




# Increased injury rates after the restructure of Germany's national second league of team handball

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Received: 30 November 2016 / Accepted: 26 January 2018 / Published online: 5 February 2018  
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## Abstract

**Purpose** Scientific injury data in men's professional team handball injuries are rare and even less scientific information exists on injury prevention. In 2011, Germany's national second team handball league was restructured by merging the existing two regional leagues into one league. This study evaluates the injury patterns in professional team handball and compares the injury rates between the first and second league before and after the restructure.

**Methods** All players of Germany's national first and second men's team handball leagues have mandatory trauma insurance with the same insurance company. This retrospective cohort study analysed the injury data of three consecutive seasons 2010–2013 using standardized injury definitions.

**Results** 1194 professional team handball players were included in this study. The majority of severe injuries affected the lower extremities, shoulders, and hands. The average injury incidence significantly differed between the first (4.9 injuries per 1000 h) and the second league (3.9 per 1000 h,  $p < 0.01$ ). The injury incidence in the restructured second league had increased from 3.7 to 4.1 per 1000 h ( $p < 0.01$ ) and prevalence from 67.1 to 79.3% ( $p < 0.001$ ), thus almost to the same levels of the first league. The second league showed more time-loss injuries at all severity levels.

**Conclusion** This study yielded a high injury incidence after the restructure of the national second team handball league and presents details on prevalence, incidence, and patterns of injury in professional men's team handball. This study is an important basis for developing injury prevention strategies that should focus on the shoulders, hands, and lower extremities and on reducing the number of matches and travel burden.

**Level of evidence** III.

**Keywords** Professional · Male · Team handball · Handball · Prevention · Bundesliga · Insurance company · Epidemiology

## Introduction

Team handball is one of the most popular types of sports in Europe. The game is governed by the International Handball Federation (IHF), founded in 1946 and was introduced to the Summer Olympics in 1972. Currently, approximately

170 members of the IHF include 795,000 teams and an estimated 25 million players worldwide. The game is played by two teams, each consisting of six field players, one goalkeeper, and seven substitutes. Team handball is a dynamic and physically demanding sport, particularly because of the intensive body contact between the players. The increase in game speed, the numbers of matches, and athleticism imposes a high demand on the musculoskeletal system and carries a high risk of injury. However, only a few recent studies on injuries in professional men's team handball have been published in recent years [5, 6, 11, 13, 16, 17, 19, 20, 22, 24, 25, 27].

In 2011, Germany's national second league consisting of 18 teams in two regional leagues was restructured to one league with 20 teams. In football, the implementation of a new professional league had increased the rate of ACL and

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PCL injuries but no data for team handball have been available so far [15]. The purpose of this study was to identify the focus points of injury prevention strategies to decrease injury rates at a national level. Based on previous findings, it was hypothesized that the restructure of the national second team handball league has increased injury incidence [15].

## Materials and methods

This retrospective study covered three consecutive German handball seasons from 1 July 2010 to 30 June 2013 and included all professional male handball players who had a contract with one of the first or second league teams and had played at least one official match for their team in one of three seasons. Players who had not participated in any official handball match were excluded.

### Injury documentation and data collection

In Germany, all professional athletes are registered with the same insurance company, the German Statutory Accident Insurance (Verwaltungs-Berufsgenossenschaft, VBG). Their database, that had been shown eligible in sports injury research, was used to obtain data on injury in professional men's team handball [3, 4, 7, 23]. Players who sustain an injury have to present to the responsible physician, in most cases the team physician, who reports the injury data to the VBG. By German law, the VBG has to be informed on every injury with a time-loss of more than three days. In the case of injuries with lesser time loss, sports physicians are advised to report such injuries to the VBG. The injury reports are subsequently coded and electronically registered by the insurance company. Therefore, data collection was identical for all players.

The league, club, nationality, age, height, weight, body-mass index, and field position of each player were documented according to the data obtained from the database of the VBG. Missing data were completed for each season by means of print and online media. For each team, the number of official matches, i.e. the matches in the national first or second league, the German Cup, the EHF-Cup, the Champions League, and the German national team matches, were collected using the electronic match reports of the databases of the German handball league (Handball Bundesliga), SIS-Handball (GateCom GmbH), and the European Handball Federation (EHF). Foreign national matches were excluded. Match exposure was calculated by means of the following formula: number of games  $\times$  14 players  $\times$  1 h. Data on the training exposure of individual players or teams were not available. Training exposure was therefore calculated by means of the personal experience in both handball training methods and volume of the junior and senior author as a

former handball players and current team coaches. This calculation comprised 45 weeks of playing handball per season with an average training volume of 12 h per week.

### Injury definition

Injuries were classified into training-related and match-related injuries depending on the date of the reported injury. Without any further information, injuries sustained on competitive match days were registered as match-related injuries and injuries occurring on non-match days as training-related injuries. Injuries were further classified into injuries requiring medical attention and injuries resulting in subsequent time loss. For medical attention injuries, the player had to require treatment by a medical doctor. Any injury disallowing a player's participation in future training session or match was defined as time-loss injury [8]. The severity of a time-loss injury was based on the duration of the inability to play handball. Time loss injuries were subdivided into slight (1–3 days), mild (4–7 days), moderate (8–28 days), and severe injuries (> 28 days) [Fuller].

Every injury without a code of the specific time loss was classified as injury severity unknown. Injury incidence was defined as injuries in 1000 h (h) of handball exposure per player [8].

No ethics approval was required because of the retrospective study design and the use of anonymized data.

### Statistical analysis

Continuous data are expressed as mean and standard deviation (SD) and categorical data as frequency counts (percentages). Proportions between two groups were compared with the Fisher's exact test and continuous variables with an exact test based on the Poisson distribution. Corresponding 95% confidence intervals (CI) are reported. The significance level was set to  $p < 0.05$  and high significance to  $p < 0.01$ . No sample size was calculated for investigating the injury incidence because the aim of the study was to include all players from both national leagues for the seasons before and after the restructure. All analyses were done using IBM SPSS Statistics, version 22.

## Results

Over the three consecutive seasons 1194 players participated in official handball matches: 549 players in the national first league and 828 in national second league. 183 of these 828 players had played in both leagues and 645 (54%) only in the second league. The two groups showed similar anthropometric data. First league players were slightly older (in years:  $25.8 \pm 5.3$  vs.  $24.8 \pm 5.3$ ), taller (in cm:  $191.3 \pm 6.6$

vs.  $189.5 \pm 6.7$ ), and heavier (in kg:  $93.2 \pm 8.9$  vs.  $90.7 \pm 9.5$ ) with a higher BMI (in  $\text{kg}/(\text{m}^2)$   $25.4 \pm 1.6$  vs.  $25.1 \pm 1.8$ ).

930 of the 1194 players had sustained 5456 injuries, which represents a prevalence rate of 77.9% and an incidence rate of 4.3 injuries per 1000 h per player over the complete observation period. Acute injuries were the most common type of injury with 88.8% and the lower extremities (52.0%) including knees (13.8%) and ankles (12.8%) were the most commonly affected. The body sites mostly affected by severe injuries were the shoulders, the hands, and the lower extremities and the most common type of injury were contusions (27.1%) and sprains (26.5%) (Tables 1, 2). 56.0% of all injuries were medical attention injuries (Table 3).

Players in the first league sustained more often medical attention injuries than players in the second league, whereas time-loss injuries of all severity levels were more common in the second league (Table 3). Overall, 7.6% of all injuries resulted in time-loss of more than 28 days (Table 3). Fractures, ruptures, and dislocations occurred more often in the second league (Table 4). 1.0% more overuse injuries occurred in the first league (11.7%) than in the second league (10.7%) (Table 4). No differences were found with regard to skin injuries, concussions, or tooth and internal injuries (Table 4). Players in the first

league had a higher prevalence of shoulder and knee injuries but a lower prevalence of wrist and hand injuries than players in the second league (Table 5). No differences were found for other parts of the lower extremities, such as thighs, lower legs, ankles, and feet.

57.1% of all injures occurred during training sessions. The overall injury risk was 26 times higher in matches than in training sessions (Table 6). With 3.3 injuries per 1000 h per player in the second league, the average incidence rate per season was lower than that in the first league (4.9 per players,  $p < 0.01$ ). The prevalence rate of the restructured second league had increased from 67.1 to 79.3% ( $p < 0.001$ ) and the incidence rate from 3.7 to 4.1 per 1000 h ( $p < 0.0.1$ ) from the first to the third seasons; hence almost to the same level of the first league (Table 7).

Taking the value of 1.0 of the first league as a reference for each season, the relative injury risk in the second league had increased from 0.86 (0.78–0.94) in the season 2010–2011 to 0.90 (0.82–0.98) in the season 2011–2012 and to 0.98 (0.91–1.05) in the season 2012–2013. The mean relative risk in the second league was 0.89 (0.83–0.94) in all three seasons. In the two seasons after the restructure, the overall injury risk in the two leagues had increased from 1.0 as a reference value in 2010–2011

**Table 1** Injury localisation and severity

	All injuries <i>n</i> (%)	Medical attention injuries <i>n</i> (%)	Slight injury (1–3 days) <i>n</i> (%)	Mild injury (4–7 days) <i>n</i> (%)	Moderate injury (8–28 days) <i>n</i> (%)	Severe injury (> 28 days) <i>n</i> (%)	Unknown injury severity <i>n</i> (%)
Head/neck	489 (9.6)	314 (10.8)	49 (12.4)	30 (8.2)	34 (5.7)	10 (2.6)	52 (11.4)
Head	430 (8.4)	274 (9.4)	40 (10.1)	29 (7.9)	32 (5.4)	9 (2.3)	46 (10.1)
Neck	59 (1.2)	40 (1.4)	9 (2.3)	1 (0.3)	2 (0.3)	1 (0.3)	6 (1.3)
Upper extremity	1464 (28.7)	889 (30.7)	96 (24.3)	85 (23.0)	132 (22.4)	152 (39.3)	110 (24.1)
Shoulder	498 (9.8)	286 (9.9)	38 (9.6)	30 (8.1)	49 (8.3)	53 (13.7)	42 (9.2)
Upper arm	20 (0.4)	14 (0.5)	1 (0.3)	2 (0.5)	0	1 (0.3)	2 (0.4)
Elbow	175 (3.4)	112 (3.9)	13 (3.3)	12 (3.3)	19 (3.2)	10 (2.6)	9 (2.0)
Forearm	185 (3.6)	127 (4.4)	14 (3.5)	12 (3.3)	8 (1.4)	7 (1.8)	17 (3.7)
Wrist	163 (3.2)	105 (3.6)	10 (2.5)	10 (2.7)	17 (2.9)	13 (3.4)	8 (1.8)
Hand	423 (8.3)	245 (8.4)	20 (5.1)	19 (5.1)	39 (6.6)	68 (17.5)	32 (7.0)
Trunk	495 (9.7)	308 (10.6)	43 (10.8)	37 (10.1)	46 (7.8)	15 (3.8)	46 (10.1)
Chest	126 (2.5)	76 (2.6)	8 (2.0)	12 (3.3)	15 (2.6)	6 (1.5)	9 (2.0)
Abdomen	48 (0.9)	23 (0.8)	4 (1.0)	4 (1.1)	9 (1.5)	3 (0.8)	5 (1.1)
Back	321 (6.3)	209 (7.2)	31 (7.8)	21 (5.7)	22 (3.7)	6 (1.5)	32 (7.0)
Lower extremity	2650 (52.0)	1390 (47.9)	208 (52.4)	217 (58.8)	376 (63.9)	211 (54.5)	249 (54.4)
Hip/groin	240 (4.7)	142 (4.9)	27 (6.8)	19 (5.1)	26 (4.4)	7 (1.8)	19 (4.2)
Thigh	444 (8.7)	224 (7.7)	33 (8.3)	34 (9.2)	80 (13.6)	19 (4.9)	54 (11.8)
Knee	706 (13.8)	338 (11.7)	52 (13.1)	52 (14.1)	87 (14.8)	107 (27.6)	70 (15.3)
Lower leg	331 (6.5)	184 (6.3)	21 (5.3)	29 (7.9)	46 (7.8)	22 (5.7)	29 (6.3)
Ankle	650 (12.8)	352 (12.1)	44 (11.1)	60 (16.3)	105 (17.9)	39 (10.1)	50 (10.9)
Foot	279 (5.5)	149 (5.1)	31 (7.8)	23 (6.2)	32 (5.4)	17 (4.4)	27 (5.9)
Total	5098 (100)	2900 (100)	396 (100)	369 (100)	588 (100)	388 (100)	457(100)

**Table 2** Injury type and severity

	All injuries <i>n</i> (%)	Medical attention injuries <i>n</i> (%)	Slight injury (1–3 days) <i>n</i> (%)	Mild injury (4–7 days) <i>n</i> (%)	Moderate injury (8–28 days) <i>n</i> (%)	Severe injury (> 28 days) <i>n</i> (%)	Unknown injury severity <i>n</i> (%)
Acute injuries	4847 (88.8)	2688 (88.0)	370 (86.7)	358 (88.4)	591 (92.2)	381 (92.0)	460 (89.5)
Contusion	1477 (27.1)	973 (31.8)	129 (30.2)	108 (26.7)	115 (17.9)	25 (6.0)	127 (24.7)
Sprain	1444 (26.5)	890 (29.1)	113 (26.5)	110 (27.2)	147 (22.9)	54 (13.0)	130 (25.3)
Rupture	667 (12.2)	207 (6.8)	49 (11.5)	54 (13.3)	162 (25.3)	140 (33.8)	55 (10.7)
Skin injuries	287 (5.3)	190 (6.2)	14 (3.3)	21 (5.2)	29 (4.5)	4 (1.0)	29 (5.6)
Strain	267 (4.9)	148 (4.8)	18 (4.2)	25 (6.2)	39 (6.1)	6 (1.4)	31 (6.0)
Fracture	242 (4.4)	57 (1.9)	14 (3.3)	13 (3.2)	39 (6.1)	91 (22.0)	28 (5.4)
Subluxation/dislocation	128 (2.3)	51 (1.7)	5 (1.2)	9 (2.2)	15 (2.3)	37 (8.9)	11 (2.1)
Concussion	55 (1.0)	27 (0.9)	6 (1.4)	6 (1.5)	8 (1.2)	1 (0.2)	7 (1.4)
Tooth injury	38 (0.7)	24 (0.8)	3 (0.7)	0	1 (0.2)	0	10 (1.9)
Internal injury	2 (0.0)	0	0	0	1 (0.2)	1 (0.2)	1 (0.2)
Unknown	240 (4.4)	120 (3.9)	19 (4.4)	12 (3.0)	36 (5.6)	22 (5.3)	31 (6.0)
Overuse injuries	609 (11.2)	368 (12.0)	57 (13.3)	47 (11.6)	50 (7.8)	33 (8.0)	54 (10.5)
Total	5456 (100)	3,056 (100)	427 (100)	405 (100)	641 (100)	414 (100)	514 (100)

**Table 3** Injury severity in the first and second leagues

	First league <i>n</i> (%)	Second league <i>n</i> (%)	Total <i>n</i> (%)
Medical attention	1581 (58.4)	1474 (53.6)	3055 (56.0)
Slight injury	183 (6.8)	244 (8.9)	427 (7.8)
Mild injury	178 (6.6)	227 (8.3)	405 (7.4)
Moderate injury	271 (10.0)	370 (13.4)	641 (11.7)
Severe injury	196 (7.2)	218 (7.9)	414 (7.6)
Unknown injury	296 (10.9)	218 (7.9)	514 (9.4)
Total	2705 (100)	2751 (100)	5456 (100)

to 1.11 (1.05–1.17) in 2011–2012 and to 1.12 (1.06–1.19) in 2012–2013.

## Discussion

The most important finding of this study was that—after the restructure of the national second league—injury rates had almost increased to the level of the first national league.

This study presents for the first time detailed information on the injury risk and patterns of professional men's team handball in the two highest national leagues. The results show significant differences in injury risk between the first and second team handball leagues. First league players had sustained more injuries: this difference may be explained by

**Table 4** Injury type in the first and second leagues

	First league <i>n</i> (%)	Second league <i>n</i> (%)	Total <i>n</i> (%)
Contusion	757 (28.0)	720 (26.2)	1477 (27.1)
Sprain	733 (27.1)	711 (25.8)	1444 (26.5)
Rupture	304 (11.2)	363 (13.2)	667 (12.2)
Skin injuries	139 (5.1)	148 (5.4)	287 (5.3)
Strain	137 (5.1)	130 (4.7)	267 (4.9)
Fracture	97 (3.6)	145 (5.3)	242 (4.4)
Subluxation/dislocation	49 (1.8)	79 (2.9)	128 (2.3)
Concussion	26 (1.0)	29 (1.1)	55 (1.0)
Tooth injury	21 (0.8)	17 (0.6)	38 (0.7)
Internal injury	1 (0.0)	1 (0.0)	2 (0.0)
Overuse	316 (11.7)	293 (10.7)	609 (11.2)
Unknown	125 (4.6)	115 (4.2)	240 (4.4)
Total	2705 (100)	2751 (100)	5456 (100)

**Table 5** Injury location in the first and second leagues

	First league <i>n</i> (%)	Second league <i>n</i> (%)	Total <i>n</i> (%)
Head	201 (7.9)	229 (8.9)	430 (8.4)
Neck	33 (1.3)	26 (1.0)	59 (1.2)
Shoulder	263 (10.4)	235 (9.2)	498 (9.8)
Upper arm	11 (0.4)	9 (0.4)	20 (0.4)
Elbow	89 (3.5)	86 (3.4)	175 (3.4)
Forearm	100 (3.9)	85 (3.3)	185 (3.6)
Wrist	72 (2.8)	91 (3.5)	163 (3.2)
Hand	191 (7.5)	232 (9.0)	423 (8.3)
Chest	63 (2.5)	63 (2.5)	126 (2.5)
Abdomen	26 (1.0)	22 (0.9)	48 (0.9)
Back	158 (6.2)	163 (6.4)	321 (6.3)
Hip/groin	113 (4.5)	127 (5.0)	240 (4.7)
Thigh	218 (8.6)	226 (8.8)	444 (8.7)
Knee	371 (14.6)	335 (13.1)	706 (13.8)
Lower leg	168 (6.6)	163 (6.4)	331 (6.5)
Ankle	323 (12.8)	327 (12.7)	650 (12.8)
Foot	133 (5.3)	146 (5.7)	279 (5.5)
Total	2533 (100)	2565 (100)	5098 (100)

the increased physical intensity, the higher psychological intensity, and the larger number of players in the first league who also compete in international matches with their respective clubs and national teams.

After the restructure of the national second league, injury prevalence had increased from 67.1 to 79.3% ( $p < 0.001$ ) and injury incidence from 3.7 to 4.1 per 1000 h ( $p < 0.01$ ); hence almost to the level of the first league (Table 6, 7). In football, the implementation of a new professional league had increased the rate of ACL and PCL injuries but no data for team handball have been available so far [15]. In this study, the incidence of time-loss injuries, particularly ruptures, dislocations, and fractures was higher in the second league, although the training exposure was calculated to be the same in both leagues. This calculated incidence rate may be different; thus the difference between the two leagues may even be larger, if a higher training exposure had been calculated for first league players. This difference in time loss with a higher injury incidence rate of second league players may be due to the rapidly changing higher physical impact on the players [9, 15]. In addition, league matches in the second league were increased from  $2 \times 17$  matches in the previous regional two league system to  $2 \times 19$  matches after the restructure; thus, the travel burden was increased, subsequently decreasing the time and quality of regeneration.

Increased training and playing intensity as a possible risk factor for severe injuries, such as ACL tears, has been discussed in the literature [18, 26]. A study conducted during the World Men's Handball Championship in 2015 had yielded a higher injury incidence rate of 104.5 per 1,000 h

match exposure [6]. The rapid increase in physical impact during the professional tournaments also seems to directly influence injury rates, similar to the restructure of the team handball league. This increase could be one explanation for the overall higher incidence rates of time-loss injuries between the two leagues, particularly ruptures, dislocations, and fractures.

The increasing professionalism of the national second league after its restructure should therefore be matched by the availability of medical infrastructure that is equal to the medical service available to first league players. Injury prevention strategies for similar situations in professional team handball should be combined with already existing prevention programs to reduce time-loss injuries, such as ruptures, dislocations, and fractures as well as their long-term consequences. Prevention strategies should therefore focus on reducing the number of matches, monitoring and managing the training and match load, identify dangerous load peaks, decrease the travel burden, and increase regeneration.

The injury risk in the second league had also increased in the second season after the restructure, indicating a longer process to adapt to the specific demands of professional team handball. Psychological and mental influencing factors on contact and non-contact injuries are well known but were not considered in this study [2, 10].

The first league showed a higher incidence rate of acute shoulder and knee injuries but a lower prevalence of wrist and hand injuries than the second league (Table 6). Knees and shoulders may be more affected by the higher training and match load of first league teams, whereas wrist and hand injuries may be higher in the second league because of different (tactical) match plays. Players of the first league also showed 1.0% more overuse injuries than players of the second league (Table 5). This increase may be explained by the higher training and match load for some teams and players, i.e. German Cup matches, international matches, and matches with the national teams, which is a known risk factor for shoulder overuse injuries [19].

Injury severity differed between the two leagues. More medical attention injuries occurred in the first league than in the second league, whereas time-loss injuries of all severity levels were more common in the second league (Table 3). This difference may be explained by the higher rate of fractures, ruptures and dislocations occurring in the second league (Table 5). These types of injury require extensive medical intervention and result in more time loss than other types of injuries, such as contusions and sprains that occurred more often in the first league. In addition, a better medical infrastructure, greater availability of equipment, increased support in return-to-competition, and higher pressure to play may be reasons for first league players to continue playing or to return to competition more quickly.

**Table 6** Injuries and injury incidence for each season

Season	League	Occasion	Injuries <i>n</i>	Exposition in hours	Incidence (injuries/1000 h)	95% CI (injuries/1000 h)
2010/11	First league	Matches	351	5523	63.6	56.9–70.2
		Training*	499	185,220	2.7	2.5–2.9
		Total	850	190,743	4.5	4.2–4.8
	Second league	Matches	507	8596	59.0	53.8–64.1
		Training*	683	311,580	2.2	2.0–2.4
		Total	1190	320,176	3.7	3.5–3.9
2011/12	First league	Matches	445	5425	82.0	74.4–89.6
		Training*	487	169,560	2.9	2.6–3.1
		Total	932	174,985	5.3	5.0–5.7
	Second league	Matches	294	5649	52.0	46.1–58.0
		Training*	466	187,380	2.5	2.3–2.7
		Total	760	193,029	3.9	3.7–4.2
2012/13	First league	Matches	406	5376	75.5	68.2–82.9
		Training*	517	180,900	2.9	2.6–3.1
		Total	923	186,276	5.0	4.6–5.3
	Second league	Matches	335	5292	63.3	56.5–70.1
		Training*	466	190,080	2.4	2.2–2.7
		Total	801	195,372	4.1	3.8–4.4
2010–2013	First league	Matches	1202	16,324	73.6	69.5–77.8
		Training*	1503	535,680	2.8	2.7–2.9
		Total	2705	552,004	4.9	4.7–5.1
	Second league	Matches	1136	19,537	58.1	54.8–61.5
		Training*	1615	689,040	2.3	2.2–2.5
		Total	2751	708,577	3.9	3.7–4.0
	First and second league	Matches	2338	35,861	65.2	62.6–67.8
		Training*	3118	1,224,720	2.5	2.5–2.6
		Total	5456	1,260,581	4.3	4.2–4.4

\* Calculated training exposure

**Table 7** Number of injured players, injuries, medical attention and time-loss injuries in the first and second leagues

	Players <i>n</i>	Injured players <i>n</i> (%)	Injuries ( <i>n</i> )	Medical attention injuries <i>n</i> (%)	Time loss injuries <i>n</i> (%)
First league					
2010/11	343	268 (75.9)	850	496 (58.4)	354 (41.6)
2011/12	314	262 (83.4)	932	521 (55.9)	411 (44.1)
2012/13	335	271 (80.9)	923	564 (61.1)	359 (38.9)
2010–2013	549	454 (82.7)	2705	1581 (58.4)	1124 (41.6)
Second league					
2010/11	577	387 (67.1)	1190	652 (54.8)	538 (45.2)
2011/12	347	260 (74.9)	760	403 (53.0)	357 (47.0)
2012/13	352	279 (79.3)	801	420 (52.4)	381 (47.6)
2010–2013	828	608 (73.4)	2751	1475 (53.6)	1276 (46.4)

In our study, the majority of injuries were acute injuries. Acute injuries with severe time-loss mainly affected the shoulders, hands, and the lower extremities, particularly the knees and ankles. A study by Giroto et al. showed

an injury incidence rate of 3.7 per 1000 h training exposure and 20.3 per 1000 h match exposure for both men and women. Similar to our results, ankles (19.4%) and knees (13.5%) were the body regions most affected by traumatic

injuries. The overall injury incidence and overall injury risk were comparable to that of previous studies on professional team handball [5, 6, 9, 17, 20, 22, 25]. However, most studies have focused on female players and tournament setting, such as the Olympic Games. Only a few studies have recently investigated the injuries in professional men's team handball in a league setting [9, 25].

So far, injury prevention programs have focused on acute knee injuries, such as ACL tears, and these studies have shown good results in preventing non-contact injuries in females and adolescents [1, 21]. But studies should also be conducted in the important group of professional male players to confirm the previous promising results. Additionally, more studies should investigate injury-prone situations. For example, video analysis may help to identify injury-inciting events, and subsequently result in the appropriate adjustment of existing preventive approaches. The data of this study recommend investing in injury prevention of acute shoulder and hand injuries in addition to the established injury prevention programs for acute knee injuries. The only study available so far on shoulder injury prevention has focused on overuse injury [5].

This study has a number of methodological limitations. Its retrospective design necessitated calculation of training exposure from the personal experiences of the first and senior author. Because many lower-ranked teams in the second league only had a few training sessions per week, especially during the first investigated season before the restructure, the different levels of professionalism had decreased the weekly average. Training exposure was not calculated for different periods of the seasons because such calculation would have been on too many unknown variables.

Second league teams might have increased their training hours after the restructure of the national second league; therefore, the calculated injury incidence had not increased as much as calculated. Nonetheless, the prevalence in this subpopulation had risen after the restructure. Another limitation was that 2-min suspensions in matches were not accounted for in the approximated estimation of match exposure. In addition, foreign national team matches were not included, and pre-season and in-season friendly matches were calculated as training exposure if they had not been announced to the VBG.

The number of non-reported slight injuries with less than 3 day absence is unknown, and report rate of minimal and slight injuries probably differs among the team physicians. Another limitation is that no differentiation could be made between medical attention injuries and time-loss injuries of 0 days. Due to the registration methods, chronic injuries were likely to be underrepresented. Chronic injuries are typically not eligible for financial reimbursement by the VBG. Thus, team physicians may have less incentive to report

chronic injuries than acute injuries. Career-ending injuries were not assessed and should be investigated in the future.

The strength of the study is the unique data sample of professional men's team handball injuries, the size of the study population, and the length over three consecutive seasons. Moreover, the study includes data before and after the rare event of restructuring a professional team handball league. A further advantage is the high accuracy and validity of the data on injuries with more than 3 days time loss using the injury data from professional sports physicians in contrast to other studies using injury self-reports from team coaches and players.

This study is the largest study on professional men's team handball so far. The aim was to provide objective data to all people involved in this sport, including medical personnel, coaches, officials, and athletes. Several recommendations can be made in support of a potentially safer environment, such as better equipment, a set of handball rules and regulations, and warm-up exercises [14]. Active prevention must be mandatory and may be addressed by reducing the training and match load combined with sufficient regeneration between matches. Teams who move up in a professional league should invest in qualified medical staff as well as in appropriate equipment and infrastructure to be able to professionally counteract the increasing injury incidence and prevalence. To prevent rapid changes in training intensity, teams who expect moving up into a higher league should slowly increase their training load to the level of the training volume expected in the following season.

## Conclusion

In conclusion, professional team handball shows significant differences in injury incidence and prevalence between the first and second leagues. After the restructure of the national second league, injury rates had almost increased to the same level of the first league, probably due to the increase in match and training load as well as travel burden. Prevention strategies should therefore focus on reducing the number of matches, monitoring and managing the match and training load, identifying dangerous load peaks, decreasing the travel burden, and increasing the quality and time of regeneration for each individual player. Injury prevention is mandatory for players with high injury profiles, and professional prevention strategies should particularly focus on injuries of the shoulders, hands, and lower extremities.

**Acknowledgements** This study was conducted in cooperation with the insurancy company Verwaltungs-Berufsgenossenschaft who provided the dataset on professional handball players. Funding was received by the VBG in the framework of the project "Entwicklung und Evaluation" (Development and evaluation). The authors declare that there is no conflict of interest.

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