Longitudinal differences in the injury profile of professional male handball players according to competitive-level

Short title: Injury profile in handball players

Abstract

The aim was to analyze the differences in professional handball players` injury profile according to the team`s competitive-level (i.e., First division vs. Second division). Fifty-three professional male handball players participated in this study during 4 consecutive seasons in the same team (2015-16 and 2016-17 for the First division league and 2017-18 and 2018-19 for the Second division league). No significant differences in overall incidence was observed between groups (3.69 vs 4.19 injuries/1000 h, RR = 0.88, 95% CI 0.64-1.22, *P* = 0.44), although significantly greater injury incidence during training sessions was observed in the Second division group (3.06 vs 1.61 injuries/1000 h, RR = 0.52, 95% CI 0.34-0.81, *P* = 0.01), while greater injury incidence during matches was reported in the First division group (84.03 vs 49.88 injuries/1000 h, RR = 1.68, 95% CI 1.00-2.83, *P* = 0.05). The second division group presented the greatest injury burden attending to overall, training and match exposure, as well as in most locations and injury types, but no statistically significant differences were observed between groups. Given the between groups differences found in the injury profile of handball player, it is suggested to implement specific preventive strategies attending to the characteristics of each level-group.

Key words: Injury & prevention, epidemiology, team-sports, health.

Introduction

Previous studies have indicated that playing handball elicits improvements in a number of physical and physiological parameters (Brown & Fletcher, 2017). However, participation in handball is also associated with a high injury risk (Moller, Attermann, Myklebust, & Wedderkopp, 2012), mainly because players are exposed to greater physical demands during training sessions and match-play (Karcher & Buchheit, 2014). Specifically, rapid changes of direction, jumps with abrupt landings and repetitive throws, as well as frequent physical contact between players, characterize this high-intensity team sport (Bere et al., 2015; Rafnsson, Valdimarsson, Sveinsson, & Árnason, 2017). Additionally, congested competition schedules and greater pressures to remain at a high competitive-level are expected by professional players (Soligard et al., 2016), which has led handball to be considered as the Olympic sport with the highest injury rate (Engebretsen et al., 2013). Injuries negatively impact team success (Hägglund et al., 2013) and financial gains (Ekstrand, 2013), and also have long-term health consequences that affect players quality of life (Øiestad, Holm, & Risberg, 2018). Thus, the reduction of injury risk is considered a priority task for coaches, physical trainers, clinicians and researchers in sports science and medicine.

To address this problem, some authors have suggested that there is a need to apply a structured preventive approach (van Mechelen, Hlobil, & Kemper, 1992). Consequently, the first step of injury prevention practice should be an epidemiological analysis, as this permits the identification and description of the injury related issue in terms of its incidence and severity (van Mechelen et al., 1992). However, the literature focused on handball studies do not present a clear consensus regarding injury definitions, injury-reporting methods and study designs, which makes it difficult to generalize the previous findings (Mónaco et al., 2019). Despite this discordance in the scientific literature, previous studies have reported that time-loss injuries in male handball players range between 4.1 to 12.4 injuries/1000 h (Bere et al., 2015; Moller et al., 2012; Mónaco et al., 2019; Olsen, Myklebust, Engebretsen, & Bahr, 2006), presenting significantly higher values during match-play (i.e., 8.3-14.3 injuries/1000 h) than in training (i.e., 0.6-4.6 injuries/1000 h) (Bere et al., 2015; Rafnsson et al., 2017). Further, lower limbs injuries are the most common in this team sport, affecting mainly the ankle, knee and thigh, although head injuries are also reported due to contact mainly when players are close to the penalty box (Bere et al., 2015; Mónaco et al., 2019; Rafnsson et al., 2017). In addition,

ligament sprains and muscle strains are the most frequent type of injuries (Bere et al., 2015; Rafnsson et al., 2017). Although handball is a contact sport with permissive rules (International HandballFederation, 2019), non-contact injuries are more predominant in comparison to contact injuries, as in recent years a change in rules has led to reduced careless tackles and collisions that previously resulted in injury (Bere et al., 2015).

Alongside injury incidence rates, injury burden is considered as a key parameter within epidemiological studies because this concept combines the rate of disease (i.e., incidence) and a measure of loss (i.e., severity) (Bahr, Clarsen, & Ekstrand, 2017). Although the burden provides valuable information in order to optimize the injury prevention process, to our knowledge there is no research that has reported injury burden in handball players. Therefore, it is necessary to analyze the injury profile of professional handball players applying an appropriate injury-reporting method and study design, that includes both incidence and burden.

Sports injuries are a complex phenomenon (Hulme & Finch, 2015) caused by the interaction of multiple intrinsic and extrinsic risk factors, such as age, sex, training load or skill level (Giroto, Hespanhol Junior, Gomes, & Lopes, 2017; Zebis et al., 2016), which are widely related to the players' physical responses. Previous studies have suggested that injury risk is higher when the age-category increases or according to the sex of the players, due in part to high-intensity and faster play (Moller et al., 2012; Olsen et al., 2006), as well as more aggressive behavior and more frequent contact between players (Nielsen & Yde, 1988; Olsen et al., 2006). However, Olsen et al. (2006) did not find gender differences in injury rates despite the higher demands (e.g., high-intensity running or high-intensity technical playing actions) placed on male handball players compared to female players (Michalsik & Aagaard, 2015). Likewise, Mónaco et al. (2019) did not observe significant differences in the injury incidence between age-categories (i.e., youth and adult players), although ankle, thigh, and head injuries were significantly more common in adults than in youth players. Conflicting data are available and Olsen et al. (2006), Nielsen and Yde (1988) and Seil et al. (1998) demonstrated an increase in injury incidence was associated with a higher competitive-level in male and female handball players. The contradictory results observed in the aforementioned studies demonstrates the need to know explore injury patterns in each specific context, as well as to identify the injury incidence for different groups with the aim to propose the most effective

subsequent individual injury risk management strategy (Ekstrand, Hägglund, Kristenson, Magnusson, & Waldén, 2013).

Given the current conflicting data and lack of injury burden data in handball it is important to explore the injury incidence and burden within the same team competing at two different competitive-levels. Therefore, this study aimed to analyze the differences in professional handball players' injury profile according to the team's competitive-level (i.e., First division vs. Second division). We hypothesized, based on previous studies (Nielsen & Yde, 1988; Olsen et al., 2006; Seil et al., 1998), that the injury incidence and burden would be higher in the First division in comparison to the Second division.

Methods

Participants

A total sample of 53 male professional handball players, from one team who competed at the highest level (i.e., First or Second division), participated in this study during four consecutive seasons (from 2015-18 and 2018-19). Sixteen players took part only in the first two seasons (i.e., First division), 23 players were involved during the last two seasons (i.e., Second division) and 14 players participated in both competitive-level groups. Specifically, the team squad was composed by 17, 17, 21 and 20 players during the first, second, third and fourth season, respectively. During the follow-up period, all players performed 5-7 in-court training sessions, 2-3 strength training sessions and 1-2 official matches per week, respectively. The team finished the season in the 6^{th} and 15^{th} positions during First division seasons and in the 14^{th} and 8^{th} positions during Second division seasons of 16 teams participating in each league. Prior to the beginning the study, club officials' assent was obtained, and written consent was given by the participants, having the option of withdrawing from the study at any time without penalty. This investigation was conducted according to the Declaration of Helsinki (2013) and was approved by ethics committee of the ***blind for review purposes***.

Procedures

A prospective cohort design was performed over four consecutive seasons to analyze the differences in the injury profile of professional handball players according to the competitive-level (i.e., First or Second division). During this period, information about each injury was registered (i.e., type, location, severity, number of absence days,

mechanism, diagnosis and whether the injury occurred during training or match play). The medical staff of the club were responsible to diagnose, treat, and record all time-loss injuries, following the consensus on definitions and data collection procedures outlined by the International Olympic Committee consensus statement (Bahr et al., 2020). For location and type, injuries were coded according to the Orchard Sports Injury Classification System (OSICS-10 codification), as in a previous epidemiological study with handball players (Mónaco et al., 2019). During the seasons when the team participated in the First division, players were supported by one doctor, two physiotherapists and on-field rehabilitation fitness coach, while during Second division seasons the medical staff was composed of a doctor and one physiotherapist, which remained the same for all four seasons.

Definitions

An injury was defined as "an injury that occurred during a scheduled training session or match that caused absence from the next training session or match" (Hägglund et al., 2005), while a recurrent injury was defined as "an injury of the same type and location of a previous injury that occurred within two months of the final rehabilitation day of the previous injury" (Hägglund et al., 2005). Injury burden was presented as the numbers of days lost per 1000 hours of exposure (Bahr et al., 2017). Exposure is considered to be "the time (in hours), both in training and match-play, during which the player is in a position to suffer an injury, and incidence refers to the number of injuries sustained during practice, both in training and match-play, for every 1000 h of exposure" (van Mechelen et al., 1992). Match-play exposure was calculated when playing against teams from different clubs and training sessions were considered those in which a coach directed physical activity carried out with the team. A player was considered fully-recovered (i.e., return to play) after an injury when he was given clearance by the medical staff to participate fully in team training and match-play (Raya-González, Suárez-Arrones, Navandar, Balsalobre-Fernández, & Villarreal, 2019).

Statistical analysis

The normal distribution of data was tested using the Shapiro-Wilk test. Level-group differences in players' characteristics and exposure time were calculated using an independent samples *t* test. Injury incidence (number of injuries/1000 h) and burden (number of absence days/1000 h) were calculated for both competitive-level groups with

95% confidence intervals (CI) (Bahr et al., 2017). To compare the injury incidence and the burden for the different competitive-level groups, rate ratios (RR) with a 95% CI were calculated using the Z-test (Kirkwood & Sterne, 2003). Statistical analysis was performed using Microsoft Excel 2011 software (Microsoft, Redmond, WA, USA) and GraphPadPrism v.6.0c (GraphPad Software, La Jolla, CA, USA) and the level of significance was set at $p < 0.05$.

Results

Exposure and incidence

Handball players' characteristics and exposure time are displayed in Table 1, while the injury incidence, recurrence, mechanism and severity by competitive-level are shown in Table 2. No significant differences ($p > 0.05$) were found in exposure time (i.e., total, training and match) between First and Second division groups. A total of 150 injuries were recorded during the study and no significant differences in the total injury incidence was observed between groups (3.69 vs 4.19 injuries/1000 h, RR = 0.88, 95% CI 0.64-1.22, $p = 0.44$). Significantly greater injury incidence during training sessions was observed in the Second division group compared to the First division group (3.06 vs 1.61 injuries/1000 h, RR = 0.52, 95% CI 0.34-0.81, $p = 0.01$), which presented the highest injury rate during matches (84.03 vs 49.88 injuries/1000 h, RR = 1.68, 95% CI 1.00-2.83, $p = 0.05$). No significant differences ($p > 0.05$) between First and Second Division groups in recurrence, mechanism and severity was observed.

Table 1 Descriptive characteristics of the participants (Mean ± SD).

	First division (n = 30)	**Second division (n = 37)**
Age (years)	25.7 ± 1.3	26.9 ± 0.6
Height (cm)	189.9 ± 2.5	188.7 ± 2.4
Body mass (kg)	91.2 ± 2.4	89.5 ± 2.7
Body mass index (kg/m²)	24.7 ± 0.9	24.9 ± 0.6
Exposure time (hours)		
Total exposure	19754	18381
Training exposure	19278	17940
Training hour per player	520 ± 37	457 ± 32
Match exposure	476	441
Match hour per player	20 ± 7	17 ± 8

SD: standard deviations.

Table 2. Injury incidence in First and Second division

Injuries	First division (n = 30)		Second division (n = 37)		Rate ratio (95% CI)	P value
	n	Incidence (95% CI)	n	Incidence (95% CI)		
Total	73	3.69 (2.94-4.65)	77	4.19 (3.35-5.24)	0.88 (0.64-1.22)	0.44
Training	31	1.61 (1.13-2.28)*	55	3.06 (2.35-3.99)*	0.52 (0.34-0.81)	0.01
Match	40	84.03 (61.64-114.56)	22	49.88 (32.85-75.76)	1.68 (1.00-2.83)	0.05
Recurrence						
No	47	2.38 (1.79-3.17)*	57	3.10 (2.39-4.02)*	0.77 (0.52-1.13)	0.18
Yes	28	1.42 (0.98-2.05)	20	1.09 (0.70-1.69)	1.30 (0.73-2.31)	0.37
Mechanism						
Overuse	56	2.83 (2.18-3.68)*	59	2.49 (2.49-4.14)*	0.88 (0.61-1.27)	0.51
Traumatic	17	0.86 (0.53-1.38)	15	0.82 (0.49-1.35)	1.05 (0.53-2.11)	0.88
Severity						
Slight	23	1.16 (0.77-1.75)¶	20	1.09 (0.70-1.69)¶	1.07 (0.84-2.58)	0.82
Minor	34	1.72 (1.23-2.41)¥¶	29	1.58 (1.10-2.27)¶	1.09 (0.84-2.58)	0.73
Moderate	12	0.61 (0.34-1.07)	23	1.25 (0.83-1.88)¶	0.49 (0.84-2.58)	0.04
Major	4	0.20 (0.08-0.54)	5	0.27 (0.11-0.65)	0.74 (0.84-2.58)	0.66

Incidence: number of injuries/1000 h exposure; n: number of observations; CI: confidence interval; P value for the comparison of injury incidence both seasons; Significant differences were set at P value < 0.05. * indicate significant differences (P < 0.05) between training and match incidence, between new injuries and recurrences, and between overuse and traumatic injuries.

¥ Significant differences in comparison to moderate injuries (P < 0.05)

¶ Significant differences in comparison to major injuries (P < 0.05)

Absence days and burden

The absent days and burden during trainings and matches in the First and Second Division groups are presented in Table 3, while absence days and burden according to the severity between the competitive-level groups are shown in Table 4. The injuries corresponded to 862 absence days in the First division group and 1609 absence days in the Second division group. Subsequently, a significantly greater injury burden ($p < 0.01$) was observed in the Second division group according to the total, training and match exposure, in comparison to the First division group. The Second division group presented the highest burden values ($p = 0.001$) in moderate and major injuries, but no significant between-groups differences ($p > 0.05$) in slight and minor ones were observed.

Injury locations and types

The injury incidence and burden in location and type between First and Second division groups are showed in Figures 1-4. Knee and ankle were the most affected areas for both competitive-level groups (Figure 1). Additionally, tendon injuries, followed by muscle injuries and ligament sprains, presented the greatest injury rates among all injury types,

Table 3 Comparison of the absence days and burden during trainings and matches between First and Second Division groups

Absence days	First division (n = 30)		Second division (n = 37)		Rate ratio (95% CI)	P value
	n	Burden (95% CI)	Nº	Burden (95% CI)		
Total	862	43.64 (40.82-46.65)	1609	87.54 (83.36-91.92)	0.50 (0.46-0.54)	0.01
Training	257	13.33 (11.80-15.06)	465	25.92 (23.67-28.39)	0.51 (0.44-0.60)	0.01
Match	605	1271.01 (1173.66-1376.43)	1144	2594.10 (2448.05-2748.87)	0.49 (0.44-0.54)	0.01

Burden: number of absence days/1000 h exposure; n: number of observations; CI: confidence interval; P value for the comparison of injury incidence both seasons; Significant differences were set at P value < 0.05.

Table 4 Comparison of the absence days and burden according to the severity between First and Second Division groups

Absence days	First division (n = 30)		Second division (n = 37)		Rate ratio (95% CI)	P value
	n	Burden (95% CI)	Nº	Burden (95% CI)		
Slight	52	2.63 (2.01-3.45)	53	2.88 (2.20-3.77)	0.91 (0.62-1.34)	0.64
Minor	158	7.99 (6.84-9.35)	157	8.54 (7.30-9.99)	0.94 (0.75-1.17)	0.56
Moderate	217	10.98 (9.62-12.55)	343	18.66 (16.79-20.74)	0.59 (0.50-0.70)	0.001
Major	435	22.02 (20.05-24.19)	1056	57.45 (54.09-61.02)	0.38 (0.34-0.43)	0.001

Burden: number of absence days/1000 h exposure; n: number of observations; CI: confidence interval; P value for the comparison of injury incidence both seasons; Significant differences were set at P value < 0.05.

similar in both groups (Figure 2). The Second division group showed higher injury burden related to the injuries suffered in ankle, leg, knee, thigh and wrist-hand (RR = 0.05-4.44, $p < 0.01$), while only injuries in the head and shoulder generated greater injury burden in the First division group (RR = 0.15-1.83, $p < 0.01$), with non-significant differences in abdomen and lumbar injuries (Figure 3). Significantly higher injury burden values in all injury types were observed for the Second division group (RR = 0.01-0.62, $p < 0.001$), except in tendon injuries, with greater values for in First division group observed (RR = 1.97, $p < 0.001$) (Figure 4).

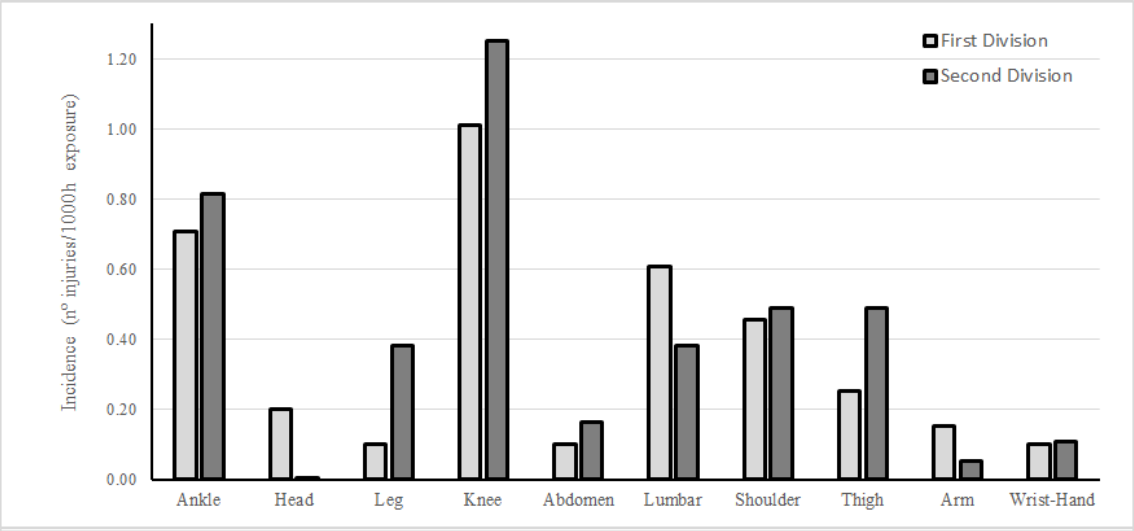

Figure 1 Differences in injury incidence attending to the location between First and Second division groups.

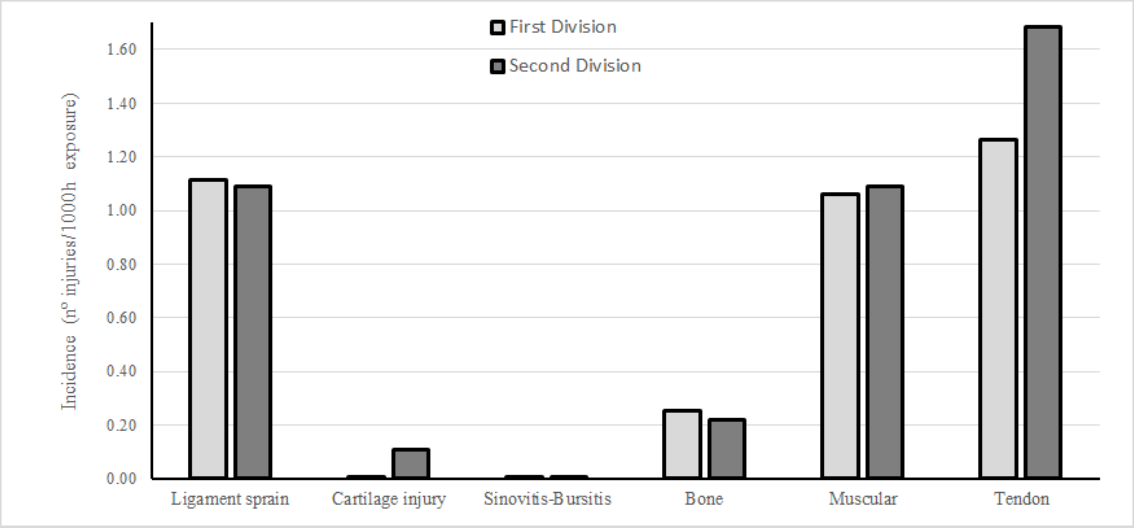

Figure 2 Differences in injury incidence attending to the type between First and Second division groups.

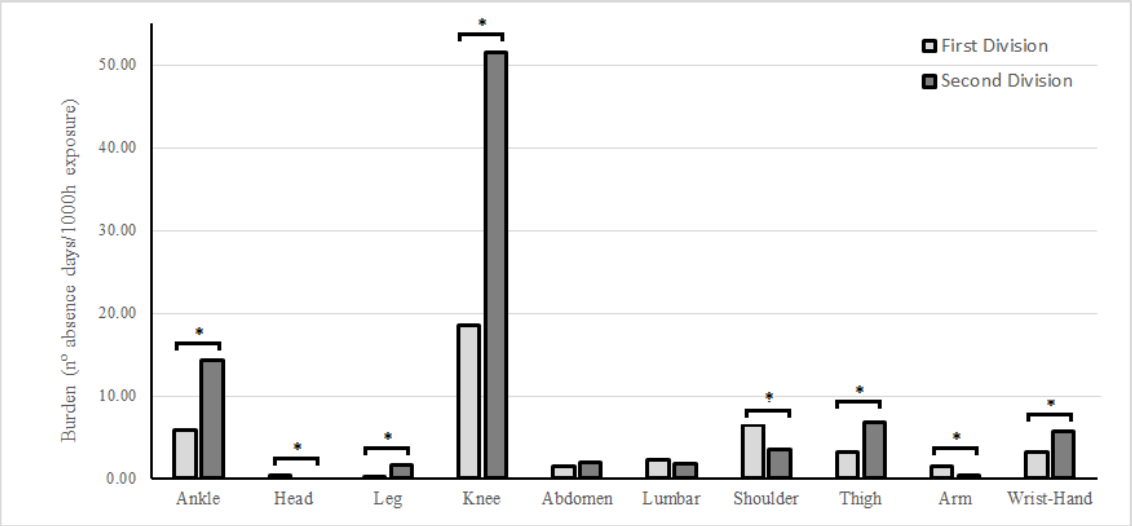

Figure 3 Differences in burden attending to the location between First and Second division groups.

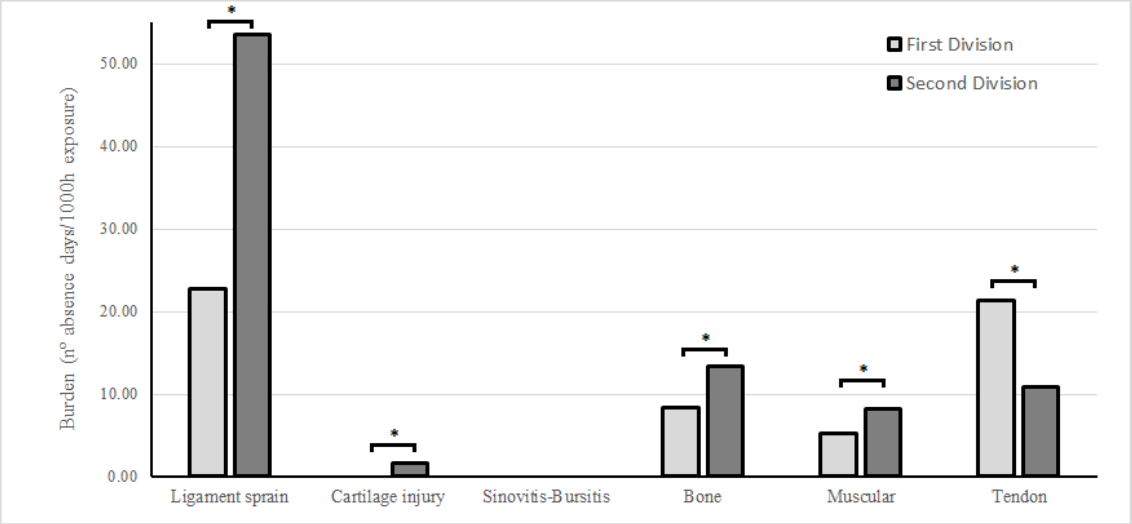

Figure 4 Differences in burden attending to the type between First and Second division groups.

Discussion

This study aimed to analyze the differences in professional handball players' injury profile according to the team's competitive-level (i.e., First division vs. Second division). Although several studies have analyzed the injury incidence of handball players in different levels (Bere et al., 2015; Rafnsson et al., 2017), including a comparison of injuries suffered by professional and young players (Mónaco et al., 2019), this is the first study that compares the injury rate of the same team (n = 53; 16 players only First division; 23 only Second division and 14 repeated in both categories) when competing at

two different levels. The main results of this investigation show a greater injury rate in training sessions in the Second division group, while higher injury incidence in matches was present in the First division group. In addition, significantly higher injury burden was observed in the Second division group in all exposure categories (i.e. total, training and match) and in moderate and major severity injuries in comparison to the First division group. In terms of injury location and type, no significant differences were observed in injury incidence between competitive-level groups, although the Second division group presented the highest injury burden in most of locations and types analyzed in comparison to the First division group.

Given the growing interest in handball, the number of epidemiological studies in this sport have increased substantially in recent years (Bere et al., 2015; Mónaco et al., 2019; Olsen et al., 2006; Rafnsson et al., 2017)**.** There appears to be a trend for greater time-loss injuries per season, based on a substantial increase in the intensity of the sport in recent years (Karcher & Buchheit, 2014). Previous studies have shown a range of injury rates from 4.1 and 12.4 injuries/1000 h exposure (Mónaco et al., 2019; Olsen et al., 2006), with higher values observed during match-play (8.3-14.3 injuries/1000 h) in comparison to training sessions (0.6-4.6 injuries/1000 h) (Bere et al., 2015; Rafnsson et al., 2017). Our results are in line with the aforementioned studies for total and training practice incidence, showing an injury incidence of 1.61-4.19 injuries/1000 h exposure. However, the present study demonstrated a substantially greater injury incidence rate during matches (49.88-84.03 injuries/1000 hours). These differences could be explained by the different methodologies used to classify and analyze the injuries data (e.g., heterogeneity of study designs, several injury definitions and registration methods, lack of clarity in exposure recording, different observation periods and players` characteristics) which has been identified in the handball injury literature (Mónaco et al., 2019). Regarding the comparison between competitive-level groups, the results obtained showed that the total injury rate is similar in both categories, although there were significant differences based on training and match injury incidence rates. The injury incidence during training sessions was higher in the Second division group, possibly due to less skilled players have reduced abilities to avoid injury-prone actions (Azubuike & Okojie, 2009). On the other hand, greater match injury incidence in the First division group were reported, which might be partly attributed to greater match intensity meaning that players need to adapt to the intense and faster play (Moller et al., 2012; Olsen et al., 2006). These findings suggest

that there is a necessity to monitor the match-load in the First division players to be able to implement specific preventive and recovery protocols with the aim of reducing the number of injuries caused during competitive play. Training also needs to match the demands of competitive match play so that players are robust enough to cope with the demands of competition.

Previous authors have highlighted the pitfall of solely considering injury incidence to describe the injury profile of professional athletes, and in prescribing appropriate prevention strategies (Bahr et al., 2017). Thus, the knowledge of the absence days generated by each injury could solve this problem and avoid biased interpretations about injuries. It would seem appropriate to use the concept of burden, since it provides a relative value to the exposure time, rather than the absence days, since it provides an absolute value, which can lead to misinterpretation (Bahr et al., 2017). However, there are few studies determining the absence days in handball players, and to the authors knowledge our study appears to be the first that has analyzed the burden in professional handball players, across two divisions and in the same team. Our injury incidence data indicated that the Second division group presented higher burden values in training. However, this group also demonstrated the greatest burden values in total and in matches. These unexpected results could be explained by the injury burden data associated with each severity (i.e., slight, minor, moderate and major) as can be seen in Table 4. The burden of severe injuries (i.e., moderate and major) were higher in the Second division group compared to the First division group, and consequently, the absence days/1000 h exposure was also larger. This could be due to the reduction of medical staff during the seasons that the team competed in the Second division (i.e., one physiotherapist and one on-field rehabilitation fitness coach less), given the importance of these practitioners in the rehab process (Kraemer, Denegar, & Flanagan, 2009).

Also, the knowledge of the injury incidence and burden associated with injury locations and types, could be a relevant factor in the ability to implement appropriate injury preventive strategies in professional handball players. Previous studies have demonstrated that lower limb injuries, especially in the ankle and the knee, are the most common injuries in handball players (Aasheim, Stavenes, Andersson, Engbretsen, & Clarsen, 2018; Moller et al., 2012; Mónaco et al., 2019), although other authors have reported higher injury incidence related to head injuries (Bere et al., 2015; Langevoort,

Myklebust, Dvorak, & Junge, 2006). On the other hand, ligament and muscle injuries have been identified as the most common type in handball (Mónaco et al., 2019; Rafnsson et al., 2017). The findings of our study showed similar common injury locations, but tendon injuries were the most common injury type. These injury profiles remain constant when comparing both competitive-level groups (i.e., First and Second division), without significant differences in the injury rate associated to any injury location or type. Conversely, burden varied according to the competitive-level, showing higher values in the Second division group related to the most common injury locations (i.e., knee and ankle). Additionally, the First division group showed greater burden values in head and shoulder injuries. We postulated that the more intense game observed in this category could lead to more situations of direct contact with opponents, generating more serious traumatic injuries. Finally, burden was significantly higher for the Second division group in all injury types except for tendon injuries, although these results must be viewed with a degree of caution and more studies are needed to clarify these findings.

This study is not exempt of limitations. It might be perceived that the case study approach used in the current study (e.g., a single handball team) is a limitation but this approach has been employed in other sports (i.e., comparison between one male team and one female team for three years) (Larruskain, Lekue, Diaz, Odriozola, & Gil, 2018). However, this approach allowed some longitudinal assessment over a 4-year period and permitted some control in terms of coaching practice and club resource, all of which impact on player injury risk (Ekstrand et al., 2018). Another limitation is that training and match loads as well as the fitness status were not collected during the study period. In this sense, we could not see if players were being adequately prepared during training for match-play. Therefore, the influence of the fitness status, external and internal loads on the handball players' injury profile could not be analyzed. A further limitation was the sample demographics (i.e., professional male handball players) involved in this investigation, so these findings should not be extended to female and young handball players. Thus, future studies should include measures of training and match load ant to compare competitive-level, fitness status, age and sex. Despite this, our study presents several strengths, including the level of the participants (i.e., professional handball players) and the longitudinal nature of the period of follow up (i.e., four seasons).

Conclusions

Despite no significant differences between competitive-level groups being observed in the total injury incidence, greater injury rates in training sessions was observed in the Second division group and higher incidence in matches in the First division group. Significantly higher injury burden was observed in the Second division group in all exposure categories (i.e. total, training and match) in comparison to the First division group. In terms of injury location and type, no significant differences were observed in injury incidence between competitive-level groups, although the Second division group presented the highest burden values in most of the locations and types. This study provides a robust comparison of the injury profile of the same professional handball team according to the competitive-level, contributing relevant information for medical and technical staff to optimize preventive strategies in these specific contexts.

In practical terms, and due to the higher match incidence in the First division group, should be necessary to implement training sessions resembling the physical, technical, tactical, and psychological demands of competition during the training sessions, as well as implementing specific recovery strategies to reduce the negative impact of the official matches (e.g., accumulated fatigue) on handball players. In addition, specific preventive training programs and recovery protocols should be developed in Second division players, with the aim not only to reduce the injury incidence, but also the injury burden and number of absence days.

Disclosure Statement

There are no conflicts of interest surrounding this scientific investigation.

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