16(1):137–46.
21. LaBella CR, Huxford MR, Grissom J, Kim KY, Peng J, Christoffel KK. Effect of neuromuscular warm-up on injuries in female soccer and basketball athletes in urban public high schools: cluster randomized controlled trial. Arch Pediatr Adolesc Med. 2011;165(11):1033–40.
22. Verhagen E, van der Beek A, Twisk J, Bouter L, Bahr R, van Mechelen W. The effect of a proprioceptive balance board training program for the prevention of ankle sprains: a prospective controlled trial. Am J Sports Med. 2004;32(6):1385–93.
23. Roos KG, Kerr ZY, Mauntel TC, Djoko A, Dompier TP, Wikstrom EA. The epidemiology of lateral ligament complex ankle sprains in National Collegiate Athletic Association Sports. Am J Sports Med. 2017;45(1):201–9.
24. Panagodage Perera NK, Joseph C, Kemp JL, Finch CF. Epidemiology of injuries in women playing competitive team bat-or-stick sports: a systematic review and a meta-analysis. Sports Med. 2018;48(3):617–40.
25. Hollander K, Wellmann K, Eulenburg CZ, Braumann KM, Junge A, Zech A. Epidemiology of injuries in outdoor and indoor hockey players over one sea-

son: a prospective cohort study. Br J Sports Med. 2018;52(17):1091–6.
26. Ireland ML. The female ACL: why is it more prone to injury? Orthop Clin North Am. 2002;33(4):637–51.
27. Boden BP, Griffin LY, Garrett WE Jr. Etiology and prevention of noncontact ACL injury. Phys Sportsmed. 2000;28(4):53–60.
28. Barber-Westin SD, Noyes FR, Smith ST, Campbell TM. Reducing the risk of noncontact anterior cruciate ligament injuries in the female athlete. Phys Sportsmed. 2009;37(3):49–61.
29. Huston LJ, Wojtys EM. Neuromuscular performance characteristics in elite female athletes. Am J Sports Med. 1996;24(4):427–36.
30. Renstrom P, Ljungqvist A, Arendt E, Beynnon B, Fukubayashi T, Garrett W, et al. Non-contact ACL injuries in female athletes: an International Olympic Committee current concepts statement. Br J Sports Med. 2008;42:394–412.
31. Voskanian N. ACL injury prevention in female athletes: review of the literature and practical considerations in implementing an ACL prevention program. Curr Rev Musculoskelet Med. 2013;6(2):158–63.
32. Caraffa A, Cerulli G, Projetti M, Aisa G, Rizzo A. Prevention of anterior cruciate ligament injuries in soccer. A prospective controlled study of proprioceptive training. Knee Surg Sports Traumatol Arthrosc. 1996;4(1):19.
33. Mandelbaum BR, Silvers HJ, Watanabe DS, Knarr JF, Thomas ST, Griffin LY, et al. Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up. Am J Sports Med. 2005;33(7):1003–10.
34. Webster KE, Hewett TE. Meta-analysis of meta-analyses of anterior cruciate ligament injury reduction training programs. J Orthop Res. 2018;36(10):2696–708.
35. Vucic S, Drost RW, Ongkosuwito EM, Wolvius EB. Dentofacial trauma and players' attitude towards mouthguard use in field hockey: a systematic review and meta-analysis. Br J Sports Med. 2016;50(5):298–304.
36. Theilen TM, Mueller-Eising W, Wefers Bettink P, Rolle U. Injury data of major international field hockey tournaments. Br J Sports Med. 2016;50(11):657–60.
37. Rossiter M, Challis M. Concussion in field hockey: a retrospective analysis into the incidence rates, mechanisms, symptoms and recovery of concussive injuries sustained by elite field hockey players. BMJ Open Sport Exerc Med. 2017;3(1):e000260.
38. Vucic S, Drost RW, van Wijk AJ, Wesselink PR, Wolvius EB. Patterns of orodental injury and mouthguard use in Dutch field hockey. Br J Sports Med. 2016;50(11):661–8.
39. Gardner EC. Head, face, and eye injuries in collegiate women's field hockey. Am J Sports Med. 2015;43(8):2027–34.
40. National Center for Catastrophic Sport Injury Research. 24th annual report: fall 1982–spring 2006. http://nccsir.unc.edu/files/2014/05/AllSport.pdf.
41. McCrory P, Feddermann-Demont N, Dvořák J, Cassidy JD, McIntosh A, Vos PE, et al. What is the definition of sports-related concussion: a systematic review. Br J Sports Med. 2017;51(11):877–87.
42. Muth CC. Sport-related concussion. JAMA. 2018;319(8):840.
43. Graham R, Rivara FP, Ford MA, Spicer CM, Committee on Sports-Related Concussions in Youth; Board on Children, Youth, and Families; Institute of Medicine; Sports-Related Concussions in Youth. Improving the science, changing the culture. Washington, DC: National Academies Press; 2014.
44. Reams N, Eckner JT, Almeida AA, Aagesen AL, Giordani B, Paulson H, et al. A clinical approach to the diagnosis of traumatic encephalopathy syndrome: a review. JAMA Neurol. 2016;73(6):743–9.
45. Bolhuis JH, Leurs JM, Flögel GE. Dental and facial injuries in international field hockey. Br J Sports Med. 1987;21(4):174–7.
46. Hendrick K, Farrelly P, Jagger R. Oro-facial injuries and mouthguard use in elite female field hockey players. Dent Traumatol. 2008;24(2):189–92.
47. Bowers AL, Baldwin KD, Sennett BJ. Athletic hand injuries in intercollegiate field hockey players. Med Sci Sports Exerc. 2008;40(12):2022–6.
48. Broekstra DC, van den Heuvel ER, Lanting R, Harder T, Smits I, Werker PMN. Dupuytren disease is highly prevalent in male field hockey players aged over 60 years. Br J Sports Med. 2018;52(20):1327–31.
49. Rosberg HE, Carlsson KS, Dahlin LB. Prospective study of patients with injuries to the hand and forearm: costs, function, and general health. Scand J Plast Reconstr Surg Hand Surg. 2005;39(6):360–9.
50. Van Hilst J, Hilgersom NF, Kuilman MC, Kuijer PP, Frings-Dresen MH. Low back pain in young elite field hockey players, football players and speed skaters: prevalence and risk factors. J Back Musculoskelet Rehabil. 2015;28(1):67–73.
51. Mortazavi J, Zebardast J, Mirzashahi B. Low back pain in athletes. Asian J Sports Med. 2015;6(2):e24718.
52. Refshauge KM, Maher CG. Low back pain investigations and prognosis: a review. Br J Sports Med. 2006;40(6):494–8.
53. Heneweer H, Vanhees L, Picavet HS. Physical activity and low back pain: a U-shaped relation? Pain. 2009;143(1–2):21–5.
54. Haydt R, Pheasant S, Lawrence K. The incidence of low back pain in NCAA Division III female field hockey players. Int J Sports Phys Ther. 2012;7(3):296–305.
55. Sherker S, Cassell E. A review of field hockey injuries and countermeasures for prevention. Report No 143. Monash University Accident Research Centre. 2002. 11–27.2.

56. Ogurkowska M, Kawałek K. Pathological changes in the lumbar intervertebral discs among professional field hockey players. J Sports Med Phys Fitness. 2016;56(1–2):85–91.
57. Barboza SD, Nauta J, van der Pols MJ, van Mechelen W, Verhagen EALM. Injuries in Dutch elite field hockey players: a prospective cohort study. Scand J Med Sci Sports. 2018;28(6):1708–14.
58. Ng L, Sherry D, Loh WB, et al. The prevalence and severity of injuries in field hockey drag flickers: a retrospective cross-sectional study. J Sports Sci. 2016;34(18):1746–51.