Handball Injuries: Epidemiology and Injury Characterization: Part 2

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12.1 Introduction

The specific features that differentiate handball from other sports also contribute to specific and typical injury patterns and distribution in the sport. Match intensity, players' positions, the contact nature of the sport, the intense and dynamic nature of each match, the dominant overhead throwing aspect of the sport, as well as the frequent pivoting movements—all these and more have an effect on *HOW* injuries occur in handball, *WHERE* do they occur, *WHEN* do they occur, and to *WHOM* do they occur.

When looking at anatomic distribution of injuries, it is evident from existing epidemiological reports that injuries to the lower extremities are very common in handball, and although several authors found an equal distribution between upper and lower extremity injuries [1–3], most studies show that most acute injuries in handball involve the lower extremities, regardless of age and gender [3–10]. This is the case when looking at injuries at the elite international level as well [11]. The most frequent injuries reported in handball involve the ankle (8–45%), while the most severe injuries involve the knee (7–27%) causing the longest absence from sport [3, 7] and accounting for most insurance-related costs [12]. A few elements distinguish handball from other team ball sports and could help explain the high incidence of ankle injuries. The amount of jumping involved in the game is significant at both ends of the court, and the most common jumping technique in handball is a single leg jump with the majority of players landing on a single leg, leading to high propulsive and impact loads on one

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Fig. 12.1 Ankle injury following an off-balance landing

leg. The most unpredictable factor in handball is the extensive amount of contact allowed, in comparison to, soccer and basketball for example. Even when the contact is sanctioned, many defensive players will risk contact for the price of being punished or sanctioned (unlike basketball, the number of fouls in handball is not counted or accumulated). Therefore, a handball player, while attempting to shoot the ball, will very often encounter contact while both legs are in the air, where even slight contact might tilt the player's balance, increasing the risk of an off-balance landing (Fig. 12.1).

It is therefore crucial to understand each of the sports' unique features in order to understand the epidemiology and in order to be able to derive constructive observations and conclusions.

The purpose of this chapter is to explore the injury distribution in handball through some of the specific aspects of the game.

12.1.1 Match Vs. Training Injuries

As in many other ball sports, match play intensity and contact are substantially increased compared to training in handball. It therefore does not come as a surprise that match injury incidence is significantly higher than training injury incidence [13–17], which is reflected by a high number of injuries caused by the opponent. This is accentuated in the highest-level competitions such as Olympic tournaments and European and world championships with match injuries comprising between 75.3 and 92.6% of injuries while training injuries comprising only between 7.4 and 24.7% of injuries [18–20]. The main reason for this pronounced difference in match and training injury proportions in major competitions is the high ratio of matches to training sessions, which is substantially different from the regular/full season.

A similar match injury to training injury ratio is also evident in young and adolescent players' populations as well with no significant gender differences apparent [11]. Significant differences between match and training injury incidence were also found recently by Piry et al. with 20.7 injuries per 1000 h of competition vs. 0.96 injuries per 1000 h of training [21]. Higher training injury incidence has been shown in lower level of play groups [7], a finding compatible with soccer player populations as shown by Ekstrand et al. [15], who noted a reduction of injuries with increasing training hours. This is attributed to improved coordination and skill, better oxygen uptake, and improved strength.

Looking at data originating from longitudinal/full season studies, the picture is different than the one evident in major competitions. While the incidence of match injuries is still substantially higher than the training injury incidence, the proportion of training injuries is much higher compared to major competitions. This is due to the "normal" ratio of training vs. match exposure during the season, with much more training sessions compared to the major competition scenario. Match injury incidence was significantly higher than training injury incidence in all age groups in a cohort of 517 elite-level players from Denmark, while the injury proportion in training was higher [22]. Another recent cohort of 339 Brazilian elite handball players demonstrated a match injury incidence rate of 20.3/1000 matches compared to 3.7/1000 h of training [23]. A study on 216 Greek male handball players of different levels showed a different pattern as at the lower level, the majority of injuries were reported during matches, whereas at the higher divisions, no difference was found between the percentage of injuries during a match or during training [24]. A similar pattern was observed by Luig et al. in the first and second men's German leagues over the 2014–2015 and 2015–2016 sea-

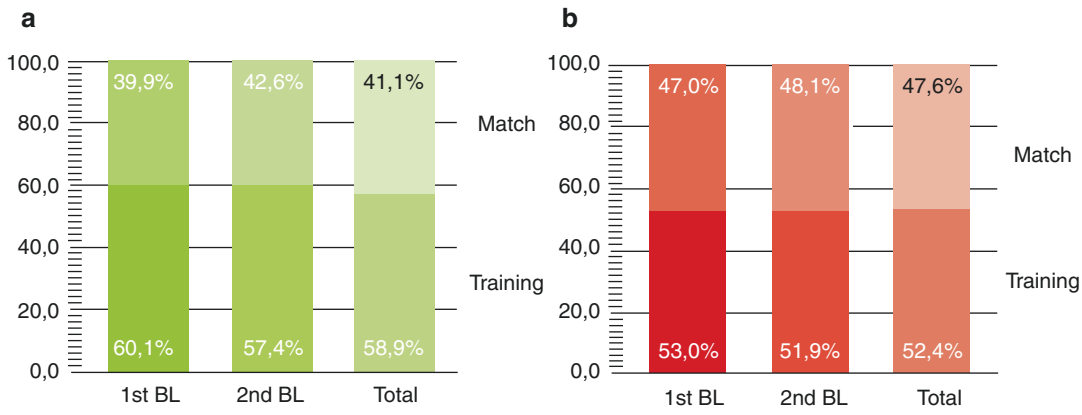

Fig. 12.2 Proportion of match vs. training injuries in the first and second German Bundesleagues (BL) over the 2014–2015 (**a**) and 2015–2016 seasons (**b**) Modified from [12, 25]. Used with permission

son based on insurance registry data [12, 25]. Figure 12.2a, b shows the injury proportion (%) between training and match injuries in the 2014–2015 and 2015–2016 seasons in the highest two divisions in Germany, showing a higher proportion of injuries occur during training (to distinguish from the incidence, which is higher in matches).

Fact Box
Match injuries incidence in handball is higher than training injuries.

12.1.2 Injuries According to Player Position

When analyzing injury data according to players' positions, it is evident that backcourt and wing players are at a higher risk of injuries. The majority of available studies have highlighted backcourt players to be more at risk for injury [5, 26, 27]. Wedderkopp et al. showed that young female back players had the highest overall incidence of injuries and the highest number of acute noncontact lower-limb injuries as compared with other player positions [9]. A retrospective study by Piry et al. of the 2008 Asian Handball Championships found 60.3% of injuries occurred to back players, whereas only 12.7% occurred to the wing players and 11.1% to the line players (pivot) [21]. A possible explanation for this trend could be that the majority of ball movements in the offense are done by the back players who therefore perform a substantial amount of planting and cutting movements as well as jump shots. In addition, they are involved in more aggressive contact than players at other positions, normally facing the biggest and strongest defenders in the opposing team.

A similar trend was observed by Moller et al. in their cohort of 517 elite-level players from Denmark, with injuries being more predominant in back court players, followed by wing players (in both genders and all age groups—senior, U-18, U16) [22].

Myklebust et al. have repeatedly shown that the relative risk of ACL injury is higher among back players [28–30].

In a year-long study of 186 players (male) in 16 senior German teams, Seil et al. [7] looked at injury distribution according to playing positions. Of the overall 91 injuries recorded, wing players sustained 36% of all injuries, backcourt players sustained 33% of all injuries, 19% occurred to line players, and goalkeepers sustained 12% of the injuries. An analysis of this data for match injury rates by position (injuries/1000 match hours) revealed 18.6 per 1000 player match hours for wing players, 17.1/1000 match hours for line players, 12.8/1000 match hours for goalkeepers, and 10.5/1000 match hours for backcourt players. Wing players also had the highest rate of serious and severe injuries

in that study, followed by backcourt players, goalkeepers, and line players [7]. They also observed an increasing rate of upper extremity injuries (shoulder and upper arm) in wing and backcourt players as well as a high prevalence (89%) of shoulder overuse symptoms in these positions [7]. The higher injury rates among wing players in that study were attributed to greater variation in motion and stress patterns compared with other player positions. Frequent jumps and falls, a high number of contact situations with opposing players, and involvement in counterattacks (Fig. 12.3) seem to increase the injury rates for wing players.

A different pattern was observed in the 2015 men's world championships in Qatar where the highest total risk of injury was for line players, followed by wings, backs, and goalkeepers. For time-loss injuries, the risk was almost the same for line and wing players. These differences from previously reported incidence rates could be explained by the fact that unlike previous studies which did not take exposure into full consideration, the data from Qatar was analyzed through distribution of the total exposure time (player-hours) in accordance with the most common team player formation (three back players, two wing players, one line player, and one goalkeeper) [31]. This may be an important starting ground for future epidemiologic studies in handball to better and closely evaluate exposure as well as taking it into a more accurate calculation when it comes to data analysis.

Fig. 12.3 A player in a shot attempt during a counterattack

12.1.2.1 Injuries According to Playing Level

Injury rate seems to be higher among players in higher-level leagues although there aren't any available studies which directly compared this aspect. Strand et al. reported early on that female players in the top three divisions have a higher ACL injury incidence than players playing at lower levels [32]. Myklebust et al. have repeatedly shown that the relative risk of ACL injury is higher among back players [28–30]. Data from Myklebust et al. suggested the proportion of ACL injuries in back players seems to be higher in studies involving elite players [30].

12.1.3 Injury Mechanism: Contact Vs. Noncontact

Most injuries in elite handball occur during player-to-player contact. Noncontact injuries mostly are related to the lower extremities, and in general those injuries are more severe (i.e., ACL injuries). Jumping, landing, and cutting maneuvers are the predominant situations leading to noncontact injuries. Luig et al. reported 30.6% of all injuries occurred during landing [11]. Studies at the top competition level show that contact injuries represent between 80 and 92% [20, 33, 34]. According to Langevoort et al. [20], about 50% of the injuries during major international tournaments are caused by a foul that is sanctioned; however, a decrease in the "foul play" injuries has been recorded for both men and women in the European championships in 2008 and 2010. In the men's Euro in 2008, only 25.5% of injuries were associated with foul play [35], while 39.6% were reported for the women's 2008 games [36]. In the 2010 men's Euro, only 11.1% of injuries were associated with foul play [37], while only 3.5% were reported in the women's 2010 Euro [38]. These high numbers are not the case when analyzing ACL injuries, which is a noncontact mechanism in the majority of cases when the player is performing a plant and cut maneuver or landing after a jump shot [28–30]. In the 2015 men's

world championships, 61.4% were reported as the result of contact between players, while 15.9% were reported as noncontact trauma (the rest were overuse injuries) [31].

Giroto et al. reported 41.4% (35.8% in women; 48.5% in men) noncontact injuries in their cohort of 339 Brazilian elite-level players, while 34.6% (40.9% in women; 26.5% in men) were contact injuries [23].

Recent insurance company injury data from Germany focusing on all professional male player teams of the German national first and second leagues (Bundesleagues) revealed contact injuries were responsible for 78.1% of injuries, while 21.9% were noncontact [12]. Out of the contact injuries, 52.3% were defined as "direct contact injuries" where direct player-to-player or object-to-player contact to the injured structure caused the injury, and 25.8% were defined as "indirect contact injuries" where the contact was not directed to the injured anatomic structure and does not directly cause the injury but leads to a situation that subsequently causes the injury, e.g., knee injury during landing after a push against the chest while airborne, etc.

Unpublished data by Andersen et al. based on video analysis from the 2015 world championships suggested that a great majority of the contact injuries were under-sanctioned by the referees. Although decision-making regarding sanctions due to fouls is easier based on video and repeated viewing, it is clear that more could be done in this aspect as well to protect the players.

Fact Box
Most injuries in elite handball occur during player-to-player contact.

12.1.4 Timing of Injury During Matches

Trying to analyze WHEN do injuries occur in handball, reports are not always consistent. Dirx et al. revealed a higher injury incidence during the second half of matches, which was attributed to increasing player's fatigue and intensity of close matches [4]. Asembo and Wekesa reported that 57% of injuries occurred in the second half [33], while Langevoort et al. reported that 45% of the injuries occurred in the middle 10 min of each half and decreased toward the end of each half [20]. Seil et al. interestingly noted up to 10% of all match injuries occurred during the warm-up phase, which can be attributed to an inadequate and perhaps too intense warm-up [7]. Luig et al. looked at data from the first 2 professional German leagues between 2010-2016 and reported a similar injury distribution between halves, with the majority of injuries occurring in the last 10 min of each half (Fig. 12.4) [11]. It is important to note that these reports (and most other studies) do not take into account the minutes played by the injured player in that specific match, as well as the player's exposure in the same week or even up until that phase of the season, and therefore should be looked at carefully.

Data from the 2015 men's world championship showed more injuries occurred during the first half of the match compared with the second half (126.7 vs. 63.4 injuries/1000 player-hours, respectively) [31]. The difference between the first and second half was even higher for time-loss injuries (68.5 vs. 29.1 injuries/1000 h, respectively). The highest risk of injury was found in the second part of the first half (188.5 injuries/1000 h). Table 12.1 summarizes injuries by match time in elite-level international competition. It is evident from this data that there is a tendency toward more second half injuries in major competitions; however, it is not consistent and less significant when looking at the women's data. One of the great difficulties in analyzing this data is that the majority is derived from major international competitions where exposure is not equal between teams as well as the fact that training exposure is not calculated (although may not be as important as during a full season). Full season data with more accurate exposure assessment would better help characterize and identify patterns in injury timing during matches and when players may be at risk.

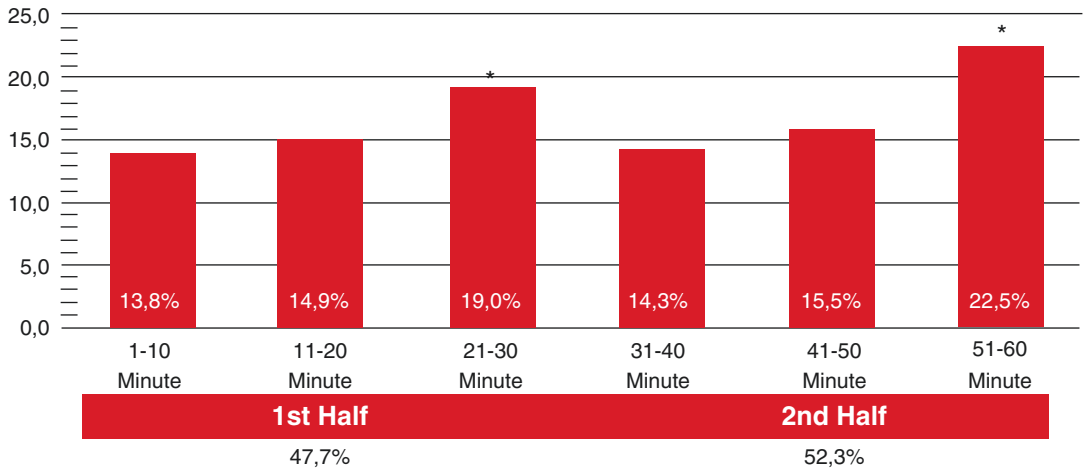

Fig. 12.4 Timing of injuries within games in the first and second German leagues in the 2010–2016 showing a very similar distribution between halves in these consecutive seasons, with a higher risk of injury in the last 10 min of every half [11]

Table 12.1 Timing of injuries within games in elite-level international competitions by gender

	Male					Female				
	2001 WC	2003 WC	2004 OG	2008 EC	2010 EC	2002 EC	2003 WC	2004 OG	2008 EC	2010 EC
First half										
1–10 min	11%	10%	13%		20% (1–15 min)	8%	7%	11%	17% (1–15 min)	12.9% (1–15 min)
11–20 min	13%	22%	15%		24.4% (16–30 min)	21%	21%	16%	38.3% (16–30 min)	21.2% (16–30 min)
21–30 min	13%	21%	13%			13%	20%	19%		
Total first half	37%	53%	41%	27.7%	44.4%	42%	48%	46%	55.3%	34.1%
Second half										
31–40 min	22%	16%	11%	38.3% (31–45 min)	20% (31–45 min)	13%	16%	13%	21.3% (31–45 min(	35.3% (31–45 min)
41–50 min	32%	22%	35%	34% (46–60 min)	26.7% (46–60 min)	29%	26%	22%	23.4% (46–60 min)	30.6% (46–60 min)
51–60 min	8%	6%	13%			15%	8%	17%		
OT	1%	3%	0			0	2%	2%		
Total second half + OT	63%	47%	59%	72.3%	46.7% (+8.9% in OT.)	57%	52%	54%	44.7%	65.9%

WC world championships, *EC* European championships, *OG* Olympic Games, *OT* over time
Data based on Langevoort [20] and Holdhaus [35–38]

12.1.5 In Which Phase Do Injuries Occur: Offense Vs. Defense

Evidence from major competitions as well as longitudinal studies shows the majority of injuries in handball occur during the offensive phase of the game (when a team is on offense), with reports ranging from 52 to 86% [2, 7, 26, 33, 34]. Several other authors showed the same trend with reports ranging from 77 to 92% of injuries occur-

ring during the offensive phase of play [8–10, 39]. Two studies, however, showed a different trend, reporting a higher incidence of injuries during the defensive phase of the game. For example, Reckling et al. [6] stated that almost two-thirds of the injuries occurred during the defensive phase [21], as did Oehlert et al. who reported 84% of the injuries in their study occurred during the defensive phase [34]. Most players are injured in contact situations, and offensive players are more at risk than defensive players as the defensive player is the one who typically initiates the contact. Seil et al. found that approximately one-third of offensive injuries occurred during the fast break/counterattack phase [7].

A similar distribution of offensive injuries dominance was observed in the German insurance company registry of handball injuries in the top two divisions, with over 60% of injuries occurring during the offensive phase [12].

Fact Box
Most players are injured in the offensive part of the game.

12.2 Injury Type

12.2.1 Traumatic/Acute Injuries

The majority of injuries reported in handball, both in adults and adolescents, are acute injuries. In international championships, contusions are the most common injury type with an incidence between 44 and 60% followed by muscle strains and ligament sprains with 7–27% of all injuries [20, 33]. Data collected in the world championships in 2015 revealed the most common injury type was contusions (38.6%), followed by sprains (23.5%) and strains (12.9%). Muscle strains affected mainly the lower extremities (88.2%; mainly in the thigh and groin), while most contusions were located in the face (6.8%), thigh (6.8%), knee (6%), and lower back. Ankle sprains (15.9%) were the most frequent specific diagnosis [31]. Other studies have highlighted sprains as the most common injury type (46–68% of all injuries) [3, 7]. These results reflect different injury definitions in these studies. Muscle strains present an overall incidence of 6–26% [7, 9, 20, 27, 40]. Contusions range from 2 to 36% of all injuries [5, 9]. Fractures and dislocations are usually less common, but two studies noted exceptions to this observation. Fagerli et al. [5] reported the fracture incidence to be 19–22%; however, they studied emergency department records, which could explain the high numbers of fractures. Asembo and Wekesa [33] reported a fracture incidence of 31% among elite-level male players; however, these numbers are not consistent with the data of Langevoort et al. [20] among a larger number of elite-level players, where the fracture incidence was only 1%–2%. Moller et al. reported an overall incidence of 63% acute/traumatic injuries in a large cohort of elite-level senior and youth players in Denmark over a season [22]. The most common injuries were sprains/distortion (46%) followed by muscle strains (17%) and contusions (9%). Giroto et al. recorded 237 traumatic injuries of the total 312 injuries (76%) in Brazilian elite players over a full season [23]. Muscle strain/rupture/tear, sprain (joint and/or ligament), and contusion were the three leading injury types. Fractures comprised 4% of injuries in this study.

12.2.2 Overuse Injuries

Over the years there have been insufficient data regarding overuse injuries in handball; however, medical personnel who attend to handball players acknowledge their incidence is quite high. In their unpublished data, Gundersen and Myklebust observed that 41% of all injuries that required treatment were overuse injuries with the most common location being the shoulder (22%). They did not distinguish overuse injuries according to gender. In another study, the incidence of overuse injury to the shoulder of German players was

reported to be 40% [41]. Similar high prevalence of shoulder overuse injuries were also reported by Nielsen and Yde where 8 out of 12 shoulder and elbow injuries were deemed to be overuse injuries; the total incidence of overuse injuries in their study was 27% of all injuries [3]. In the study by Leidinger et al., the most common locations of overuse injury were the knee (26.9%) and ankle (20.3%), but handball-specific overuse injuries like "throwing shoulder" and "throwing elbow" accounted for 17.1% and 11.9% of the overuse injuries [2]. Tyrdal and Bahr stated that 41% of 729 (male and female) goalkeepers reported current elbow injuries [42]. The condition was termed "handball goalie's elbow" and appeared to result from repeated elbow hyperextension trauma. These reports are consistent with the findings of Seil et al. [7] at the nonprofessional level, where one out of three goalkeepers suffered from elbow overuse symptoms; 66% of the players suffered from 183 overuse symptoms overall (n = 123). The shoulder was the most common region (19%), followed by low back complaints (17%) and knee (16%). In a study by Lian et al. [43] looking at "jumper's knee" among elite athletes from different sports, the total prevalence among male handball players was 30% and 10% among females [43]. Olsen et al. reported that lower-leg pain (periostitis) was the most common overuse problem [40].

Moller et al. reported 37% overuse injuries in their cohort of 517 elite-level senior and youth players from Denmark [22]. Prevalence distribution between senior, U-18, and U-16 players was 31%, 36%, and 45%, respectively. These numbers are slightly higher than previously reported by Wedderkopp et al. [9] and Seil [10] in youth players (7–21%). Shin splints (22%) were the most common overuse injuries, accounting for 35 of the 39 reported lower-leg injuries, followed by tendinopathy (22%) and bursitis (7%). The knee was the most commonly affected site after the lower leg, followed by the shoulder. Clarsen et al. studied the prevalence and impact of overuse injuries in Norwegian sports, including 55 handball players [44]. They reported the shoulder was the most common site of injury for overuse injuries (22%) followed by the knee (20%); however, the knee was the most common site for substantial overuse injuries (8%) compared to the shoulder (6%).

Bere et al. recorded 12.1% overuse injuries during the 2015 men's world championship; however, this is probably an underestimation as it is likely that many players played despite overuse injuries and pain and did not wish to miss the opportunity of playing at the front stage of international handball [31]. Giroto et al. reported a prevalence of 24% overuse injuries in elite Brazilian male and female player over a full season (25% and 23.3%, respectively) [23]. Of those, the majority of overuse injuries were recorded in the shoulder (44%) followed by the knee (26.7%).

Luig et al. reported 11.2% overuse injuries in their analysis of first and second Bundesleague players (Germany) over three seasons, with 6.2% of overuse injuries causing time-loss of >28 days [45].

12.3 Summary

The game of handball is ever growing in popularity with the increasing involvement of different media platforms (Internet, TV, social media) and endorsements accompanying this type of exposure. This growing popularity attracts more and more participants, as well as the variations of the game, such as beach handball and street handball. The natural evolution of the game of handball has resulted in more intense competition at the top levels. The combination of greater intensity and the frequent matches played in multiple competitions (and the resulting loss of recovery time between matches) places the players at high risk for injuries.

Data from existing epidemiologic studies in handball is not uniform in its methodology, a fact that may explain some of the inconsistencies in various observations. Yet several patterns have been recognized. The majority of injuries occur during matches when compared to training[3, 7], and more injuries occur during the offensive

phase of the game compared to the defensive phase [8–10, 39]. Lower extremities account for most of the acute injuries, followed by injuries of the upper extremities and head injuries. Sprains and contusions are the predominant injury types. Knee injuries represent by far the largest share of severe injuries, and women are clearly more vulnerable to knee injuries, in particular to ACL tears. Backcourt players seem to sustain more injuries compared to other player positions, followed by wing players.

The majority of injuries in handball are contact induced, and since up to 50% of the injuries are "foul play" related, referees have an important role in protecting the players and enforcing fair play. An emphasis should clearly be directed to this aspect.

Sufficient data regarding overuse injuries is especially limited [46]. As these injuries sometimes draw less attention and are less dramatic than acute injuries, many players choose to keep playing with overuse injuries and pain despite the consequence of a reduced performance level. Overuse injuries often possess a real challenge and are difficult to manage within the tight schedule typical at the highest competitive levels. Better characterization and understanding of the extent of overuse injuries in handball are necessary and should be the focus of future studies [47, 48].

Another important aspect when trying to understand injuries and their effect on various populations is their long-term consequences. Such studies are sparse in handball players; however, few studies looking at the rates of osteoarthritis in former handball players suggest this should also be an important focus of future studies [47, 48].

It is clear that Injuries are part of a handball player's career span. A better understanding of injury types and mechanisms can aid with injury reduction and improved injury management. Improved knowledge on injury mechanisms is also required in order to plan and incorporate appropriate and effective prevention measures. Well-designed studies addressing the specific demands and needs of handball players will improve the understanding of these issues and help apply the derived conclusions in all aspects of the game, from national and international competition schedules, to protect players, educate coaches, and provide guidelines for referees to better balance permitted contact with players' safety.

References

1. Hoeberigs JH, van Galen WC, Philipsen H. Pattern of injury in handball and comparison of injured versus noninjured handball players. Int J Sports Med. 1986;7:333–7.
2. Leidinger A, Gast W, Pforringer W. Traumatology in indoor handball sports. A sports medicine analysis of the incidence of injuries and accident epidemiology of indoor handball sports in senior players in the Federal Republic of Germany after 1981. Sportverletz Sportschaden. 1990;4:65–8.
3. Nielsen AB, Yde J. An epidemiologic and traumatologic study of injuries in handball. Int J Sports Med. 1988;9:341–4.
4. Dirx M, Bouter LM, de Geus GH. Aetiology of handball injuries: a case–control study. Br J Sports Med. 1992;26:121–4.
5. Fagerli UM, Lereim I, Sahlin Y. Injuries in handball players. Tidsskr Nor Laegeforen. 1990;110:475–8.
6. Reckling C, Zantop T, Petersen W. Epidemiology of injuries in juvenile handball players. Sportverletz Sportschaden. 2003;17:112–7.
7. Seil R, Rupp S, Tempelhof S, Kohn D. Sports injuries in team handball. A one-year prospective study of sixteen men's senior teams of a superior nonprofessional level. Am J Sports Med. 1998;26:681–7.
8. Wedderkopp N, Kaltoft M, Holm R, Froberg K. Comparison of two intervention programmes in young female players in European handball—with and without ankle disc. Scand J Med Sci Sports. 2003;13:371–5.
9. Wedderkopp N, Kaltoft M, Lundgaard B, Rosendahl M, Froberg K. Injuries in young female players in European team handball. Scand J Med Sci Sports. 1997;7:342–7.
10. Wedderkopp N, Kaltoft M, Lundgaard B, Rosendahl M, Froberg K. Prevention of injuries in young female players in European team handball. A prospective intervention study. Scand J Med Sci Sports. 1999;9:41–7.
11. Laver L, Myklebust G. Handball injuries: epidemiology and injury characterization. In: Doral MN, Karlsson J, editors. Sports injuries. Springer-Verlag Berlin Heidelberg; 2015. https://doi.org/10.1007/978-3-642-36569-0_287.
12. Luig P, Bloch H, Burkhardt K, Klein C, Kühn N. VBG-Sportreport 2017—Analyse des Unfallgeschehens in den zwei höchsten Ligen der Männer: Basketball, Eishockey, Fußball und Handball. Hamburg: VBG; 2017.

13. Backx FJ, Beijer HJ, Bol E, Erich WB. Injuries in high-risk persons and high-risk sports. A longitudinal study of 1818 school children. Am J Sports Med. 1991;19:124–30.
14. Yde J, Nielsen AB. Sports injuries in adolescents' ball games: soccer, handball and basketball. Br J Sports Med. 1990;24:51–4.
15. Ekstrand J, Gillquist J, Moller M, Oberg B, Liljedahl SO. Incidence of soccer injuries and their relation to training and team success. Am J Sports Med. 1983;11:63–7.
16. Lorentzon R, Wedren H, Pietila T. Incidence, nature, and causes of ice hockey injuries. A three-year prospective study of a Swedish elite ice hockey team. Am J Sports Med. 1988;16:392–6.
17. Twellaar M, Verstappen FT, Huson A. Is prevention of sports injuries a realistic goal? A four-year prospective investigation of sports injuries among physical education students. Am J Sports Med. 1996;24:528–34.
18. Engebretsen L, Soligard T, Steffen K, Alonso JM, Aubry M, Bidgett R, Dvorak J, Jegathesan M, Meeuwisse WH, Mountjoy M, Palmer-Green D, Vanhegan I, Renstrom PA. Sports injuries and illnesses during the London Summer Olympic Games 2012. Br J Sports Med. 2013;47(7):407–14.
19. Junge A, Engebretsen L, Mountjoy ML, Alonso JM, Renstrom PA, Aubry MJ, Dvorak J. Sports injuries during the Summer Olympic Games 2008. Am J Sports Med. 2009;37:2165–72.
20. Langevoort G, Myklebust G, Dvorak J, Junge A. Handball injuries during major international tournaments. Scand J Med Sci Sports. 2007;17:400–7.
21. Piry H, Fallahi A, Kordi R, Rajabi R, Rahimi M, Yosefi M. Handball Injuries in Elite Asian Players. World Appl Sci J. 2011;14:1599–64.
22. Moller M, Attermann J, Myklebust G, Wedderkopp N. Injury risk in Danish youth and senior elite handball using a new SMS text messages approach. Br J Sports Med. 2012;46(7):531–7.
23. Giroto N, Hespanhol Junior LC, Gomes MR, Lopes AD. Incidence and risk factors of injuries in Brazilian elite handball players: a prospective cohort study. Scand J Med Sci Sports. 2017;27(2):195–202.
24. Hatzimanouil D, Oxizoglou N, Sikaras A, Hatzimanouil K, Koronas K, Tsigilis N, Abatzides G. Factors related to the incidence and severity of injuries in team handball. J Hum Mov Stud. 2005;45:335–51.
25. Luig P, Bloch H, Burkhardt K, Klein C, Kühn N. VBG-Sportreport 2016—Analyse des Unfallgeschehens in den zwei höchsten Ligen der Männer: Basketball, Eishockey, Fußball und Handball. Hamburg: VBG; 2016.
26. Frobose I, Knaak AK, Menke W. Haufigkeit und Lokalisation von Verletzungen im Frauenhandball. Dtsch Ztschr Sportmed. 1996;47:472–8.
27. Jorgensen U. Epidemiology of injuries in typical Scandinavian team sports. Br J Sports Med. 1984;18:59–63.
28. Myklebust G, Engebretsen L, Braekken IH, Skjolberg A, Olsen OE, Bahr R. Prevention of anterior cruciate ligament injuries in female team handball players: a prospective intervention study over three seasons. Clin J Sport Med. 2003;13:71–8.
29. Myklebust G, Maehlum S, Engebretsen L, Strand T, Solheim E. Registration of cruciate ligament injuries in Norwegian top level team handball. A prospective study covering two seasons. Scand J Med Sci Sports. 1997;7:289–92.
30. Myklebust G, Maehlum S, Holm I, Bahr R. A prospective cohort study of anterior cruciate ligament injuries in elite Norwegian team handball. Scand J Med Sci Sports. 1998;8:149–53.
31. Bere T, Alonso JM, Wangensteen A, Bakken A, Eirale C, Dijkstra HP, Ahmed H, Bahr R, Popovic N. Injury and illness surveillance during the 24th men's Handball World Championship 2015 in Qatar. Br J Sports Med. 2015;49:1151–6.
32. Strand T, Tvedte R, Engebretsen L, Tegnander A. Anterior cruciate ligament injuries in handball playing. Mechanisms and incidence of injuries. Tidsskr Nor Laegeforen. 1990;110:2222–5.
33. Asembo JM, Wekesa M. Injury pattern during team handball competition in east Africa. East Afr Med J. 1998;75:113–6.
34. Oehlert K, Drescher W, Petersen W, Zantop T, Gross V, Hassenpflug J. Injuries in olympic handball tournaments: a video analysis. Sportverletz Sportschaden. 2004;18:80–4.
35. Holdhaus H. Summary of the injury study conducted at the EHF men's Euro 2008 in Norway. Vienna: EHF Web Periodical; 2008a.
36. Holdhaus H. Summary of the injury study conducted at the womens' handball EHF 2008 Euro. Vienna: EHF Web Periodical; 2008b.
37. Holdhaus H. Summary of the injury study conducted at the EHF women's Euro 2010 in Denmark & Norway. Vienna: EHF Web Periodical; 2010a.
38. Holdhaus H. Summary of the injury study conducted at tht EHF men's Euro 2010 in Austria. Vienna: EHF Web Periodical; 2010b.
39. Olsen OE, Myklebust G, Engebretsen L, Holme I, Bahr R. Relationship between floor type and risk of ACL injury in team handball. Scand J Med Sci Sports. 2003;13:299–304.
40. Olsen OE, Myklebust G, Engebretsen L, Bahr R. Injury pattern in youth team handball: a comparison of two prospective registration methods. Scand J Med Sci Sports. 2006;16:426–32.
41. von Gohlke F, LIppert MJ, Keck O. Instabilität und impigement an der Schulter des Leistungssportlers mit Überkopfbelastung. Sportverletz Sportschaden. 1993;7:115–21.
42. Tyrdal S, Bahr R. High prevalence of elbow problems among goalkeepers in European team handball—'handball goalie's elbow'. Scand J Med Sci Sports. 1996;6:297–302.

43. Lian OB, Engebretsen L, Bahr R. Prevalence of jumper's knee among elite athletes from different sports: a cross-sectional study. Am J Sports Med. 2005;33:561–7.
44. Clarsen B, Myklebust G, Bahr R. Br J Sports Med. 2013;47:495–502.
45. Luig P. Verletzungen im deutschen Profihandball der Männer—Epidemiologische Aspekte von Wettkampfverletzungen bei Erst- und Zweitligaspielern (2010–2013) unter Berücksichtigung systematischer Videoanalysen. Dissertation. Bochum: Ruhr-Universität Bochum; 2016.
46. Bahr R. No injuries, but plenty of pain? On the methodology for recording overuse symptoms in sports. Br J Sports Med. 2009;29:966–72.
47. L'Hermette M, Polle G, Tourny-Chollet C, Dujardin F. Hip passive range of motion and frequency of radiographic hip osteoarthritis in former elite handball players. Br J Sports Med. 2006;40:45–9; discussion 45–49
48. Myklebust G, Holm I, Maehlum S, Engebretsen L, Bahr R. Clinical, functional, and radiologic outcome in team handball players 6 to 11 years after anterior cruciate ligament injury: a follow-up study. Am J Sports Med. 2003;31:981–9.