

ORIGINAL ARTICLE
OTHER AREAS

Game-specific characteristics of sport-related concussions

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ABSTRACT

BACKGROUND: Concussions are common incidences in sports. However, game-specific characteristics such as tactics, field positions, etc. might positively/negatively contribute to the occurrence of mild traumatic brain injuries (mTBI) in various sports such as soccer, volleyball, handball, or basketball. Thus, the intention of this study was to analyze game-specific characteristics of concussive incidents in active players from the perspective of different sportive disciplines.

METHODS: Four sport-specific questionnaires for soccer, handball, volleyball and basketball were established using an online survey tool.

RESULTS: A total of 3001 participants completed the questionnaires. 18% of the participants answered that they had experienced a concussion which significantly differed depending on the sport practiced ($\chi^2(3)=56.868$, $P<0.001$; soccer 25%, handball 24%, volleyball 13%, basketball 15%). Whereas handball and soccer players experienced most concussions on the amateur level, volleyball players experienced most on the professional level and basketball players during leisure play ($\chi^2(9)=112.667$, $P<0.001$). Soccer players experienced most concussions by a collision with another player, volleyball players instead experienced most concussions by hits from the ball ($\chi^2(6)=211.260$, $P<0.001$). In soccer, goalkeepers and defensive midfield players showed most concussive incidences ($\chi^2(7)=19.638$, $P<0.01$); in volleyball, the libero position and outside positions showed to be significantly affected from sport-related concussions ($\chi^2(6)=13.617$, $P<0.05$).

CONCLUSIONS: The present results showed that factors critically contributing to the occurrence of concussions are sport-specific and particularly concern amateurs. This indicates that most concussions in ball games appear in situations, where medical care units are not necessarily present. Preventive measures should therefore especially address amateurs in ball sports.

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Key words: Athletic injuries - Traumatic brain injury - Soccer - Basketball - Volleyball.

Participation in sports has increased over the past few years and so have the reported physical injuries.¹⁻³ The study of injuries at the soccer FIFA World Cup 2014 reported 1.68 injuries per game with thigh (25%) and head (18%) injuries being the most frequent injured body parts.¹ The analysis of injuries during international handball tournaments such as Men's World Cups also showed that the second most affected body-part was the head and neck totaling 26% of all injuries.² Concussions were the most often reported injury to the head with an increasing incidence when compared to previous FIFA world cup tournaments.¹ Injuries in sporting events such as the FIFA World Cup 2014 have been defined as

*“any musculoskeletal complaint (including concussion) 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.”*⁴ This definition is particularly problematic because concussions have a high rate of being not reported due to a number reasons: players think the incident was not serious enough to warrant medical attention (66.4% of unreported injuries), motivation not to be withheld from competition (41.0%), and lack of awareness of probable concussion (36.1%).⁵ The concern associated with unreported concussion is an athlete's increased risk of cumulative effects from recurrent injury. Thus, it is

necessary to gain insights into the occurrences of sport-related concussions independently of medical reports.

In fact, a self-report study showed that 70.4% of football and 62.7% of soccer players had experienced symptoms of a concussion during the previous year. However, only 23.4% of the players realized that the symptoms they had suffered represented a concussion.⁶ The fact that athletes do not realize they have suffered a concussion will make it unlikely that they receive medical attention. Thus, it is likely that players will continue playing with potential symptoms even after an experienced concussion. Furthermore, one-quarter of players experienced pressure from at least one source, whether coaches, teammates, parents, or fans to continue playing after a head impact during the previous year.⁷ This leads to further problems as players might dissimulate potential symptoms after sport-related concussions (such as cognitive deficits such as reduced reaction times, dizziness, memory problems, etc.) in order to keep playing. This raises the danger to the athlete of suffering another concussion during their sport.

As the rate of concussion in contact sports is higher than the incidence of recorded injuries,⁵ most scientific attention has focused on sports such as American football, rugby, ice hockey, basketball, soccer, etc.^{8, 9} However, sports like soccer or basketball are characterized by different aims of the game, rules, etc., and thus, concussions in contact sports are likely to occur in different ways, which might result in different outcomes regarding the long-term associated consequences. Concussions in soccer have been reported at frequencies of 2-22%^{6, 10} but 7.0% in basketball.¹¹ Collisions with another player have been reported to be the most common cause of a concussion in soccer.^{10, 12} According to Delaney *et al.*,⁶ goalies are the players most commonly affected in soccer. However, contrary findings showed that in men 76% sustained a concussion when playing forward or midfield and 67% of women when playing defense.¹² Other differences have been reported regarding the competitive level of participation, *i.e.*, the overall rate of concussion was found to be higher in collegiate sports than in their high school counterparts.¹³ Thus, it seems that the frequency of sport-related concussion depends on game-specific characteristics. The purpose of the present study was therefore to investigate the occurrence of experienced concussions in sports such as soccer, handball, basketball, and volleyball and

analyze game-specific factors such as competitive level, field positions, etc. leading to concussive incidences. To reach out to active players not only participating in clubs, but also playing as amateurs or for leisure, we used an online questionnaire sent out *via* sport-related Facebook groups and email lists.

Materials and methods

Persons actively playing either soccer, volleyball, handball, or basketball were asked to fill out a questionnaire to self-report their participation in sports, history of experienced concussions, and information about level of play (league), field position, etc. In all, 3001 participants completed the questionnaire (5798 sent-out questionnaires; response rate: 52%). The mean age was 27.5±8.8 years (range 18-68), with 1648 (55%) male and 1352 (45%) female players. Among the latter, 34% actively played soccer, 45% volleyball, 14% handball, and 7% played basketball. Furthermore, 26% of the players play their sport as a leisure sport, 59% in a club at an amateur level (4th to last German league such as Kreisliga, Bezirksliga, Verbandsliga, or Oberliga), and 15% at a professional level (1st to 3rd German leagues such as 1., 2., and 3. Bundesliga/Regionalliga).

Study design

Four sport-specific questionnaires (soccer, handball, volleyball, basketball) were developed using “Unipark” for online surveys (QuestBack GmbH). To reach out to active players, soccer/volleyball/handball/basketball-related social network groups (mostly Facebook) were searched via the internet and the questionnaire was posted to each group. Further contacts were made via sport-specific email-lists. The questionnaire comprised questions regarding sport participation and history of concussions. First, each person was asked about his/her gender and anthropometric dimensions such as height, weight and age. The second part of the questionnaire concerned questions about participation in the particular sport (“How many years do you play?,” “How many hours per week?,” “Are you a member in a club?,” “Which league do you play in?,” “How often do you train with your team per week?,” “How often do you participate in games/tournaments/etc.?” “Which position do you play?”). The third part of the question-

naire comprised questions regarding the occurrence of concussions during the particular sports. We therefore asked the participant to answer “yes” or “no” if they experienced a sport-related concussion during their particular sport. We combined the question about the occurrence of a concussion with a text providing the definition of concussions/mTBI from the German Institute of Sportscience.¹⁴ By this, we could control that only participants with mild TBIs would answer “yes.” We further asked the participants that answered “yes” that they experienced a concussion during their sport about how the concussion happened (“What kind of action led to the concussion (e.g., in volleyball answers could be chosen from “Block, Pass, Saving, etc.?” “What was your position in that moment?” “Which league did you play in when it happened?” “Was it a competitive game or training or leisure play?” etc.). In order to include active players from alternative leagues, e.g. student leagues, a club membership was not obligatory for participation in the study. Participants had to be older than 18 years. All participants were informed that their participation was voluntary and were assured anonymity and confidentiality of their responses. The local Ethics Committee of the German Sports University Cologne has approved the study.

Statistical analysis

Data analysis was performed anonymously using Microsoft Excel 2011 and SPSS v. 23 for Macintosh. Statistical tests (χ^2 tests) were performed for the distribution of persons with or without a concussion on sport-specific items such as which sport, gender, playing position, competitive level (which particular league), how the concussion happened (offense, defense, sport-specific actions, etc.). To answer if concussions are differently distributed regarding the level of play, i.e., whether playing in a professional, alternative/leisure, or amateur league, we pooled the data of the “leagues” into three categories: professional, amateur, and alternative/leisure. A professional league player was defined as someone who participates in one of the first three leagues of either sport, e.g., in soccer that would be players from the 1., 2., and 3. Bundesliga. The leagues from the 4th German league until the last league (Kreisliga) were defined as amateur/non-professional leagues. Players playing in alternative or student leagues were

categorized as alternative/leisure league players (to give an example in German soccer: Bunte Liga). Significant results are reported with P values smaller than 0.05. Post-hoc tests were Bonferroni corrected according to Beasley *et al.*¹⁵

Results

Number of concussions in different sports

Overall, 18% of the participants (N.=506) experienced a concussion during their sport. The distribution of concussions between female and male players revealed equal distributions, i.e., 17% were male and 19.5% were females. The distribution of concussions between sports revealed a significant deviation from the expected distribution ($\chi^2(3)=56.868$, $P<0.001$). Post-hoc analyses showed that handball players (24%, adjusted Z-score=3.3, $P<0.001$) and soccer players (25%, adjusted Z-score=5.6, $P<0.001$) experienced significantly more concussions than expected. Volleyball players experienced a concussion significantly less often than expected (13%, adjusted Z-score=-6.7, $P<0.001$), whereas no significant deviations were observed for basketball players (15%, experienced a concussion).

The distribution of concussions dependent on the level of play, i.e., whether playing in a professional, alternative/leisure league, or amateur exhibited a significant deviation from the expected distribution ($\chi^2(3)=22.536$, $P<0.001$). Most concussions took place at the amateur level (20%, adjusted Z-score=3.6, $P<0.001$).

Relating the level of play with regard to the different sports revealed significant deviations from the expected distribution ($\chi^2(9)=112.667$, $P<0.001$). Post-hoc analyses showed that handball (87%, adjusted Z-score=5.0, $P<0.001$) and soccer players (74%, adjusted Z-score=3.0, $P<0.001$) experienced significantly more concussions at the amateur level. Volleyball players suffered significantly more concussions than expected at the professional level (37%, adjusted Z-score=9.3, $P<0.001$) whereas with basketball players significantly more concussions than expected were observed in leisure play (38%, adjusted Z-score=3.1, $P<0.01$) (Figure 1).

When analyzing whether concussions occur during either a competitive game, training or leisure play, deviations from expected distributions appear in the different sports ($\chi^2(6)=120,485$, $P<0.001$). *Post-hoc*

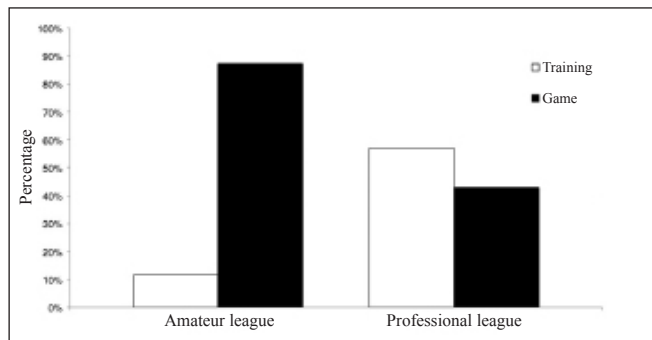


Figure 5.—Level of play and concussion incidences in training or game.

significant deviations from expected distributions ($\chi^2(4)=19,074$). Whereas 87% (adjusted Z-score=3.2, $P<0.01$) of concussions happen during the game at the amateur level, 57% were found to occur during training in the professional leagues (adjusted Z-score=3.2, $P<0.01$; Figure 5).

SOCCER

The distribution of experienced (/not experienced) concussions and playing position significantly differed from the expected distribution ($\chi^2(7)=19.638$, $P<0.01$). Goalkeepers showed large numbers of concussions (adjusted Z-score=2.5, $P=0.01$), followed by defensive midfielders (adjusted Z-score=1.7, $P=0.09$), however, the Bonferroni correction ($P=0.003$) did not allow for *post-hoc* significance. Interestingly, defensive outside players differed from the expected distribution with significantly fewer concussions than expected (adjusted Z-score=-2.7, $P=0.007$). The analysis of “how the concussion happened” for the different playing positions was also found to be significant ($\chi^2(35)=55.009$, $P<0.05$). Goalkeepers mostly hit another player (56%), followed by hits to the goal (19%), and the ball (11%). Central defensive players suffered most concussions after a collision with another player (79%), followed by a fall (12%), and hits to the ball (9%). Central defensive midfielders exhibited most concussions after a colliding with another player (69%), followed by hits with the ball (21%) and falls (7%).

VOLLEYBALL

A marginal significant gender effect was observed ($\chi^2(1)=3.404$, $P=0.065$), *i.e.*, more women (63%) ex-

perience a concussion in volleyball than men (37%). Another significant deviation from the expected distribution was found with regard to the position played during the game ($\chi^2(6)=13.617$, $P<0.05$). Most concussions take place at the libero position (22%, adjusted Z-score=2.8, $P=0.005$), however, the Bonferroni correction ($P=0.004$) allows only for marginal *post-hoc* significances. The analysis of whether different positions are affected differently in relation to the three levels of play revealed significant effects ($\chi^2(10)=18.625$, $P<0.05$). Whereas at the professional level the “libero” position is mostly associated with a concussion (27%, adjusted Z-score=2.9, $P=0.00373$), at the amateur and leisure levels concussions appear more often at outside positions (42%). However, the Bonferroni correction ($P=0.0033$) did not allow for *post-hoc* significances. Further analysis regarding which action led to a concussion showed significant effects ($\chi^2(7)=298.605$, $P<0.001$). 55% answered that it happened during a defending action, 13% during a “unspecific action running back into basic position,” and 11% that it happened during a “saving action.”

BASKETBALL

A significant deviation from the expected distribution was observed within the concussed group depending on whether the concussion happened during an offensive or defensive play ($\chi^2(1)=4.5$, $P<0.05$), *i.e.*, more concussions happen during the offensive play (69%). The item “how a concussion happened” also revealed significant deviations ($\chi^2(4)=35.188$, $P<0.001$), *i.e.*, most concussions were caused by a collision with another player (56%), secondly, by falls (31%) and thirdly through hits by the ball (6%).

Discussion

Occurrence and course of events

To our knowledge, this is the first study comparing different ball sports, *i.e.*, soccer, basketball, handball, and volleyball concerning the influence of game-specific characteristics such as level of play, tactics, positions, and course of events on the occurrence of sport-related concussions. Overall, 18% of individuals reported that they had experienced a concussion equally distributed between men and women.

The differentiation between the four ball games resulted in unequally distributed occurrences of concussions. Soccer (25%) and handball (24%) showed highest concussion rates, whereas fewer were reported for basketball (15%) and volleyball (13%). The different percentages might be explained by the varying rules specific to each game. Whereas in soccer and basketball most concussions were reported to happen due to a collision with another player, in volleyball, most concussions appeared to result from hits by the ball (in handball, most concussions happened due to falls, followed by collisions with other players). Thus, physical contact might represent the main risk factor for concussions in soccer and basketball. This is in line with previous research showing that the most frequent factor leading to concussions in soccer was athlete-to-athlete contact.^{12, 16, 17} However, the present results showed that physical contact should not be considered the main source of concussions in contact sports. Handball and basketball players also showed that falls are relevant factors leading to concussions. In contrast to soccer, where most games in Germany are played on grass, the case for handball and basketball might be that most games are played on hall or court floor (or even asphalt in basketball, *i.e.*, in “Streetball”). Interestingly, further analyses showed that in handball and volleyball most concussions take place during defensive plays whereas in soccer and basketball most happen in offensive plays. The present results therefore indicate that the combination of contact with other players and falls might be relevant to the occurrence of concussions in sport, in particular in soccer, handball, and basketball. Volleyball related concussions instead seem to be mainly linked to hits from the ball.

Competitive aspects

The occurrence of concussions is not equally distributed between professional leagues (1st-3rd league), amateur leagues (leagues lower than the first 3 up until the last in a club organized league) and leisure/alternative leagues (student leagues and similar organized leisure leagues). Most sport-related concussions occur at the amateur level. This is particularly concerning because when injuries occur at a professional level, players are medically treated and guided by physicians and physical therapists hired or (partially) employed by the club.^{18, 19} Subsequently, interventions related to the injuries could

be applied. This practice does not necessarily exist at the amateur level. However, most games at least in Germany, *e.g.* in soccer are played at the amateur level.²⁰ This indicates that most concussions in ball sports appear in situations, where medical personal that could diagnose and treat potential incidences might not be as present (/trained) as in the more professionalized sport structures. This is particular relevant since previous data showed that only 23.4% of the concussed football players and 19.8% of the concussed soccer players realize that they actually had suffered a concussion.⁶ Thus, most sport-related concussions go undetected, and as observed in the present dataset particularly appear in amateur sports.

When differentiating between the different ball games, most concussions occur at the amateur level solely for soccer and handball. Volleyball instead seems to be as affected at the professional as well as the amateur level. This is particularly interesting when knowing that most concussions happen in volleyball by hits from the ball, which might be explained that better trained professionals hit a lot harder than amateurs. Basketball players reported most concussive incidences at the amateur level as well as during leisure play. The reason why basketball is particularly affected at the leisure play level might be because this sport is often played as a leisure sport in so-called “streetball” games. Streetball is a variation of basketball typically played on outdoor courts (often on asphalt). This variation is characterized by a less formal structure and enforcement of the game’s rules. However, to our knowledge it has not been addressed as a potential candidate for incidences of sport-related concussions.

Further analyses showed that handball and soccer players experience most concussions during a competitive game. Volleyball players instead experience most concussions during training. For basketball players, the occurrence was equally distributed between competitive games, training, and leisure play. Furthermore, for handball players it was observed that when differentiating between the levels of play, *i.e.*, whether individuals play at the professional, amateur, or leisure sports level, most concussions were sustained during the game at the amateur level but during training at the professional level. Previous reports showed that concussion rates appear to be higher during competition than during practice for soccer, handball, and basketball.^{21, 22} However, although sport-specific analyses showed that concus-

sion rates in volleyball are higher in competition than in training.^{23, 24} Other authors reported equally distributed concussion rates in girls' volleyball between competitive games and training.²¹ The present results therefore suggest that although competitive games show highest concussion rates overall, sport-specific characteristics determine whether training sessions might be more or less associated with concussions as well. Knowing that most concussions in handball appear to be due to a collision with another player, amateurs seem to play differently during a competitive game as compared to training. Professionals instead seem to play "the same game" in training and in competition. Thus, the focus on potential concussions in handball should not only be on games but also on trainings, particularly when playing at a professional level. The same is true for volleyball. However, further questions have to be answered regarding sport-specific differences observed for handball that would appear during training but not in competition.

Playing positions

Concussions are not equally distributed with regard to the different playing positions. Whereas in handball and basketball the position did not lead to significant differences in the occurrence of concussions, in volleyball and soccer the position was particularly relevant. In soccer, goalkeepers and defensive midfield players showed most incidences. In contrast, defensive outside players are not as prone to concussions as central players. Physical contact remained the main source of concussion. However, whereas goalkeepers reported that they experienced second most concussions by collisions with the goalpost, midfielders reported falls. It has been reported that midfielders are engaged in significantly more 'other' types of movements (jumping, landing, diving, sliding, slowing down, falling and getting up) compared with the other positions.²⁵ Thus, there are likely consequences of muscle fatigue linked to the technical aspects of performance during match play that might increase the risk of concussions for midfield players. However, future studies should attempt to determine if there are relationships between fatigue and incidence rates of concussions in soccer. Thus far, one can only conclude that certain positions in soccer, *i.e.*, goalkeepers and defensive midfield players are more affected by sport-related concussions than other positions.

In volleyball at the professional level the libero position showed to be mostly affected whereas at the amateur and leisure level, concussions appeared more often with outside positions. The libero position in volleyball is a specialized defense position. Thus far, defense has been associated with a small number of volleyball injuries as most injuries occurred in frontline positions.²³ As the present results showed that most concussions in volleyball happened due to hits by the ball, but high percentages of players do not realize that they experienced a concussion,⁹ the libero might be the critical position to sustain a concussion in volleyball.

Conclusions

Factors that critically contribute to the occurrence of sport-related concussions are game-specific and particularly involve amateurs. Most concussions occurred in soccer and handball and mostly due to a collision with another player. Furthermore, concussions not only appeared during competition, but also during training or even leisure play depending on the sport. These results are of concern since players seem to be largely unaware of the common signs and symptoms indicating concussion and the potential seriousness of continued participation in sports after an initial concussion.⁹ Although we did not formally diagnose symptoms in this study regarding severity of post-concussive symptoms, previous studies showed that athletes often have impaired reaction time and delayed information processing after sport-related concussions.²⁶ The fact that 43% of athletes return to play the same day²⁶ leads to an increased risk of sustaining another concussion. Multiple mTBIs can often have a much more prolonged symptomatic state,²⁷ further delaying return to normal activities. The present study therefore points out that instructional programs concerning sport-related concussions must particularly address amateurs and not only be tailored to professional sport organizations in order to prevent prolonged time of injury or potential cumulative effects of sport-related concussions.

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