Handball Injuries: Epidemiology and Injury Characterization

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Abstract

Handball (referred by many as "team handball") is a worldwide popular Olympic team ball sport. Over the years, handball has been in continuous development, which is evident in the increases in player speed, strength, and technique, as well as changes in the rules and tactics. Handball is characterized by intense body contact, frequent intermittent running, demanding one-on-one confrontations, and quick direction changes in combination with challenging technique and coordination elements like catching, throwing, passing, and dribbling.

Aggressive contact is an integral part of the game and often used not only to stop the opponent but also to intimidate opponents from approaching the goal. Contact-related injuries represent a large fraction of all handball injuries, and therefore, the referee has an important task in taking care of the player's health by keeping the game fair and severely sanctioning foul play.

At the professional level, matches are played year round with elite players playing between 70 and 100 matches a year. The physiologic load that each player is exposed to varies depending on their playing level and the total number of players in the teams, but is considered to be high within the spectrum of all ball sports. Unfortunately, as in other ball and contact sports, injuries are a part of the game. The purpose of this chapter is to improve the understanding of the etiology and incidence of handball injuries in order to increase awareness, recognize the risk factors for injuries, and incorporate prevention strategies and proper treatment.

Introduction

Handball (referred by many as "team handball") is a worldwide popular team ball sport, and it has been an Olympic sport since Münich in 1972. Today, handball is played in 199 countries; there are 19 million players worldwide in approximately 800,000 teams (International Handball Federation 2010). Handball has been a game in continuous development that is evident in the increase in players' speed, strength, and technique, as well as changes in the rules and tactics over the years. Handball is characterized by intense body contact, frequent intermittent running, demanding one-on-one situations, and quick direction changes in combination with challenging technique and coordination elements like catching, throwing, passing, and dribbling.

Since unlike basketball, handball players are allowed an unlimited number of fouls, which, within the game's rules, are considered good defense and aims to disrupt the attacking team's rhythm. It is common that aggressive contact is often used not only to stop the opponent (Fig. 1) but also to intimidate opponents from approaching the goal. Therefore, the referee has an important task taking care of the player's health by keeping the game fair and sanctioning brutal play.

Earlier studies in the handball literature have reported that contact-related injuries represent between 40 % and 84 % of the total number of injuries (Nielsen and Yde 1988; Fagerli et al. 1990).

Matches are played year round at the professional level. The top-level players, in addition to their club activity, are usually engaged in activity with a national team. Combining international competitions with both their club and national team, elite players play between 70 and 100 matches a year. World Championships and continental championships are played every other year (consecutive years), and every 4 years, there is also a handball tournament as part of the Olympic Games. The physiologic loads that each player is exposed to varies depending on their playing level and the total number of players in the teams, but it is considered high, and there is only a brief time to rest during major competitions where the top teams can play 8 matches in 13 days, such as during the European Championships. Unfortunately, sports injuries are a part of the game. The purpose of this chapter is to review the handball literature on injury incidence, injury type, and anatomic location. Match-related aspects will be

Fig. 1 Contact commonly seen in handball in an attempt to stop a player trying to shoot (Photos courtesy of Lothar Gudat. Used with permission)

discussed for injury mechanisms, injury time, and on-court position. Knowledge and understanding of the etiology, as well as incidence of handball injuries, may be useful in increasing awareness, recognize the risk factors for injuries, incorporate prevention strategies, and proper treatment. This chapter aims to create a concise knowledge base and provide better tools for the medical personnel in handball to face these challenges.

Epidemiology

Injuries are common in handball as in other team ball sports, such as football and basketball (Jorgensen 1984; Nielsen and Yde 1988; Fagerli et al. 1990; Lindblad et al. 1992; Kujala et al. 1995; Wedderkopp et al. 1997, 1999; de Loes et al. 2000; Reckling et al. 2003). The potential for injury in this sport is related to its dynamic character and the less restrictive rules regarding physical contact when compared with basketball, for example. There are many studies on handball, but there is a lack of knowledge concerning men's handball and especially in the elite level. Some studies have been performed looking at injuries at the top international level for men in the Olympic Games in Athens 2004, Beijing 2008, and London 2012 (Junge et al. 2006, 2009; Engebretsen et al. 2013) and the World Championships in 2001 and 2003 (Langevoort et al. 2007). Furthermore Asembo and Wekesa studied East and Central Africa Senior Clubs Championship in Kenya in 1995 (Asembo and Wekesa 1998), and Oehlert et al. made a video analysis of injuries during the Olympic Games in Barcelona 1992 (Oehlert et al. 2004). A more recent study was performed in the Asian Handball Championships in 2008 (Wedderkopp et al. 1997); these studies represent the highest performance level, but many other studies and data exist in handball, involving different age groups, gender comparisons, and in different levels of play. Assessing the true incidence and risk of injury in handball is a challenging task because of differences in the definition of injury in the literature. The time-loss definition is used in most studies, but some investigators have included injuries that do not necessarily answer the time-loss injuries criteria. Most studies in elite handball define an injury as "any physical complaint incurred during a match that received medical attention from the team physician regardless of the consequences with respect to absence from the match or training" (Nielsen and Yde 1988; Tyrdal and Bahr 1996; Fuller et al. 2006; Junge et al. 2006; Langevoort et al. 2007). Another common definition is an event causing time loss from at least one match or training session. A third

Table 1 Duration of absence in elite-level competition >7 d

Male									Female			
	2001 WC	2003 WC	2004 OG	2008 EC	2010 EC	2012 OG	2002 EC	2003 WC	2004 OG	2008 EC	2010 C	2012 OG
Players (n)	160	160	87			178	96	160	66			171
All injuries	96	110	49	47	45	31	52	106	65	53	85	45
>7 d	4 (5 %)	6 (7 %)	4 (9 %)	10 (21.3 %)	7 (15.5 %)	6 (3.4 %)	3 (6 %)	4 (4 %)	2 (4 %)	7 (13.2 %)	12 (14.6 %)	10 (5.8 %)

Data based on Langevoort and Holdhaus
WC World Championships, *EC* European Championships, *OG* Olympic Games

definition is "all injuries which led either to a temporary stoppage of the match or to substitution of the injured player (Asembo and Wekesa 1998; Oehlert et al. 2004). An additional challenge when analyzing the data is presented in the definition of injury severity. The most widely used classifications of injury severity in the handball literature are minor injury (1–7 days absence), moderate injury (8–21 days absence), and major injury (>21 days); however, some studies do not include injuries without time loss, and some use different criteria (van Mechelen et al. 1992), which is based on injury nature and duration, treatment type, time lost from sports, time lost from work, permanent damage, and costs. Langevoort et al. and Junge et al. based their data on estimations of the duration of absence after injuries and not actual follow-up. Table 1 presents the incidence of injuries causing an absence of >7 days in elite-level international competitions. An additional important aspect is that the injury-registration level and methods vary between studies. In some studies, injuries were registered from hospital records or large national surveys (Fagerli et al. 1990; de Loes 1995; Myklebust 2009). Others collected data of injuries from hospital records or insurance companies, which can cause a bias and probably present a larger number of more serious and more acute injuries; minor injuries and overuse injuries can be missed using this method. Other studies used questionnaires and telephone or in-person interviews as registration methods. It is also important to notice whether the registration was performed prospectively or retrospectively. When it comes to epidemiologic studies, the registration method can affect the accuracy and reliability of the data.

The incidence of major injuries ranges from 5 % to 36 % and reinjuries are common (Nielsen and Yde 1988; Seil et al. 1998; Wedderkopp et al. 1999, 2003; Myklebust et al. 2003b; Olsen et al. 2006; Langevoort et al. 2007). In one study, 20 % of the players reported absence from handball for 4 weeks because of injury (Nielsen and Yde 1988). In the study by Langevoort et al., 5 % of the injuries led to >1 week absences. Ankle, knee, and head injuries most frequently led to absences (Langevoort et al. 2007). In addition, they reported that noncontact injuries caused longer absence from handball when compared to contact injuries. In a study of youth players, Olsen et al. reported that 56 % of the acute match injuries and 50 % of acute training injuries were moderate (<8 days lost) or major (>21 days lost) injuries (Olsen et al. 2006). In an unpublished prospective study performed in Norway, Gundersen and Myklebust reported a 30 % prevalence of major injuries with a time loss over 28 days.

Few studies have compared handball injury rates with other sports. In a population of school children, handball training injuries were less frequent than volleyball (4.3 versus 6.7 injuries per 1,000 training hours) and were also less than match injuries in basketball (14 versus 23 injuries per 1,000 match hours) (Backx et al. 1991). Yde and Nielsen 1990 found no significant difference in injury incidence between handball, soccer, and basketball in an adolescent population(Yde and Nielsen 1990). Another study using the same

injury definition reported a similar match injury incidence in soccer (16.9 per 1,000 match hours), but a much higher training injury incidence (7.6 per 1,000 training hours) (Ekstrand et al. 1983).

Adults

At the senior/adult level, the incidence of time-loss injuries in prospective studies has been estimated to be 11.2–14.3 per 1,000 exposure hours in matches and 0.6–2.4 in training (Nielsen and Yde 1988; Seil et al. 1998; Wedderkopp et al. 2003). In a retrospective study of 288 male players in Denmark (division 1–3), Jorgensen reported an overall rate of 8.3 injuries per 1,000 h (Jorgensen 1984).

Langevoort et al. followed male and female elite-level players during major international tournaments (2002 women's European Championship, 2003 women's World Cup, 2001 and 2003 men's World Cup, 2004 Olympics – men and women) and recorded 478 medical attention injuries (regardless of consequences). The competition injury rate was 89–129 injuries per 1,000 match hours for males and 84–145/1,000 match hours for females (Langevoort et al. 2007). For comparison, Ekstrand et al. studied highest level of professional football play (the UEFA injury study) and reported that the acute injury incidence was 27.5 injuries/1,000 match hours (Ekstrand et al. 2011).

In the Langevoort study, the injury incidence per match per player was 1.2 for males and 2.0 for females (Langevoort et al. 2007). When looking just at time-loss injuries, the rates were 31–40/1,000 h for males and 13–36/1,000 h for females (0.6 and 0.5 injuries per match per player for males and females, respectively). For the 2008 summer Olympics in Beijing, Junge et al. defined injury as any musculoskeletal complaint that received medical attention regardless of the consequences (i.e., any absence) (Junge et al. 2009). There were 58 injuries among the 334 handball players (male and female); the total number of injuries was 58 (17.4 %). They estimated the incidence of players with time-loss injuries to be 13.4 %. Four injuries occurred during training (7.4 %) and 50 during matches (92.6 %). Engebretsen et al. (2013) used the same definitions for the 2012 Olympics. Among 349 players (male and female), they recorded a total of 76 injuries (21.8 %). A total of 32 injuries (9.2 %) caused more than 1-day time loss and 16 (4.6 %) led to more than 7 days time loss. There were 18 (24.7 %) training injuries and 55 (75.3 %) match injuries. Of the 171 female players, 45 injuries (26.3 %) were recorded of which 10 (5.8 %) were >7 days time-loss injuries. Of the 178 male players, 31 injuries were recorded, of which 6 (3.4) were >7 days time-loss injuries (Engebretsen et al. 2013).

Asembo and Wekesa followed the East and Central Africa Senior Clubs Championship in 1995, reporting an average incidence of 2.74 injuries/match (Asembo and Wekesa 1998). They also reported an incidence of 0.9 injuries/player during the 19 matches played. In a recent unpublished study, Gundersen and Myklebust registered all acute and overuse injuries that needed medical attention and/or led to absence from match or training in Norwegian elite handball players during the 2008–2009 season. They found a total incidence of 3.9 injuries/1,000 match hours. Acute injuries presented a rate of 1 injury/1,000 training hours and 15.2 injuries/1,000 match hours, showing a 15 times higher risk of injury during match in comparison to training. Leidinger et al. analyzed injuries that required medical attention during a 5-year period (1981–1986) in German senior players (Leidinger et al. 1990). They found that 96 % of the players at the highest performance level (Bundesliga) were injured each year. Piry et al. (2011) performed a retrospective descriptive study evaluating the incidence of injuries during the 2008 Asian Handball Championships. They used the time-loss injury definitions, but also recorded non-time-loss injuries as well. In total, 63 injuries were recorded with an incidence of 20.7 injuries per 1,000 h of competition and 0.96 injuries per 1,000 h of training. As expected, acute injuries (82.5 %) were significantly more common than chronic injuries (17.5 %). 15.9 % of the injuries were severe (>21 days of absence from training

and competition), while 20.6 % were moderate (8–21 days of absence from training and competition), and 38.1 % were minor injuries (1–7 days of absence from training and competition). The remaining 25.4 % did not require absence from training and competition.

In a case control study conducted in the Netherlands among 642 players, trying to characterize handball injuries distribution players >20 years of age were shown to have a significantly greater risk of injury than players <20 years of age (odds ratio = 1.9) (Dirx et al. 1992).

Youth

Injury rates in youth team handball seem to be similar, estimated to range between 8.9 and 14 injuries/1,000 match hours and 1.7–4.3 injuries/1,000 training (Nielsen and Yde 1988; Backx et al. 1991). Nielsen and Yde prospectively followed young handball players (7–18 years) in a single sports club in Denmark reporting an overall match injury incidence of 10 injuries/1,000 match hours (11/1,000 mh in girls and 9/1,000 mh in boys) (Nielsen and Yde 1988). Using insurance records, De Loes et al. reported lower injury risks in adolescents (and similar between boys and girls) with 0.7 injury per 1,000 playing hours (de Loes 1995). Wedderkopp et al. evaluated the total incidence of injuries in Danish handball, not just time-loss injuries. They first conducted a retrospective study that showed young female players (16–18 years) have the highest injury incidence with up to 41 injuries/1,000 match hours (Wedderkopp et al. 1997). In their subsequent prospective study (Wedderkopp et al. 1999), the incidence in the control group (the same players that were followed in the previous retrospective study) was 23 injuries/1,000 match hours. However, these studies cannot be directly compared with the other existing studies, as time-loss injuries were not reported separately. Wedderkoop et al. later conducted another retrospective study in a population of 163 young female (ages 14–16 years) players, over 1 season, reporting a rate of 52 injuries/1,000 match hours (Wedderkopp et al. 2003).

In a prospective study in Norway, Olsen et al. followed 428 players (aged 15–18 years) in 25 female and 9 male teams. They recorded all injuries (not only time-loss ones) and found a match injury rate of 8.3 injuries/1,000 h in males and 10.4 injuries/1,000 h in females; training injury rates were 0.6 injuries/1,000 h and 1.0 injuries/1,000 h, respectively (Olsen et al. 2006). In a randomized controlled trial of an injury prevention program, Olsen et al. studied 1837 players aged 15–17 (120 teams) and recorded 298 injuries. The control group (male and female combined) showed a rate of 10.3 injuries/1,000 h during matches and 0.6 injuries/1,000 h during training (Olsen et al. 2005). Reckling et al. evaluated 100 German juvenile players (50 male and 50 females), reporting 130 injuries in 73 players (Reckling et al. 2003).

Gender Differences

When attempting to compare male injury rates versus females according to time-loss injuries studies, significant gender-based differences are found only at the national team level, as shown by Langevoort et al. (2007) and Holdhaus (2008a, b, 2010a, b) (Table 2). In other studies, minimal sex differences were found (Nielsen and Yde 1988; Olsen et al. 2006) (Table 3). Gender differences, however, are evident when it comes to ACL injuries in handball, where women have an incidence 3–5 times higher than men (Lindenfeld et al. 1994; Arendt and Dick 1995; Bjordal et al. 1997; Myklebust et al. 1997, 1998; Powell and Barber-Foss 2000). Figure 2a, b summarize injury frequency based on data from elite level international competitions.

Match Versus Training Injuries

As expected, match injury incidence is significantly higher than training injury incidence (Yde and Nielsen 1990; Backx et al. 1991) because of the intense play and contact during matches (Ekstrand et al. 1983; Lorentzon et al. 1988; Twellaar et al. 1996) which is reflected by a high

Table 2 Injury rates from men's elite-level international competitions

	Male						Female					
Location	WC 2001 (men)	WC 2003 (men)	Olympics 2004 (men)	Euro 2008 (men)	Euro 2010 (men)	Avg. (%)	Euro 2002 (women)	WC 2003 (women)	Olympics 2004 (women)	Euro 2008 (women)	Euro 2010 (women)	Avg. (%)
Head and neck	11 (11.0 %)	30 (28.0 %)	15 (32.0 %)	3 (6.4 %)	11 (24.4 %)	20.4 %	15 (29.0 %)	30 (29.0 %)	23 (35.0 %)	13 (24.6 %)	19 (22.3 %)	28.2 %
Shoulder, arm, and elbow	21 (22.0 %)	21 (19.0 %)	10 (21.0 %)	5 (10.6 %)	5 (11.1 %)	16.7 %	8 (16.0 %)	1810 (17.0 %)	7 (11.0 %)	6 (11.3 %)	10 (11.7 %)	13.4 %
Hand and finger	8 (8.0 %)	10 (9.0 %)	4 (9.0 %)	11 (23.4 %)	8 (17.8 %)	13.4 %	3 (6.0 %)	13 (12.0 %)	2 (3.0 %)	9 (17.0 %)	6 (7.3 %)	9.1 %
Trunk	16 (17.0 %)	14 (13.0 %)	5 (11.0 %)	3 (6.4 %)	2 (4.4 %)	10.4 %	4 (8 %)	20 (19.0 %)	12 (18 %)	6 (11.3 %)	19 (22.3 %)	15.7 %
Leg	13 (14.0 %)	1 (1.0 %)	3 (6.0 %)	10 (21.3 %)	14 (31.1 %)	14.7 %	3 (6.0 %)	3 (6.0 %)	3 (5.0 %)	11 (20.8 %)	15 (17.5 %)	11.1 %
Knee	15 (16.0 %)	15 (14.0 %)	5 (11.0 %)	6 (12.8 %)	2 (4.4 %)	11.6 %	5 (10 %)	12 (11.0 %)	10 (15.0 %)	4 (7.5 %)	6 (7.0 %)	10.1 %
Foot and ankle	9 (9.0 %)	17 (16.0 %)	8 (17.0 %)	6 (12.8 %)	3 (6.8 %)	12.3 %	7 (14.0 %)	15 (14.0 %)	5 (8.0 %)	4 (7.5 %)	10 (12 %)	11.1 %
Total	**92 (100 %)**	**106 (100 %)**	**48 (100 %)**	**47 (100 %)**	**45 (100 %)**		**50 (100 %)**	**98 (100 %)**	**63 (100 %)**	**53 (100 %)**	**85 (100 %)**	

Data based on Langevoort and Holdhaus
WC World Championships, *EC* European Championships

Table 3 Epidemiologic studies on incidence of handball injuries among adults

						Injuries/ 1,000 h		
	Design	Country, period	Population	Injury definition	#players/ #injuries	Match	Training	Total
Jørgensen	Retrospective cohort	DEN 1981–1982, 40 week	Selected players from division I–III; male players age: 17–37 years	Any injury occurring in connection with the game or in training that handicaps the player during the game or requires special treatment (i.e., special bandaging or medical attention) or both in order to play or completely prevents the player from playing	M: 288/282			M: 8.3
Nielsen	Prospective cohort	DEN 9/1985–5/1986	1 club, division I and II and lower division male and female players age:18 years	An injury occurring during a game or practice causing the player to miss at least one game or practice session	M: 69/44	M: 13.3	M: 2.4	
					F: 58/24	F: 13.8	F: 0.7	
Seil	Prospective cohort	GER 7/1995–5/1996	16 teams, division III–IV male players mean age: 25.8 years	An injury occurring during handball practice or competition leading to nonparticipation in at least one practice session or game	M: 186/91	M: 14.3	M: 0.6	M: 2.5
Asembo	Prospective cohort	Africa Club Championship April 9–17, 1995	14 elite teams;	Injuries leading to temporary stoppage of the game or substitution for the injured player	M: 52 injuries			M: 0.9[a]
			9 male teams		F: 15 injuries			F: 0.5[a]
			5 female teams					
			Total: 406 players					
Petersen	Prospective cohort	GER 8/2001–5/2002	1 division III team	An injury occurring during a game or training session causing the player to miss part of the training or match or leading to absence for at least several days of activities	M: b/62	M: 12.1	M: 2.6	
			Male players					
			Age not reported					
Langevoort	Prospective cohort	EC, WC, and OG	National team players	Any physical symptom incurred during a match receiving medical attention from the team physician regardless of the consequences with respect to absence from match or training	M_F: [b]/478	M: 89–129		M: 1.2[a]
		Men and women	Male and female			F: 84–145		F: 2.0[a]
						Time loss		Time loss:
						M: 31–40[c]		M: 0.6[a]
						F: 13–36[c]		
								F: 0.5[a]

Table reproduced from Myklebust. Used with permission

M males, *F* females, *DEN* Denmark, *GER* Germany, *EC* European Championships, *WC* World Championships, *OG* Olympic Games

[a]Data were presented as injuries per match per player

[b]Number of players or injuries not reported

[c]This is injuries/1,000 h

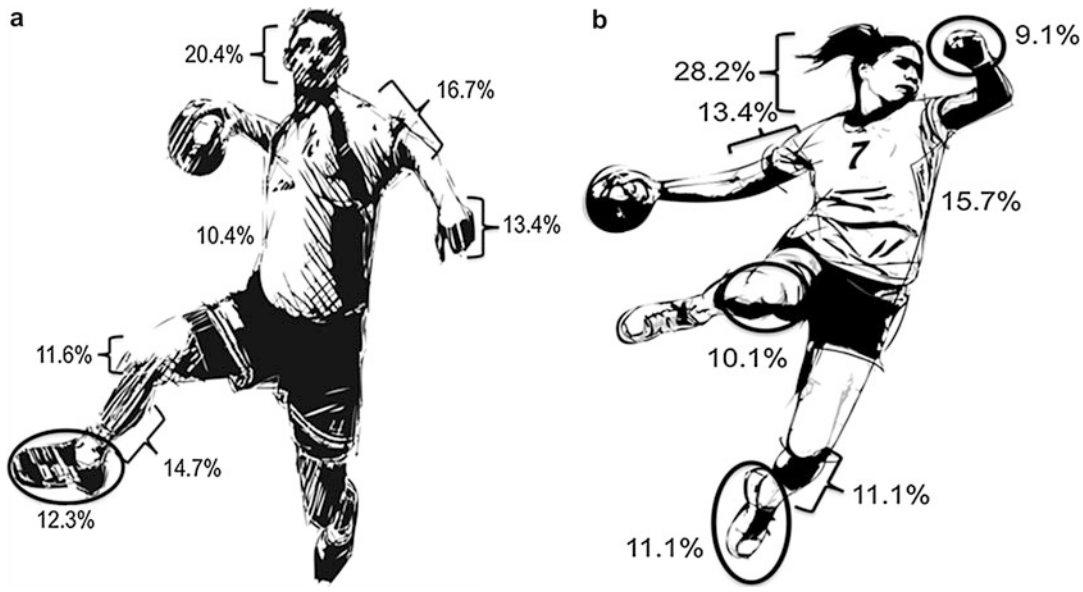

Fig. 2 Injury frequency in males (**a**) and females (**b**) based on data from elite-level international competitions

number of injuries caused by the opponent. This is accentuated in the highest level competitions like Olympic tournaments and European and World Championships (Langevoort et al. 2007). In the 2008 Olympic Games in Beijing, 92.6 % of injuries occurred during matches, while only 7.4 % occurred during training (Junge et al. 2009). In the 2012 Olympic Games in London, 75.3 % of injuries occurred during matches, whereas only 24.7 % occurred during training (Engebretsen et al. 2013). This ratio is also evident in young and adolescent player population as well with no significant gender differences apparent. Similar significant differences between match and training injury incidence were found recently by Piry et al. with 20.7 injuries per 1,000 h of competition versus 0.96 injuries per 1,000 h of training (Piry et al. 2011). Higher training injury incidence has been shown in lower level of play groups (Seil et al. 1998), a finding compatible with soccer player populations as shown by Ekstrand et al. (1983), who noted a reduction of injuries with increasing training hours. This is attributed to improved coordination, better oxygen uptake, greater strength, and more skill. One 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 (Hatzimanouil et al. 2005).

Injuries According to Player Position

The majority of injuries in handball occur when a team is on offense, with reports ranging from 52 % to 86 % (Leidinger et al. 1990; Seil et al. 1997; Asembo and Wekesa 1998; Oehlert et al. 2004). In a yearlong study of 186 players (male) in 16 senior German teams, Seil et al. (1998) looked at injury distribution according to positions on the field. Wing players sustained 33 of the 91 injuries (36 %; 26 match and 7 training injuries), 33 % of all injuries happened to backcourt players (22 and 8, respectively), 19 % happened to line players (13 and 4, respectively), and goalkeepers sustained 12 % of the injuries (9 and 2, respectively). By position, the match injury was rated (injuries/1,000 match hours): 18.6 per 1,000 player match hours for wing players = 18.6, line players = 17.1, goalkeepers = 12.8, and backcourt = 10.5 (Fig. 3).

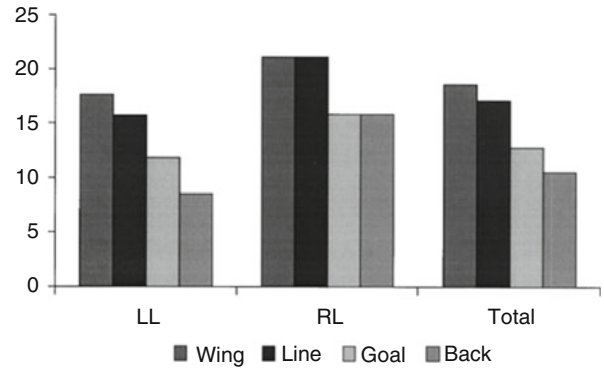

Fig. 3 Incidence of injuries per 1,000 game hours with respect to position and performance level. Goalkeepers and backcourt players showed the lowest; wing and line players showed the highest injury incidence. *LL* local league, *RL* regional league (From Seil[24] used with permission)

Fig. 4 A player in a shot attempt during a counterattack

The higher injury rates among wing players 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. 4) seem to increase the injury rates for wing players. Other studies, however, have noticed that backcourt players were more at risk for injury (Jorgensen 1984; Frobose et al. 1996). 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 (Wedderkopp et al. 1997). The high incidence of injuries among back players was also reported earlier by Fagerli et al. (1990). The 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) (Piry et al. 2011).

Injury rate was higher among players in a higher-level league. However, although differences between levels of play were noted, these differences were not statistically significant. Wing players have the highest rate of serious and severe injuries followed by backcourt players, goalkeepers, and line players (Fig. 5) (Seil et al. 1998). They also observed an increasing rate of upper extremity injuries (shoulder and upper arm) in wing and backcourt players (Seil et al. 1998). Thirty-one of 35 players (89 %) with overuse symptoms of the shoulder were backcourt and wing players. Myklebust et al. have repeatedly shown that the relative risk of ACL injury is

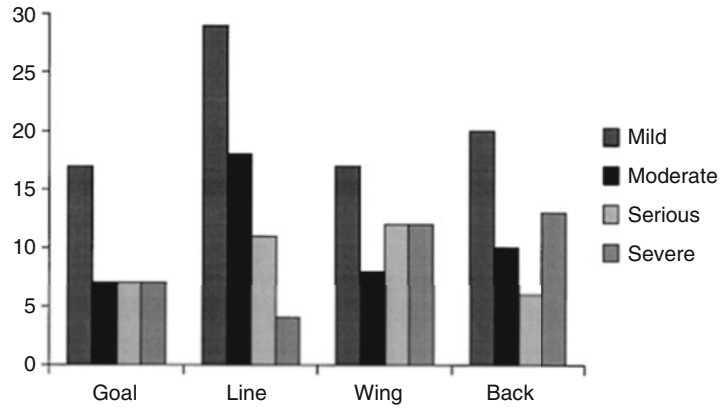

Fig. 5 Injuries per 100 players with respect to severity and player position. Line players and goalkeepers had proportionally more mild and moderate injuries compared with serious and severe injuries than did wing and backcourt players (From Seil[24] used with permission)

higher among back players (Myklebust et al. 1997, 1998, 2003a). The proportion of back players injured seems to be even higher in studies involving elite players (Myklebust et al. 1998). 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 and 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.

Injury Mechanism: Contact Versus Noncontact

Most injuries in elite handball occur during player-to-player contact. Studies at the top competition level show that contact injuries represent between 80 % and 92 % (Asembo and Wekesa 1998; Oehlert et al. 2004; Langevoort et al. 2007). According to Langevoort et al. (2007), 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 (Holdhaus 2008a), while 39.6 % were reported for the women's 2008 games (Holdhaus 2008b). In the 2010 men's Euro, only 11.1 % of injuries were associated with foul play (Holdhaus 2010b), while only 3.5 % were reported in the women's 2010 Euro (Holdhaus 2010a). These high numbers are not the case when analyzing ACL injuries, which are noncontact mechanisms in the majority of cases when the player is performing a plant and cut maneuver or landing after a jump shot (Myklebust et al. 1997, 1998, 2003a).

Time of Injury During Matches

Dirx et al. revealed a higher injury incidence during the second half with increasing player's fatigue and intensity of close matches (Dirx et al. 1992). Asembo and Wekesa reported that 57 % of injuries occurred in the second half (Asembo and Wekesa 1998), while Langevoort et al. reported that 45 % of the injuries occurred in the middle 10 min of each half and decreased toward the end (Langevoort et al. 2007). 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 (Seil et al. 1998). 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, the same week, or even up until that phase of the season and therefore should be looked at carefully.

The majority of match injuries were shown to occur during offensive plays (Leidinger et al. 1990; Frobose et al. 1996; Seil et al. 1998). Several other authors showed the same trend with

Table 4 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
1st 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 1st half	37 %	53 %	41 %	27.7 %	44.4 %	42 %	48 %	46 %	55.3 %	34.1 %
2nd 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 2nd half + OT	63 %	47 %	59 %	72.3 %	46.7 % (+8.9 % in OT)	57 %	52 %	54 %	44.7 %	65.9 %

Data based on Langevoort and Holdhaus
WC World Championships, *EC* European Championships, *OG* Olympic Games, *OT* overtime

reports ranging from 77 % to 92 % of injuries occurring during the offensive phase of play (Wedderkopp et al. 1997, 1999; Olsen et al. 2003; Wedderkopp et al. 2003). Two studies showed a different trend, however, reporting a higher incidence of injuries during the defensive phase of the game. For example, Reckling et al. (2003) stated that almost two-thirds of the injuries occurred during the defensive phase as did Oehlert et al. who reported 84 % of the injuries occurred during the defensive phase (Oehlert et al. 2004). 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 contact. Seil et al. found that approximately one-third of offensive injuries occurred during the fast-break/counterattack (Seil et al. 1998). 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. Table 4 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.

Injury Type

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 (Asembo and Wekesa 1998; Langevoort et al. 2007). In other studies (Nielsen and Yde 1988; Seil et al. 1998), sprains are the most common injury type (46–68 % of all injuries). Again, these results reflect different injury definitions in these studies. Muscle strains present an overall incidence of 6–26 % (Jorgensen 1984; Wedderkopp et al. 1997; Seil et al. 1998; Olsen et al. 2006; Langevoort et al. 2007). Contusions range from 2 % to 36 % of all injuries (Fagerli et al. 1990; Wedderkopp et al. 1997). Fractures and dislocations are usually less common, but two studies noted exceptions to this observation. Fagerli et al. (1990) 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 (1998) reported a fracture incidence of 31 % among elite-level male players; however, these numbers are not consistent with the data of Langevoort et al. (2007) among a larger number of elite-level players, where the fracture incidence was only 1–2 %.

Overuse Injuries

There is 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 ($n = 50$, 22 %). They did not distinguish overuse injuries according to gender. The incidence of overuse injury to the shoulder of German players was reported to be 40 % (von Gohlke et al. 1993). Similar high prevalence 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(Nielsen and Yde 1988). 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 injuries like "throwing shoulder" and "throwing elbow" accounted for 17.1 % and 11.9 % of the overuse injuries (Leidinger et al. 1990). Tyrdal and Bahr stated that 41 % of 729 (male and female) goalkeepers reported current elbow injuries (Tyrdal and Bahr 1996). 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. (Seil et al. 1998) 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. (2005) looking at "jumper's knee" among elite athletes from different sports, the total prevalence among male handball players was 30 % and 10 % among females (Lian et al. 2005). Olsen et al. said that lower-leg pain (periostitis) was the most common overuse problem (Olsen et al. 2006).

Osteoarthritis

Osteoarthritis (OA) is a possible consequence both after an injury and long-term elite handball. L'Hermette et al. showed that 60 % of retired elite male handball players were diagnosed with premature hip OA in at least one of the hip, compared with 13 % of the control subjects (L'Hermette et al. 2006). Osteoarthritis (OA) is also a possible consequence following an ACL injury, whether the patient has undergone surgery or has been treated conservatively. Myklebust and colleagues reported a 42 % prevalence of OA among surgically treated patients and 46 % among nonsurgically treated patients within 6–11 years after ACL injury (Myklebust et al. 2003b). These high numbers were supported in a similar study among soccer players (von Porat et al. 2004).

Anatomic Location

Head and Neck

A high number of injuries to the head and neck are observed in international championships. Asembo and Wekesa reported the highest rate in the African Championship where 43 % of the injuries among males involved the head and neck; females sustained only 16 % of all injuries to the head and neck (Asembo and Wekesa 1998). Langevoort et al. reported similar numbers from the World Cup 2003 and the Olympic Games in 2004 (28 % and 32 %) (Langevoort et al. 2007) as did Oehlert et al., reporting an incidence of 34 % (15) (Oehlert et al. 2004). Few of the head injuries were reported to be concussions. Asembo and Wekesa reported only 2 out of 52 injuries were concussions, while 31 were contusions (Asembo and Wekesa 1998). A study on orofacial/cerebral injuries from Switzerland among 73 handball players reported that the most common injuries were a soft tissue lesion (40 %) and a tooth fracture (35 %). Cerebral concussions were recorded in 8 % of the injuries among handball players without mouth guard (69 of 73 players) (Lieger and von Arx 2006). In a recent study conducted in 97 Iranian female handball players, head and neck injuries had the lowest rate of all injuries (4.62 % during practice and 3.25 % during matches) (Asuli et al. 2012). In data collected at the 2008 men's European Championship in Norway, head and neck injury rate was reported to be 6.4 % ($n = 3$) (Holdhaus 2008). At the 2008 women's European Championship in Macedonia, the reported rate was 24.6 % ($n = 13$) (Holdhaus 2008). At the 2010 men's European Championship in Austria, the reported rate was 24.4 % ($n = 11$) (Holdhaus 2010), while at the women's championship that year in Denmark and Norway, the reported rates were 22.3 % ($n = 19$) (Holdhaus 2010). The overall relatively high incidence of head and neck injuries is not surprising as handball is a contact overhead throwing sport, where contact is often made in the upper body and especially near the head and neck region aimed to stop the opponent during a shot attempt (Fig. 6). In addition, contact is often generated in high velocities of both the defender and attacker in handball, situations in which there is less control for collision avoidance.

Upper Extremity

As mentioned earlier, reports of injury distribution according to anatomic locations vary between different studies due to injury definitions, data collection methods, and level of play. Acute injuries to the upper extremities are frequent, and different studies report them to constitute from 7 % to 50 % of all injuries (Jorgensen 1984; Nielsen and Yde 1988; Fagerli et al. 1990;

Fig. 6 Contact around the neck and head area is common in handball (Photos courtesy of Lothar Gudat. Used with permission)

Wedderkopp et al. 1997; Seil et al. 1998; Olsen et al. 2006; Langevoort et al. 2007).

In major competitions, injuries to the upper extremity represent around 21–25 % of all injuries (Langevoort et al. 2007; Holdhaus 2008a, b, 2010a, b). Table 2 and Fig. 2a, b present the upper extremity injury rates from the men's and women's elite-level international competitions. Leidinger et al. (1990) reported an incidence of 35 %, whereas Seil et al. reported a 38 % incidence at the regional leagues in Germany (Seil et al. 1998), and Nielsen and Yde reported an incidence of 41 % in 221 players in Denmark (Nielsen and Yde 1988). When looking at injury location within the upper extremity, hand and fingers tend to have a slightly higher incidence compared to shoulder and arm, both in major competitions (Table 2 and Fig. 2a, b) and in other player populations (Table 5).

Shoulder. Handball players perform up to 48,000 throws per year (Langevoort 1996). The most severe acute shoulder injury in handball is glenohumeral dislocation and is not encountered often. Considering that throwing arm is frequently and unexpectedly opposed or blocked by an opponent, causing repetitive microtrauma to the capsulolabral structures of the shoulder, it is not surprising to see that most of the acute shoulder injuries occur to players who throw most (backcourt and wing players). The forces encountered by a player's shoulder affect the joint, especially during the cocking phase of the throw. In addition, the defense often strains the shoulder by charging the arm (Fig. 7). The incidence of acute or chronic shoulder pain in handball players has been reported to range between 30 % and 57 % (Konig et al. 1996; Pieper 1996; Myklebust et al. 2013). Myklebust et al. evaluated the prevalence and consequences of shoulder pain problems among Norwegian female elite handball players (179 players from all 12 teams of the Norwegian elite league) (Myklebust et al. 2013). Fifty-seven percent of all players reported previous or current shoulder pain at the time of evaluation of which 36 % ($n = 65$) reported current shoulder pain upon evaluation and 22 % ($n = 40$) reported previous shoulder pain. Positive apprehension and relocation tests were recorded by 29 % ($n = 51$) of all players and among 60 % of players with pain at the time of evaluation. The majority of players continued to play with pain and reported changing their training habits (Myklebust et al. 2013). Seil et al. identified the shoulder as the most common site for overuse symptoms (Seil et al. 1998). In an attempt to characterize shoulder pathology in handball players, Jost et al. evaluated the shoulders of 30 fully competitive professional handball players and 20 randomly selected volunteers using magnetic resonance imaging and correlated imaging and clinical findings. Abnormal MRI findings were found in 93 % of the throwing shoulders, but only 37 % of the shoulders were symptomatic. Typical asymptomatic MRI findings included tendinopathies and partial rotator cuff tears, posterosuperior glenoid impingement, and impressive superolateral osteochondral defects of the humeral head; 71 % of the throwing shoulders with osteochondral defects were asymptomatic (Jost et al. 2005).

An increase in maximal external shoulder rotation of about 10–15° in the throwing arm of handball players can be found in the majority of players, compared to the nondominant side (Fig. 8) (Pieper 1994). Anterior laxity due to chronic overuse (i.e., stretching the joint capsule and ligaments) is a possible explanation. Pieper et al. studied the functional characteristics of shoulders of handball players (Pieper 1998). In addition to the increase in external rotation, they observed a considerable reduction of maximal internal rotation of the dominant arm (Fig. 9) (Pieper 1985). Similar findings (approximately 10° reduction of internal rotation) have been reported for athletes in unilateral overhead or throwing sports like tennis (Chinn et al. 1974; Chandler et al. 1990; Kibler et al. 1996) or baseball (Magnusson et al. 1994; Bigliani et al. 1997). They also found increased humeral retrotorsion in the throwing arm of handball players.

This seems to be an adaptation to extensive external rotation in throwing training during growth. The increased retrotorsion allows more external rotation of the shoulder before the humeral head puts excessive strain on the anterior capsulolabral complex, potentially leading to

Table 5 Frequency (% of total) of injury by location, gender, and study

	Fagerli		Jorgensen	Seil	Asembo		Langevoort		Olsen	Nielsen (Sr)		Nielsen (Jr)		Wedderkopp
	Female	Male	Male	Male	Female	Male	Female	Male	Both	Female	Male	Female	Male	Female
Head/neck	(10)			4 (2)	11 (16)	29 (43)	8 (29)	68 (31)	5 (5)					
Trunk	(4)			2 (1)	2 (3)	13 (18)	2 (7)	36 (15)	8 (9)					
Upper extremity														
Shoulder	(13)		13 (8)	13 (7)			5 (2)	11 (5)	4 (4)		12 (27)	1 (5)	2 (13)	2 (1)
Arm (upper/lower)			11 (4)				11 (5)	5 (2)	2 (2)					
Hand, wrist, and fingers	(37)		17 (6)	20 (11)			22 (9)	18 (7)	16 (18)		9 (20)	5 (23)	1 (7)	2 (1)
Lower extremity														
All LE	(36)													
Hip/groin			1 (2)	5 (3)			9 (3)	3 (2)	2 (2)					
Thigh			7 (16)				17 (6)	19 (10)	3 (3)	2	4 (9)[a]	0	2 (13)[a]	
Knee			25 (9)	18 (10)			35 (13)	27 (12)	27 (27)	2	3 (7)	4 (18)	1 (7)	31 (15)
Lower leg			52 (18)	9 (5)			17 (7)	9 (6)	2 (2)					
Ankle			45 (16)[b]	14 (8)			28 (12)	22 (9)	22 (24)	9	12 (27)	10 (45)	4 (27)	56 (27)
Foot/toes				3 (2)			6 (2)	5 (2)	1 (1)					1 (0.5)
Other			20 (7)							1	4 (9)	2 (9)	2 (13)	0

Table reproduced from Myklebust. Used with permission

[a]Includes lower leg

[b]Foot and ankle

Fig. 7 The attacker's shoulder is often strained by the defender by charging the arm during shot attempts (Photos courtesy of Lothar Gudat. Used with permission)

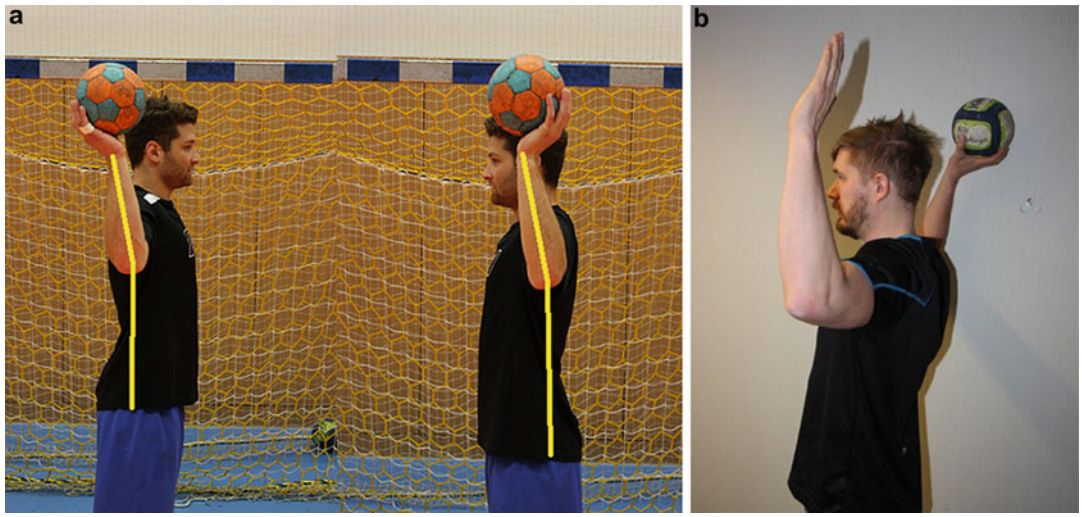

Fig. 8 Increased external rotation (ER) in the dominant shoulder (Rt.) compared to the nondominant side (Lt.) in an elite professional level handball player (**a**) and an amateur level player (**b**). It is important to note that these differences are accentuated during a throwing action (during the cocking phase) (Photos courtesy of Chen Pomeranz (**a**) and Grethe Myklebust (**b**). Used with permission)

anterior shoulder instability. Players who fail to adapt in this manner seem to sustain more strain on their anterior capsule at less external rotation and are thus at higher risk to develop anterior instability and chronic shoulder pain. It is still unclear whether these torsional changes correlate with the starting age of playing handball, the intensity of training and competition, the hours

Fig. 9 (**a**, **b**) Internal rotation (IR) deficit in dominant shoulder (Rt.) of the same players as in Fig. 8 (Photos courtesy of Chen Pomeranz (**a**) and Grethe Myklebust (**b**). Used with permission)

of exposure, or the interaction of these factors. A more recent study by Almeida et al. evaluated glenohumeral range of motion in handball players with and without throwing-related shoulder pain (Almeida et al. 2013). Handball players with pain had significantly greater glenohumeral internal rotation deficit, external rotation gain, and external rotation in the throwing arm and lesser internal rotation in the throwing arm in comparison to the players without pain. Side to side comparisons (dominant versus nondominant) exhibited a significant difference in the two groups regarding internal and external rotation, but differences within the group with pain were greater.

Another recent study by Edouard et al. evaluated internal (IR) and external (ER) rotator shoulder muscles strength and imbalances in female elite handball players (Edouard et al. 2013). ER/IR ratios were found to be lower for dominant than for nondominant side. A higher injury risk was associated with imbalanced muscular strength profile.

These studies accentuate the adaptations in the throwing shoulder of handball players and provide a basis to assist in recognizing shoulder pathologies early in this population, giving grounds for injury awareness and even prevention strategies, like maintaining a balanced muscular strength profile.

Elbow. Goalkeepers suffer from a much higher incidence of elbow injuries compared to other positions on the field. The condition has been termed "handball goalie's elbow" caused by repeated elbow hyperextension trauma. Tyrdal and Bahr reported elbow problems among goalkeepers among 41 % of 729 goalkeepers in the top four divisions (both genders) (Tyrdal and Bahr 1996). This is consistent with the findings of Seil et al.'s 1998 study where one out of three goalkeepers suffered from overuse symptoms from the elbow (Seil et al. 1998). Other sports with a high prevalence of elbow injuries are tennis, golf, and baseball. Among highly skilled tennis players, 37 % were found to have had major elbow

symptoms (Priest et al. 1974). In golf the career prevalence of elbow problems has been found to be 33 % (McCarroll et al. 1990). In two studies of young baseball pitchers, Gugenheim and coworkers reported that approximately 17–20 % had a history of elbow symptoms (Gugenheim et al. 1976; Larson et al. 1976), while Grana and Rashkin reported a career prevalence of 58 % in high school-aged pitchers (Grana and Rashkin 1980). It is evident that elbow problems affect a significant number of goalkeepers in handball, with a prevalence at least as high as that observed in tennis, golf, and baseball. Popovic and Lemaire evaluated the elbows of 30 elite goalkeepers compared to a control group of 30 age-matched subjects from the normal population (Popovic et al. 2001). They performed plain and stress radiographs and ultrasound examination of both elbows. They found radiographic evidence of osteophyte formation in 67 % of the goalkeepers, loose bodies in 5.5 %, and periarticular calcification in 5.5 %. Significantly greater differences in medial joint space opening were measured between stressed and unstressed elbows (in both elbows) compared to the control group. Ultrasonographic findings showed thickening of the medial collateral ligament in 50 %, thickening of the triceps tendon in 11 %, and signs of ulnar neuritis in 22 %. An intra-articular effusion was found in 66 % and small loose bodies in 33 %. No significant differences were found between the dominant and nondominant elbows at radiological and ultrasound examination. Leidinger et al. indicated that described elbow complaints accounted for 11.9 % of the overuse injuries in their study (Leidinger et al. 1990).

Lower Extremity

Injuries to the lower extremities are very common in handball, and although several authors found an equal distribution between upper and lower extremity injuries (Hoeberigs et al. 1986; Nielsen and Yde 1988; Leidinger et al. 1990), most studies show that most acute injuries in handball involve the lower extremities, regardless of age and gender (Nielsen and Yde 1988; Fagerli et al. 1990; Dirx et al. 1992; Wedderkopp et al. 1997, 1999, 2003; Seil et al. 1998; Reckling et al. 2003). This is the case when looking at injuries at the elite international level as well (Table 2). The most frequent injuries reported in handball are to the ankle (8–45 %), while the most severe injuries are to the knee (7–27 %) (Table 5). In a case control study conducted in the Netherlands (Dirx et al. 1992) trying to characterize handball injury distribution, the lower extremities were found to be the most common location (54 % of injuries), especially the ankles (35 %) and knees (16 %). In major competitions, as shown by Langevoort et al., the incidence of lower extremity injuries in men was 42 %. Knee injuries represented 13 % of all injuries, while 11 % affected the ankle (Langevoort et al. 2007). Leidinger et al. revealed a similar incidence (46 % of all injuries were to the lower extremities, 21 % to the ankle, 12 % to the knee) (Leidinger et al. 1990). Jørgensen (1984) and Nielsen and Yde (1988) reported similar incidences, while Gundersen and Myklebust observed a higher incidence of knee injuries (22 %), although they did not distinguish between genders when reporting injury location distribution (unpublished observations). For Seil et al., 54 % of all injuries were to the lower extremity with knee injuries being more frequent than ankle injuries (Seil et al. 1998). This distribution of lower extremity injuries was also reported by Heck et al. and by Hoeberigs et al. in previous studies (Hoeberigs et al. 1986; Heck and Henke 1995). Knee injuries typically are severe causing the longest absence from sport (Nielsen and Yde 1988; Seil et al. 1998).

Anterior Cruciate Ligament Injuries. Injuries to the ACL represent one of the most severe injuries in handball, and several studies have reported the incidence of ACL injuries. For example, Strand et al. studied top-level players in Norway over 10 seasons (from 1979 to 1989) and reported the incidence of ACL injury was found to be highest among women (0.82 ACL injuries/1,000 match hours versus 0.31 injuries per 1,000 match hours (Strand et al. 1990). In 1997, Myklebust et al. recorded ACL injuries during two seasons (1989/1990 and 1990/1991) in Norwegian elite handball players (Myklebust et al. 1997).

They found the match injury rate for men to be 0.54 injuries/1,000 match hours and 1.62/1,000 h for women (3× the rate for men). At the second division, the rate for men was found to be 0.84 injuries/1,000 match hours and 1.82/1,000 h for women (2,2× the rate for men) and at the third division, 0.27/1,000 h for men and 0.72/1,000 h for women (2.7× the rate for men) (Myklebust et al. 1997). Myklebust et al. later (1998) performed a prospective study in 24 Norwegian elite teams over three seasons (seasons 1993/1994 through 1995/1996). They recorded a total of 5 ACL injuries in men and 23 in women (Myklebust et al. 1998). The overall rate of ACL injury was calculated to be 0.06 ± 0.03 injuries/1,000 activity hours for men and 0.31/1,000 h for women. The rate during competition was 0.23 ± 0.13 injuries/1,000 match hours for men and 1.6/1,000 h for women. This study showed a fivefold higher overall risk for ACL injury among women compared to men and a nearly sevenfold higher risk of match injury in women. The reason for the marked gender difference is unknown, but several hypotheses have been suggested, both intrinsic (e.g., anatomic, strength, coordination, hormonal, level of skill, and conditioning) and extrinsic (e.g., shoe and surface type) (Myklebust et al. 1998). Myklebust et al. followed up with another prospective study of 60 women's teams in the top three divisions in Norway over one season (1998–1999) (Myklebust et al. 2003a). The overall incidence of ACL injury in all three divisions was 3.07 % (29 injuries in 942 players); however, in the elite level, the incidence was significantly higher, with 5.77 % (13 injuries in 225 players). The overall rate in all three divisions was found to be 1.48/1,000 match hours but was 2.79/1,000 match hours at the elite level.

Olsen et al. (2003) pooled the data collected in the three previous studies by Myklebust et al. (1997, 1998, 2003b). ACL injuries had been prospectively registered for seven seasons during which 9 ACL injuries occurred in regular league matches in men, providing a rate of 0.24 ± 0.09 injuries/1,000 match hours. In women, however, there were a total of 44 ACL injuries for a rate of 0.77 ± 0.04 injuries/1,000 match hours.

Practically, an international elite team has in average 6–10 h of pure handball training weekly. Other physical conditioning and training and approximately two matches a week adds to this. This adds up to about 300 h of handball training and 80 matches a year. 80 matches translate to 560 h of exposure per team, and with the incidence of 0.54 ACL injuries/1,000 match hours found at the highest performance level by Myklebust et al. in 1997, this translates to 0.3 ACL injuries in matches per team over a competitive year (Myklebust et al. 1997).

Ankle Injuries

As mentioned earlier, most studies report that the majority of acute injuries in handball are located to the lower extremities. The majority of these studies indicate the ankle is the most frequently injured area with incidences ranging from 8 % to 45 % (Table 5). In major elite-level competitions, however, the percentage of foot and ankle injuries is in the lower end of that range (Table 2). Dirx et al. found that 54 % of all injuries were to the lower extremity; 35 % and 12 % of all injuries were to the ankle and knee, respectively (Dirx et al. 1992).

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 leg. The most unpredictable factor in handball is the greater amount of contact that is allowed than in, for example, soccer and basketball. Even when the contact is punished, many defensive players will risk contact for the price of being punished (unlike basketball, the number of fouls in handball is not counted or accumulated). Therefore, a handball player, while attempting to shoot the ball, will encounter contact while both legs are in the air where even slight contact might tilt the player off balance, increasing the risk of an off-balance landing (Fig. 10).

Fig. 10 Ankle injury in handball

Protective Equipment and Playing Surface

Although handball is an intense contact sport, there is no mandatory requirement to use protective gear, and its use is not regulated. The decision to use protective equipment is the individual's choice, and many players have personal preferences about the types of protective equipment (to avoid injuries, reduce the impacts on different body parts, enable themselves to play with existing injury or pain/discomfort). In Seil et al.'s 1998 study, nearly 90 % of the higher-level players wore some kind of protective gear (e.g., prophylactic taping, ankle support, mouth guard, knee/elbow pads, other orthoses). Wing and line players – who fall more often and more frequently use throwing techniques that involve falling – often use knee protectors to prevent skin injuries, contusions, and traumatic bursitis caused by repetitive falls on the floor. Goalkeepers often use different equipment because falling is a frequent part of their game as is encountering high-velocity throws (Seil et al. 1998).

Shoe–surface interaction has been shown to be a risk factor for ACL injury in handball, with a 2.4 times greater injury risk when competing on artificial floors (with an increased coefficient of friction) in comparison with wooden floors (Olsen et al. 2003). It has been well established that the shoe–playing surface interface is an important factor in injury reduction strategies, and for many years, the vast majority of players have been using shoes designed to reduce the coefficient of friction especially for indoor surfaces.

Summary

The game of handball is constantly growing in popularity with the increasing involvement of different media platforms (the Internet, TV) and endorsements that accompany this type of exposure. This growing popularity attracts more and more participants, as well as variations of the game, such as beach handball (Fig. 11). The natural evolution of the game of handball has resulted in more intense competition at the top levels. The combination of the greater intensity and the frequent matches played in multiple competitions (and the resulting loss of recovery time between matches) puts the players at high risk for injuries.

One of the main difficulties when analyzing epidemiologic studies of handball injuries lies in the injury definition that varies between studies and therefore presents a challenge when attempting to identify patterns. Yet several patterns have been recognized. The majority of injuries occur during matches when compared to training (Nielsen and Yde 1988; Seil et al. 1998), and higher injury incidences exist at higher performance levels (Asembo and Wekesa 1998; Langevoort et al. 2007). Lower extremities account for most of the acute injuries, followed by injuries of the upper extremities and head injuries.

Fig. 11 Beach handball

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 ruptures. Backcourt players seem to sustain more injuries compared to other player positions.

If we use an injury incidence of 108 injuries/1,000 match hours like Langevoort et al., this leads to 56 injuries in matches per team a year. These are high values, and even though the majority of these injuries are not major injuries and only 25 % of all match injuries result in any time loss, they accentuate the need to find and implement strategies to prevent and lower these rates, as well as a good and continuous medical coverage for handball teams. The high incidence of acute injuries and prevalence of overuse injuries, combined with up to one hundred matches per year for the top players, necessitates the teams to employ a medical team that is familiar with the risk factors, common injuries, and mechanisms in order to be able to both diagnose quickly and institute the best treatment for a rapid recovery and return to play. One thing is clear, as the majority of injuries in handball are contact induced and since up to 50 % of the injuries are "foul play" related, referees have a role in protecting the players and enforcing fair play.

New prospective studies and data are in demand in handball, especially with the rapid evolution of the game and the high intensity and match density the players encounter nowadays at the competitive level. Sufficient data regarding overuse injuries is especially limited (Bahr 2009). As these injuries sometimes draw less attention and are less dramatic than acute injuries, many players choose to keep playing with overuse injuries despite the price of a reduced performance level. Overuse injuries often possess a real challenge and are difficult to manage within the tight schedule typical at the highly competitive levels.

Injuries are part of an athlete's daily life. A better understanding of injury types and mechanisms is required to reduce these injuries and improve injury management. More knowledge on the injury mechanisms is also needed in order to plan and incorporate appropriate and effective prevention measures. Well-designed studies addressing the specific demands and needs of handball players will enable important data extraction in order to apply conclusions at all aspects of the game, from optimal adjustments of national and international competition schedules, to strategies to protect players and also providing guidelines for referees that will balance permitted contact with player safety.

Cross-References

- ▶ Acute Hamstring Muscle Injury: Types, Rehabilitation, and Return to Sports
- ▶ Anterior Cruciate Ligament Injuries and Surgery: Current Evidence and Modern Development
- ▶ Anterior Cruciate Ligament Injuries Identifiable for Pre-participation Imagiological Analysis: Risk Factors

- Anterior Cruciate Ligament Injuries: Prevention Strategies
- Collaboration with International Sports Federations
- Combined Anterior and Posterior Cruciate Ligament Injuries
- Common Elbow Fractures
- Common Reasons of Groin Pain in Sports
- Concussion in Sports Traumatology: Future Trends
- Factors Affecting Return to Sport After Anterior Cruciate Ligament Reconstruction
- Head Injuries in Sports
- Injury Prevention in Different Sports
- Lateral and Medial Elbow Tendinopathies
- Natural Course of the Ankle Injury: Based on Volleyball Experience
- Olympic Sports and Prevention
- Prevention of Hamstring Muscle Injuries in Sports
- Prevention Strategies of Shoulder Injuries
- Return to Play Decision-Making Following Anterior Cruciate Ligament Reconstruction: Multi-factor Considerations

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