Research Square

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Severe Injuries in Competitive Cycling During an Olympic Cycle: Injury Patterns, Time Loss, and Return-to-Performance Outcomes

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Abstract

Background

Cycling is an established Olympic sport associated with a distinct injury profile that has not yet been comprehensively investigated. This study aimed to retrospectively assess and analyze severe cycling-related injuries resulting in ≥ 3 weeks of time loss over a complete Olympic cycle.

Methods

A total of 192 cyclists were included, based on a retrospective online questionnaire assessing injury location, type, context, time loss, and return-to-sport outcomes. Data were analyzed using descriptive statistics, Chi-square tests, Mann–Whitney U tests, and exact tests (Fisher/Fisher–Freeman–Halton).

Results

Seventy-two of 192 athletes sustained at least one severe injury, corresponding to a 5-year period prevalence of 37.5%. A total of 237 injuries were recorded, with the upper extremity (33.8%) and lower extremity (27.8%) being the most frequently affected regions. Hand fractures (n = 14), clavicle fractures (n = 13), and non-specific knee injuries (n = 9) were the most common diagnoses. Significant discipline-specific differences were observed for hand fractures (p = 0.038) and shoulder dislocations (p = 0.046), while hand fractures also occurred more frequently in competitive athletes (p = 0.040). Clavicle fractures occurred predominantly during competition, whereas non-specific knee injuries were mainly training-related. Mean time loss ranged from 6.5 weeks for hand fractures to 13.3 weeks for shoulder dislocations. Return to pre-injury performance varied markedly, from 85.7% after hand fractures to 28.6% after acromioclavicular joint separations.

Conclusion

Severe cycling injuries follow two main patterns: competition-related traumatic injuries of the upper extremity and training-associated overuse injuries. Discipline-specific differences in hand and shoulder injuries highlight the need for targeted prevention strategies. The discrepancy between return to sport and full return to performance, particularly after acromioclavicular joint injuries, emphasizes the importance of sport-specific rehabilitation approaches.

Introduction

Cycling is an established Olympic sport with worldwide participation and increasing societal relevance. Beyond its role as a competitive discipline, cycling is widely used as a recreational activity and means of transportation, contributing to a substantial number of bicycle-related injuries at the population level [1,2].

The Olympic cycling program comprises multiple disciplines, including road cycling, track cycling, mountain bike cross-country, BMX racing, and BMX freestyle, which differ in competition format, environmental conditions, technical demands, and biomechanical loading patterns [2,3].

Despite growing research interest, the epidemiology of cycling-related injuries remains incompletely characterized. Available studies indicate substantial discipline-specific differences in injury risk, with BMX and mountain biking demonstrating higher injury rates compared with road and track cycling during Olympic competitions [4,5]. Reported injury patterns include acute traumatic injuries, particularly fractures and shoulder injuries, as well as overuse conditions associated with repetitive mechanical loading and prolonged cycling positions [6,7]. However, comparisons between studies remain challenging due to heterogeneous methodologies, inconsistent injury definitions, and varying classification systems [6]. Prospective data from professional road cycling demonstrate that acute traumatic injuries represent a major cause of time loss, with fractures contributing substantially to injury burden [8]. In mountain biking, large-scale surveillance studies have identified the head, wrist/hand, and shoulder as frequently affected regions, with differences observed between male and female athletes [9]. Similarly, recent reviews of BMX highlight the importance of discipline-specific injury mechanisms related to falls, jumps, and collisions [9]. Nevertheless, available literature rarely provides a comprehensive analysis of severe injuries across cycling disciplines while simultaneously considering sex, performance level, injury context, time loss, and return-to-performance outcomes.

A detailed understanding of severe injuries and their consequences is essential for developing targeted prevention strategies and optimizing medical management in competitive cycling. Therefore, this study aimed to retrospectively analyze severe cycling-related injuries resulting in ≥ 3 weeks of time loss over a complete Olympic cycle (2012–2016) [10]. Specifically, we investigated injury prevalence, injury patterns, discipline- and context-related differences, time loss, and return-to-performance outcomes among cyclists.

Methods

Study design and setting: This retrospective cross-sectional study investigated the prevalence and characteristics of sports injuries sustained during one Olympic cycle, spanning from the 2012 Summer Olympic Games in London to the 2016 Summer Olympic Games in Rio de Janeiro. Self-reported injuries were analyzed with regard to their anatomical location, injured tissue, time loss, and subsequent return to sport.

Survey instrument: Data were collected using a previously developed 139-item questionnaire consisting of three sections [11]. The survey was distributed electronically by the German Olympic Sports Confederation and the respective national sports federations, which invited athletes to participate via e-mail.

The first section collected information on the athletes' highest competitive level, categorized as international elite, international, national, regional, or recreational.

The second section focused on sports injuries. Participants were instructed to report only injuries that resulted in an interruption of training and competition lasting more than three weeks. For each reported injury, participants specified the affected anatomical region, injury diagnosis, and damaged anatomical structure. Additional information included age at injury, duration of time loss (weeks), and sporting performance after return to sport, classified as return to the previous or a reduced performance level.

The final section recorded demographic and anthropometric characteristics, including age at the time of survey completion, sex, and body dimensions.

Ethical approval

The authors were guided by the ethical principles of the “Declaration of Helsinki on Medical Research Involving Human Subjects”. The ethical application for disclosure was submitted to the Ethics Committee of Witten/Herdecke University and subsequently approved (Nr.154/2017). At the beginning of the study, a written declaration of consent was obtained from all athletes. The athletes were informed about the anonymous use of the data for scientific purposes and the aggregated data.

Study population: A total of 194 cyclists completed the questionnaire. Two participants aged under 16 years were excluded, resulting in a total of 192 participants. For comparisons according to competition level, athletes competing at the international elite, international, or national level were classified as competitive athletes, whereas regional and recreational participants were grouped as recreational athletes.

For discipline-specific analyses, participants were categorized into four cycling disciplines: road cycling, mountain biking, track cycling, and BMX.

Statistical analysis: Statistical analyses were performed using IBM SPSS Statistics (version 29; IBM Corp., Armonk, NY, USA). Continuous variables are presented as means ± standard deviations (SD), and categorical variables as frequencies and percentages. Python (version 3.13) was additionally used to verify statistical calculations and ensure analytical reproducibility.

The most common injury diagnoses were analyzed with respect to injury context, time loss, return to sport, sex, cycling discipline, and performance level. Group comparisons were performed using Pearson's chi-square test for categorical variables and the Mann–Whitney U test for non-normally distributed continuous or ordinal variables. Fisher's exact test was applied for 2 × 2 contingency tables with expected cell counts <5. For larger contingency tables violating chi-square assumptions, the Fisher–Freeman–Halton exact test was used. Statistical significance was defined as a two-sided p-value <0.05.

Results

A total of 192 cyclists were included in the study (Table1). Participant characteristics are summarized in Table 1. During the five-year study period, 72 athletes (37.5%) sustained at least one injury, resulting in a total of 237 reported injuries. Injury prevalence did not differ significantly between male and female athletes (37.2% vs. 38.2%, p = 0.902). Road cycling represented the largest discipline (44.8%), followed by mountain biking (36.5%), track cycling (10.9%), and BMX (7.8%). 50% (n=96) of the athletes were competitive athletes and 50% (n=96) belonged to the group of recreational athletes.

Injured body region: Injuries predominantly affected the upper extremity, accounting for 33.8% of all reported injuries (80/237). The arm was the most frequently injured anatomical region (n = 42; 17.7%), followed by the lower extremity, including the foot (n = 38; 16.0%), and the shoulder (n = 38; 16.0%). Overall, injuries to the lower extremity accounted for 27.8% of all reported injuries (66/237).

Most frequent injuries: The most frequently reported injury was hand fracture (n = 14), followed by clavicle fracture (n = 13) and non-specific knee injury (n = 9). Mild traumatic brain injury (concussion), shoulder dislocation, acromioclavicular (AC) joint separation, and forearm fracture each ranked fourth, with seven cases reported.

Most common injuries diagnose by sex: No statistically significant sex-related differences (Figure 1) were observed for the most common injury diagnoses (all p > 0.05). Hand fractures occurred in 85.7% (n = 12) of male and 14.3% (n = 2) of female athletes (p = 0.365). Clavicle fractures were reported in 76.9% (n = 10) of males and 23.1% (n = 3) of females (p = 1.000). No significant differences were found for non-specific knee injuries (p = 0.270), mild traumatic brain injuries (p = 0.402), shoulder dislocations, or ACJ separations (both p = 0.678). Forearm fractures occurred exclusively in male athletes (n = 7), without a significant sex difference (p = 0.197).

Most frequent injuries by cycling discipline: Analysis of the most common injury diagnoses according to primary cycling discipline revealed significant differences for hand fractures (p = 0.038) and shoulder dislocations (p = 0.046) (Figure 2). Of the 14 hand fractures, seven occurred in road cyclists and five in BMX athletes, whereas one case each was reported in mountain biking and track cycling. Shoulder dislocations (n = 7) occurred predominantly in BMX and mountain biking (three cases each), with one additional case in track cycling and none in road cycling.For clavicle fractures (n = 13), the association with cycling discipline narrowly missed statistical significance (p = 0.065). Cases were distributed across track cycling (n = 4), road cycling (n = 4), mountain biking (n = 3), and BMX (n = 2).No significant discipline-specific differences were observed for the remaining injury diagnoses. Non-specific knee injuries (n = 9) occurred most frequently in mountain biking (n = 5; p = 0.570). Mild traumatic brain injuries (concussions) (n = 7) were distributed across all disciplines, with the highest number reported in road cycling (n = 4; p = 0.501). Acromioclavicular (AC) joint separations and forearm fractures (n = 7 each) occurred in BMX, mountain biking, and road cycling but were not observed in track cycling (p = 0.704 for both).

Competition versus Training Setting: Clavicle fractures occurred predominantly during competition, with 84.6% (n = 11) sustained during races. Mild traumatic brain injuries and acromioclavicular (AC) joint

separations also showed a tendency to occur more frequently in competition, with 57.1% (n = 4) of each injury type reported during races.In contrast, several injury types were primarily associated with training. This was most evident for non-specific knee injuries, of which 88.9% (n = 8) occurred during training sessions. Shoulder dislocations (71.4%; n = 5), forearm fractures (71.4%; n = 5), and hand fractures (57.1%; n = 8) were likewise sustained predominantly during training.

Injury Distribution among competitive and recreational athletes: Differences in injury patterns were observed between competitive and recreational athletes. A statistically significant association between competition level and the occurrence of hand fractures was identified ($p = 0.040$). Hand fractures occurred predominantly among competitive athletes (92.9%; n = 13), whereas only 7.1% (n = 1) were recorded in recreational athletes.

Several other injury types were also more frequently observed in competitive athletes, although these differences did not reach statistical significance. These included forearm fractures (85.7%; n = 6), mild traumatic brain injuries (71.4%; n = 5), clavicle fractures (76.9%; n = 10), and acromioclavicular joint separations (57.1%; n = 4). In contrast, shoulder dislocations (57.1%; n = 4) and non-specific knee injuries (66.7%; n = 6) were more commonly reported among recreational athletes. No statistically significant differences between competition levels were observed for these or any other injury types (all $p > 0.05$).

Injury-Related Time Loss: The longest mean time loss was observed following shoulder dislocations (Figure 4), with athletes being unable to participate for an average of 13.3 ± 12.5 weeks (median: 8 weeks; range: 4–40 weeks). Mean time loss was also substantial following clavicle fractures (9.7 ± 9.2 weeks; median: 6 weeks; range: 3–36 weeks), mild traumatic brain injuries (9.6 ± 5.3 weeks; median: 9 weeks; range: 3–20 weeks), forearm fractures (9.5 ± 4.5 weeks; median: 10 weeks; range: 3–16 weeks), and non-specific knee injuries (9.3 ± 6.1 weeks; median: 7 weeks; range: 3–20 weeks).

Shorter recovery periods were observed following acromioclavicular joint separations (8.7 ± 5.8 weeks; median: 8 weeks; range: 3–20 weeks) and hand fractures (6.5 ± 3.5 weeks; median: 5 weeks; range: 3–15 weeks). Considerable variability in recovery duration was evident across injury types, particularly for shoulder dislocations and clavicle fractures, as reflected by the relatively large standard deviations.

Return to Pre-Injury Performance Level: The highest rate of complete return to the pre-injury performance level was observed after hand fractures, with 85.7% (n = 12) of athletes returning without limitations (Figure 5). Mild and severe limitations were reported in 7.1% (n = 1) each. Forearm fractures, mild traumatic brain injuries, and shoulder dislocations showed similarly high recovery rates, with 71.4% (n = 5) of athletes in each group regaining their previous performance level. Following clavicle fractures, 69.2% (n = 9) achieved complete recovery, while 30.8% (n = 4) reported mild limitations. The greatest reduction in performance level was observed after non-specific knee injuries, affecting 44.4% (n = 4) of athletes (33.3% mild, 11.1% severe limitations). The lowest rate of complete recovery was found after acromioclavicular (AC) joint separations, with only 28.6% (n = 2) returning to their previous level; 57.1% (n = 4) reported mild and 14.3% (n = 1) severe limitations.

Discussion

This study provides the first comprehensive overview of injury epidemiology across all Olympic cycling sports in both competitive and recreational athletes. 237 injuries among 192 cyclists over a five-year period were analyzed, with 37.5% of athletes sustaining at least one injury resulting in a time loss of ≥3 weeks. Upper extremity injuries were predominant, with hand and clavicle fractures being the most frequent diagnoses. Injury patterns differed according to discipline, competition level, and injury setting, with hand fractures occurring more frequently in competitive athletes and clavicle fractures predominantly during competition. Clinical outcomes varied substantially between injury types: shoulder dislocations were associated with the longest time loss, whereas hand fractures showed the highest rate of complete functional recovery. These findings highlight that time to return to sport does not necessarily reflect a full return to pre-injury performance level.

Injury Location and Patterns

The upper extremity was the most frequently injured body region (33.8%), followed by the lower extremity (27.8%), consistent with previous reviews reporting a predominance of upper extremity injuries in cycling [6]. Population-based data also demonstrate that upper extremity injuries occur more frequently than lower extremity injuries among cyclists, suggesting that this pattern is not restricted to competitive athletes [12]. Similarly, BMX-specific data identified the upper extremity as the most commonly affected region despite substantial differences in discipline-specific demands and injury mechanisms [13]. A likely explanation is the instinctive use of the arms and shoulders to break a fall, resulting in high impact forces on these structures [14].

Hand fractures and clavicle fractures were the most common injury diagnoses in the present cohort. This finding agrees with national registry data showing that fractures of the hand, forearm, and clavicle represent the most frequent fracture locations following cycling accidents [1]. Together, these studies indicate that traumatic upper extremity injuries constitute the characteristic injury pattern across different cycling disciplines.

Although shoulder injuries were common in both the present study and previous reports [9,13], the proportion of head injuries was considerably lower than that reported in youth mountain bikers (7.4% vs. 23.3%) [9]. This discrepancy may reflect differences in study populations, cycling disciplines, terrain, and technical demands. The predominance of traumatic upper extremity injuries observed in the present study emphasizes the importance of discipline-specific injury prevention strategies focusing on fall mechanisms, protective equipment, and safe riding skills.

Factors Associated with Injury Patterns

No significant sex-related differences were observed for the most common injury diagnoses, consistent with the overall injury prevalence in our cohort. Although forearm fractures occurred exclusively in male athletes, this finding was based on small numbers and contrasts with registry data reporting a higher

proportion of forearm fractures among female cyclists [1]. Likewise, sex-specific injury patterns described in youth mountain bikers may not be directly transferable to our heterogeneous cohort of competitive cyclists [9].

In contrast, injury patterns differed significantly between cycling disciplines. Hand fractures were most common in road cycling and BMX, while shoulder dislocations predominantly occurred in BMX and mountain biking. These findings agree with previous studies identifying upper extremity injuries and fractures as characteristic injuries across cycling disciplines, particularly in BMX and mountain biking [1,6,9,13]. The observed differences likely reflect discipline-specific crash mechanisms, although detailed information on fall direction and collision characteristics was not available in the present study.

Hand fractures were also more frequent in competitive athletes, possibly reflecting higher riding speeds and more frequent race-related contact. However, this finding should be interpreted cautiously because of the limited number of cases.

Finally, clavicle fractures occurred predominantly during competition, whereas non-specific knee injuries were mainly training-related. This is consistent with previous studies demonstrating that acute traumatic injuries occur primarily during competition, while overuse injuries are associated with training exposure [8,14]. These findings highlight the importance of discipline- and context-specific injury prevention strategies in competitive cycling.

Clinical Course - Time Loss and Return to Performance

Shoulder dislocations resulted in the longest mean time loss (13.3 weeks), reflecting the wide spectrum of injury severity and treatment strategies reported in the literature [12]. In contrast, hand fractures showed the shortest recovery time (6.5 weeks) and the highest rate of return to pre-injury performance (85.7%), consistent with previous studies demonstrating favorable outcomes following appropriate management of hand fractures in athletes [15,16].

Clavicle fractures, one of the hallmark injuries in cycling, resulted in an intermediate time loss (9.7 weeks). Reported recovery times vary considerably depending on treatment, with operative management facilitating earlier return to competition in professional cyclists [17,18]. The heterogeneous recovery observed in the present cohort likely reflects differences in injury severity, treatment, and athletic level.

The poorest functional outcome was observed after acromioclavicular joint (ACJ) separations, with only 28.6% of athletes returning to their pre-injury performance level despite a moderate mean time loss (8.7 weeks). Although based on few cases, this contrasts with previous reports describing substantially higher return-to-sport rates [19]. These findings suggest that, in cycling, successful return to competition may not necessarily indicate full recovery of performance, highlighting the importance of distinguishing return to sport from return to performance [20]. Prospective studies are needed to better define performance outcomes following shoulder injuries in cyclists.

Clinical implication

This study demonstrates that severe injuries are common in competitive cycling, affecting more than one-third of athletes over a five-year period. Injury patterns differed according to discipline and injury context, with traumatic upper extremity injuries occurring predominantly during competition, whereas non-specific knee injuries were mainly associated with training. These findings support the need for discipline- and context-specific prevention strategies, including crash prevention for competition and optimized training load management to reduce overuse injuries.

Hand fractures and shoulder dislocations showed significant discipline-specific distributions, suggesting that prevention programs should account for the distinct biomechanical demands of road cycling, BMX, mountain biking, and track cycling. Although hand fractures were associated with favorable recovery, shoulder injuries—particularly acromioclavicular joint separations—were linked to poorer return to pre-injury performance despite moderate time loss. This highlights the importance of distinguishing return to sport from return to performance when evaluating rehabilitation outcomes.

Future prospective studies should combine standardized injury surveillance with exposure-based data to better quantify injury risk and identify sport-specific preventive strategies. Such data are essential for optimizing injury prevention and rehabilitation in competitive cycling.

Abbreviations

ACJ : acromioclavicular (AC) joint separation

BMX: bicycle motocross

Declarations

Description of Author Contributions

CL, ML and SS designed the study. CL and SS directed its implementation. CL and ML performed the data collection. CL, MG and RR wrote the paper. CL, MG and RR helped to design the study's analytic strategy. Cl, ML, MG, BW, CG, SS and RR reviewed the paper. All authors read and approved the final manuscript.

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Data sharing statement

The datasets generated and/or analyzed during the current study are not publicly available due to not finished analysis on other parts of this data, which are not published until this moment. But are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

Participants provided informed consent, and the study was approved by the Ethics Committee of the University of Witten/Herdecke.

Competing interests

The authors declare that they have no competing interests.

Consent for publication

Not applicable.

Patient involvement:

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

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Tables

Table 1. Participant characteristics and injury status.

Variable	Category	Total cohort (n = 192)
Sex	Male	137 (71.4%)
	Female	55 (28.6%)
Age (years)	Mean ± SD	32.3 ± 13.9
	Range	16–70
Level of competition	Competitive	96 (50%)
	Recreational	96 (50%)
Primary cycling discipline	Road cycling	86 (44.8%)
	Mountain biking	70 (36.5%)
	Track cycling	21 (10.9%)
	BMX	15 (7.8%)
Injury status	Injured	72 (37.5%)
	Not injured	120 (62.5%)
Total injuries reported		237

Table 2. Distribution of injuries according to competition level.

Injury type	Competitive athletes, n (%)	Recreational athletes, n (%)	p-value
Hand fracture	13 (92.9)	1 (7.1)	0.040*
Clavicle fracture	10 (76.9)	3 (23.1)	0.555
Non-specific knee injury	3 (33.3)	6 (66.7)	0.066
Mild traumatic brain injury	5 (71.4)	2 (28.6)	1.000
Shoulder dislocation	3 (42.9)	4 (57.1)	0.232
Acromioclavicular joint separation	4 (57.1)	3 (42.9)	0.692
Forearm fracture	6 (85.7)	1 (14.3)	0.430

*Note. Data are presented as absolute frequencies (n) and row percentages (%). P-values were calculated using Pearson's chi-square test or Fisher's exact test, as appropriate. *p < 0.05.*

Figures

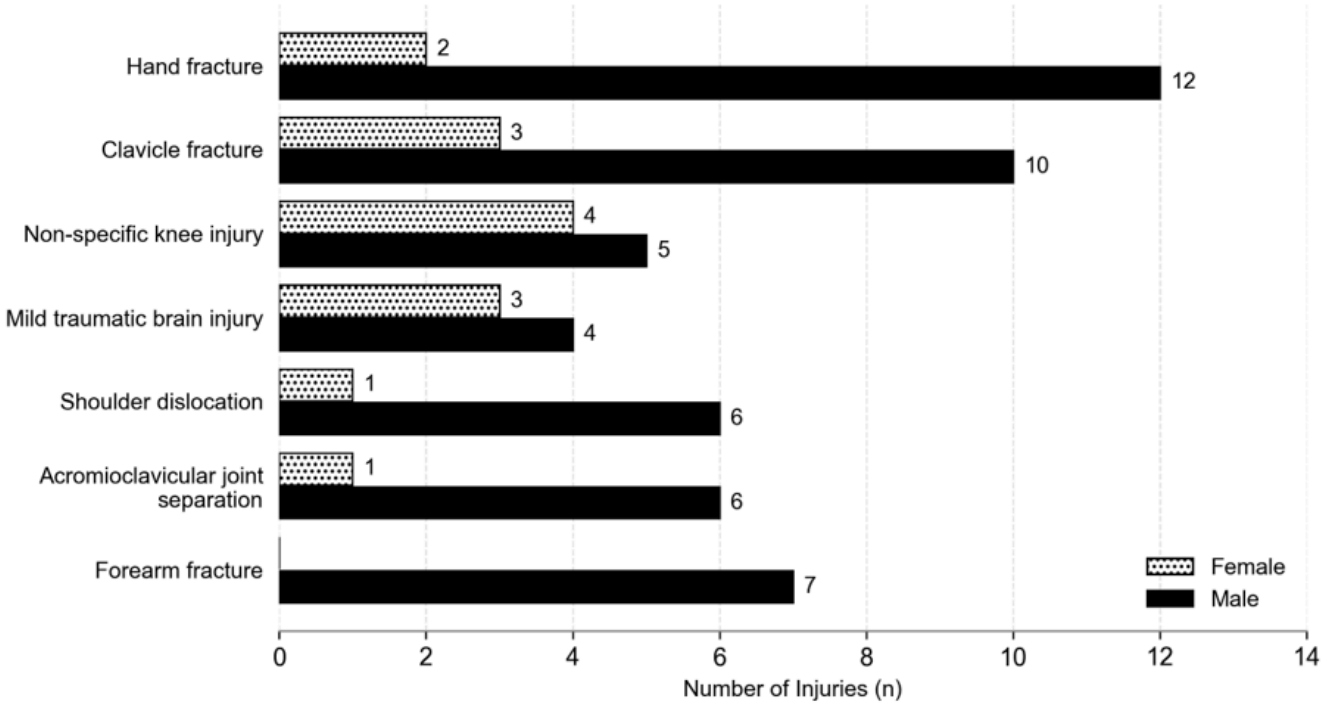


Figure 1

Distribution of the seven most common injury diagnoses according to sex. Bars represent the absolute number of injuries in male and female cyclists. Hand fractures and clavicle fractures were the most frequently reported injuries, followed by non-specific knee injuries, mild traumatic brain injury (concussion), shoulder dislocation, acromioclavicular (AC) joint separation, and forearm fractures.

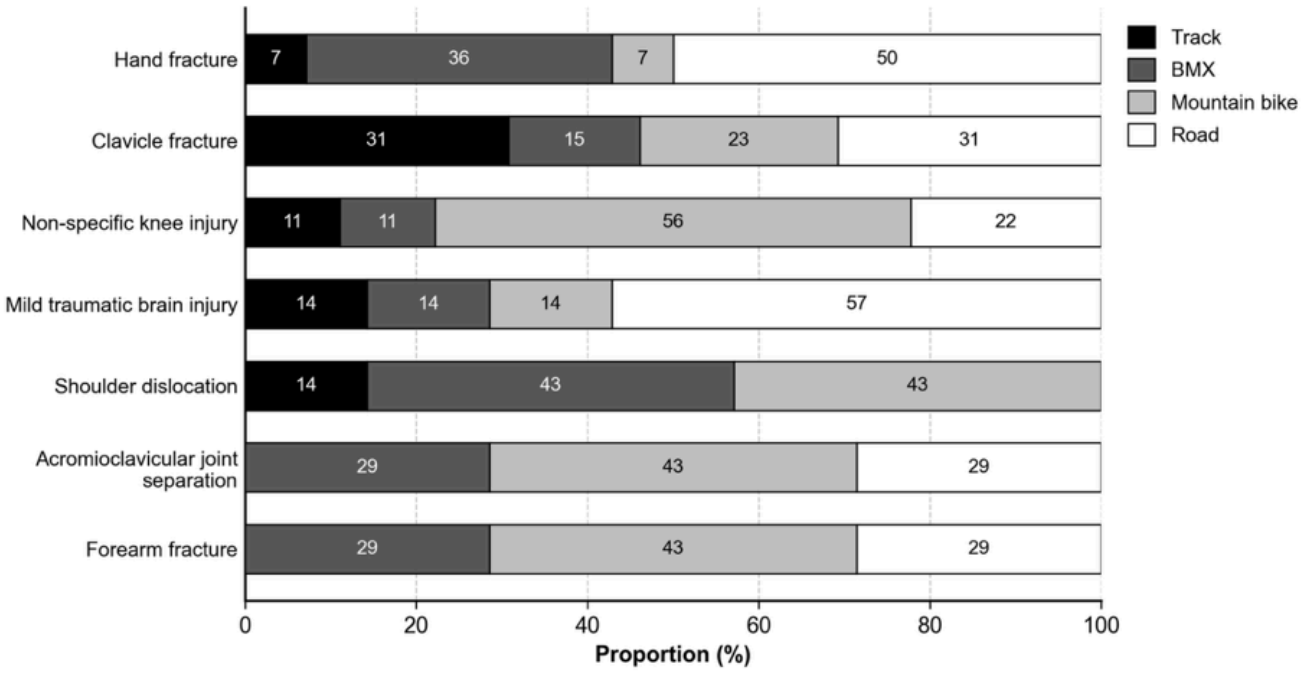


Figure 2

Distribution of the seven most common injuries per cycling discipline. Proportional distribution (%) of the seven most common injury diagnoses across cycling disciplines.

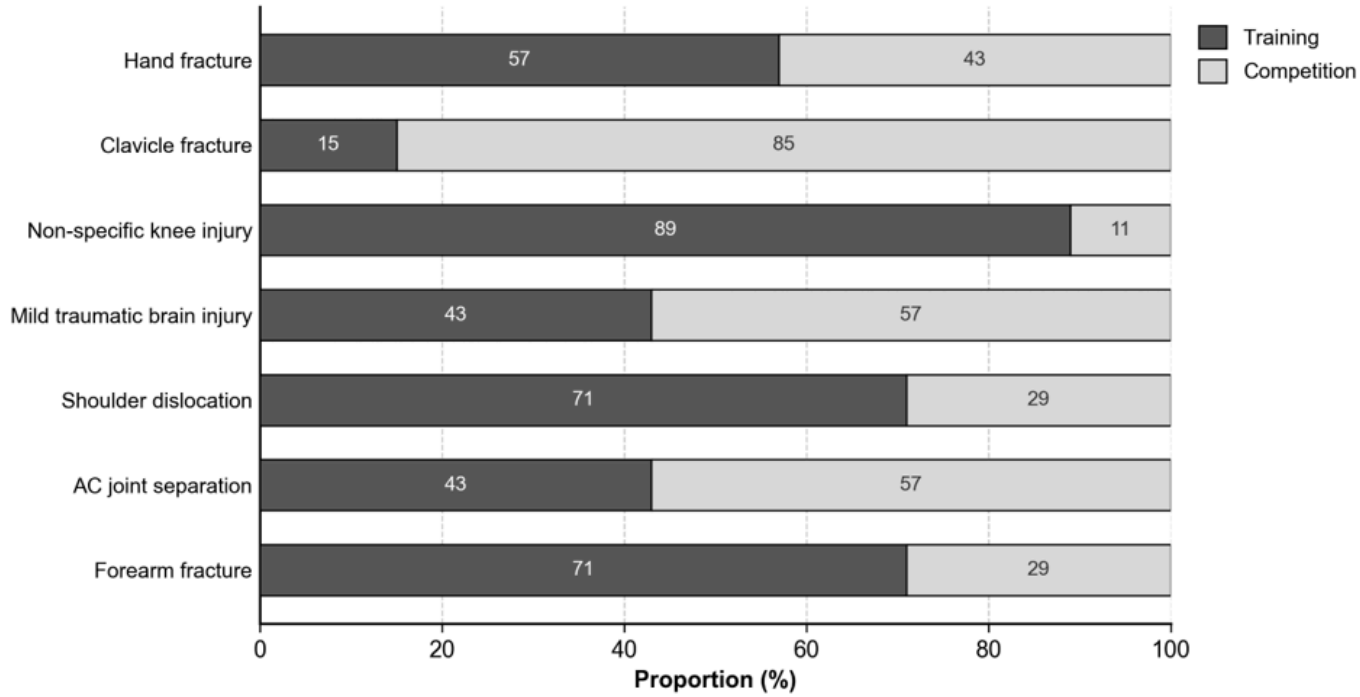


Figure 3

Injury situation differentiated alongside competition and training from top to bottom the most frequent injuries.

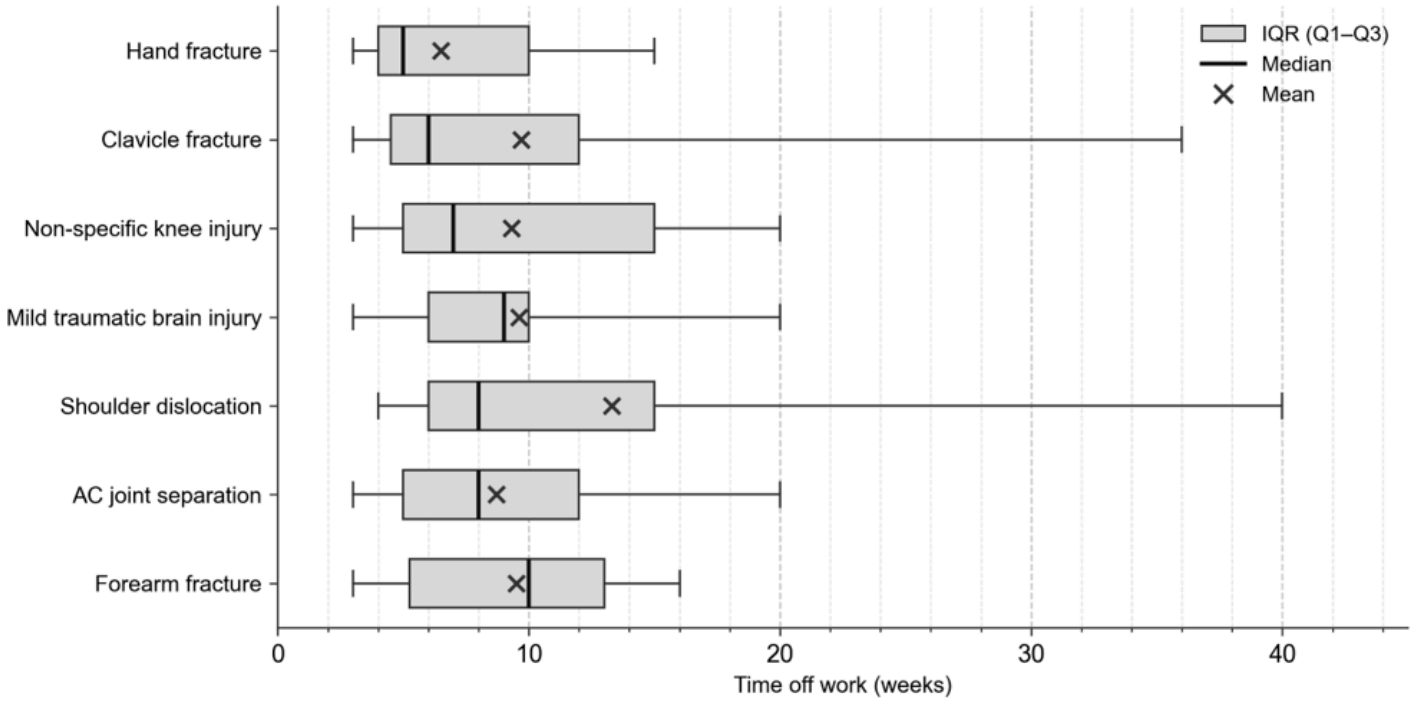


Figure 4

Down time after injury for the most frequent diagnoses (top to bottom). Boxes represent the interquartile range (IQR, from the 25th [Q1] to the 75th [Q3] percentile), the vertical line inside each box indicates the median, and the ×-symbol denotes the mean. Whiskers extend to the minimum and maximum values.

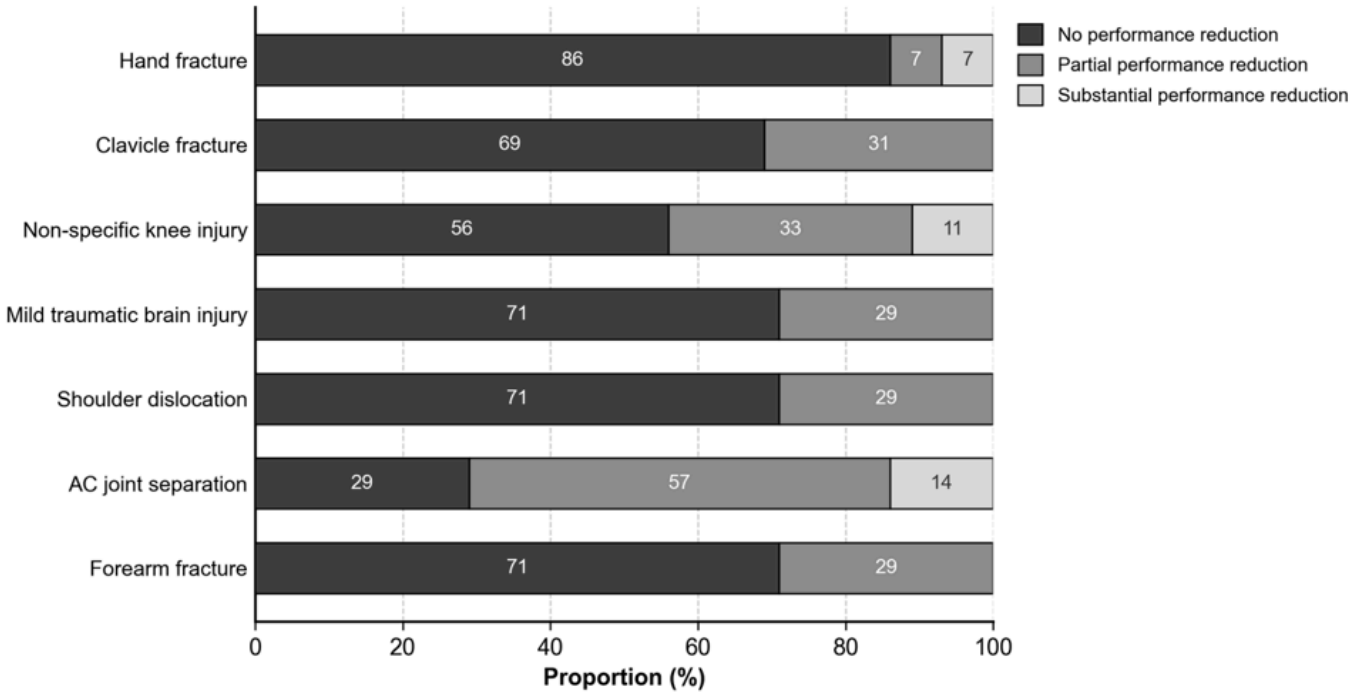


Figure 5

Post-injury performance outcomes categorized into three distinct groups: full recovery to the pre-injury performance level, slightly reduced performance level, and significantly reduced performance level.