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# Injury epidemiology in male and female competitive diving athletes: A four-year observational study

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ABSTRACT

*Objectives:* To describe the incidence, severity, burden and sport specific characteristics of injuries reported in elite diving athletes.
*Design:* Descriptive epidemiology study.
*Methods:* Medical attention and time-loss injuries from 63 (43 female, 20 male) Australian national diving programme athletes were prospectively collected over four seasons (September 2018–August 2022). Injury incidence rates and burden were calculated, standardised per 365 athlete days, and compared across groups using negative binomial generalised linear models.
*Results:* In total 421 injuries were reported (female = 292, male = 129) at an injury incidence rate of 2.36 (95 % confidence interval = 2.14–2.60) per 365 athlete days. Annual injury prevalence ranged from 70.0 to 85.1 %. Approximately two-thirds of injuries (67.2 %) resulted in a period of time-loss. The overall injury burden was 91 days of absence (95 % confidence interval = 81–102) per 365 athlete days. Stress fractures in springboard diving athletes incurred the largest mean days of time-loss compared to other injured tissue types. The majority of injuries were reported to occur during training (79.3 %) as opposed to competition (2.4 %), with more than half (55.3 %) of all reported injuries occurring during pool training sessions. Water entry (30.4 %) or take-off (27.8 %) were the most frequently reported mechanism of injury.
*Conclusions:* Annual injury prevalence reported in competitive Australian diving athletes was found to be high. Contrary to existing literature, competitive diving injuries were reported to occur within the daily training environment, with few injuries occurring during competition. Notable injury differences between springboard and platform athletes were observed.


## Practical implications

- As competitive diving injuries were reported to most commonly occur during training compared to competition, injury prevention strategies should include interventions that are implemented within the daily training environment.
- Targeting injury prevention strategies for bone stress injuries in springboard diving athletes is recommended.
- As there is no difference in the rate of injury incidence between male and female diving athletes, injury prevention strategies could be applied at a universal level to diving athletes irrespective of sex.

## 1. Introduction

The Olympic sport of diving is physically demanding and requires athletes to complete complex aerial manoeuvres before entering water from either a 3 m springboard or 10 m platform.[1] Diving athletes undertake a substantial volume of training in preparation for competition, which can lead to injury and consequently limit performance.[1,2] Despite the recognised injury risk associated with competitive diving,[1,2] there is limited longitudinal evidence that describes the injury epidemiology in this athlete population.[3,4]

Research into injury in elite level diving populations has been predominantly limited to International Benchmark Events where surveillance is typically conducted over short one-to-two-week durations, or

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studies are limited to cross-sectional designs. Published injury epidemiological data from previous Olympic Games suggest that injury incidence in diving is low relative to other sports.[3–5] However, a large percentage of diving athletes have been reported to commence International Benchmark Events with pre-existing injuries that are not captured within the surveillance process (51–56 %), which could explain the lower injury rates reported during competitions.[6,7] Furthermore, a survivor bias exists through the selection process to the Olympic Games where typically only uninjured athletes compete.[8] A gap exists in the understanding of injury epidemiology throughout entire seasons, inclusive of training and competition, as well as across multi-year surveillance periods in competitive diving.

The level of diving injury-specific detail reported in multi-sports papers is limited. The body site and nature of injury are commonly reported,[3,6,9] however, the specific types of injuries experienced by diving athletes are seldom reported. Recent research that extended surveillance beyond competition periods also only reported findings specific to the body site, nature of injury, and severity of injury.[10,11] Whilst these findings are useful in identifying frequently injured body sites, for example the lumbar spine (100 % lifetime prevalence),[12] shoulder (22.7 % period prevalence),[6] and wrist/hand (85.7 % point-prevalence),[13] they do little to establish what specific types of injuries occur in competitive diving athletes, nor provide detail regarding the mechanisms or modes of onset through which injuries occur. Without these data available, it is challenging to develop targeted injury prevention strategies for competitive diving that effectively protect athlete health and mitigate performance reductions associated with injury occurrence.[14]

Therefore, the aims of this study were to (1) describe the incidence, prevalence and burden of injuries reported by Australian elite diving athletes, (2) describe injury occurrence according to athlete sex, and (3) describe the diving specific mechanisms of injury across four continuous seasons inclusive of both training and competition.

## 2. Methods

### 2.1. Study design and participants

Athletes in the national Diving Australia programme were followed prospectively over four consecutive 12-month seasons, from 1 September 2018 to 31 August 2022. Australian competitive diving athletes are based within one of five national training centres across Australia, with occasional domestic travel for training camps or competition required. In addition, athletes travel internationally for competitions (FINA Grand Prix, Final World Series, FINA World Cup, FINA World Championships, and Olympic Games) dependent on their ability to qualify and/or be selected for these events. Athletes in the national Diving Australia programme typically complete 25–30 h of training per week, including approximately 200 somersaults in dryland training and between 450 and 700 water entries per week. Athletes were ineligible if they did not reside in Australia for each season (e.g., they attended college in the USA) as they were not under continuous surveillance. Ethics approval was granted by the Australian Institute of Sport Ethics Committee (approval number 20200205.R2), with cross-institutional ethics approval granted by the University of Canberra Human Research Ethics Committee (approval number 6905).

### 2.2. Injury definitions and data collection

Injury was defined in accordance with the medical attention definition outlined in the FINA consensus statement on the methodology of injury and illness surveillance as “a physical complaint or observable damage to body tissue produced by the transfer of energy experienced or sustained by an athlete during participation in training or competing in an aquatic discipline, where a qualified clinician assessed the athlete's medical condition”.[15] Medical attention injuries were also subcategorised according to whether they resulted in a period of time loss from training and/or competition.

All injury data was prospectively captured in a centralised Athlete Management System (AMS) database (Smartabase, Fusion Sport Pty Ltd., Brisbane Australia) by a sports and exercise physiotherapist or sports and exercise physician at the time of point of care. Each injury recorded was assigned a four-character injury diagnosis code (Orchard Sports Injury Classification System 10.1),[16] that detailed the body site and nature of the injury reported. In addition, data were recorded to identify the date of injury occurrence, date of injury resolution, and duration (days) that the athlete was unable to fully participate (time loss) in training and/or competition. Specific data relating to injury occurrence was captured, including the training mode (water, dryland, gym, other), mechanism of injury (take-off, water entry, other), and if the injury occurred during training or competition. All injuries that were reported during the surveillance period were included. Data collection was completed in accordance with the guidelines provided within the Australian Institute of Sport AMS data dictionary,[17] and study outcomes reported aligned to the Strengthening of Observational studies in Epidemiology — Extension for Sport Injury and Illness Surveillance (STROBE-SISS) statement.[18]

### 2.3. Analysis

Athlete exposure was quantified for each individual athlete using the diving scholarship start and end dates (1st September–31st August) for each season. In circumstances where athletes left the programme and were not under surveillance for the entire season, left and right censoring was conducted. Descriptive analysis of injury data was undertaken with results reported as frequencies and proportions. These data are presented according to athlete sex and across each season of surveillance. Injury incidence rates (IIRs) were calculated using the following formula: the number of injuries / exposure in athlete days $\times$ 365, with 95 % CIs calculated. Negative binominal generalised linear models that included a random effect for athlete and fitted with a logarithm link function were used to compare IIRs between male and female athletes using incidence rate ratios, with an incidence rate ratio considered statistically significant where the 95 % CI did not include 1.0. To establish a clear understanding of the impact of injury on the ability to train, injury burden was quantified as the product of the time-loss IIR and mean days of time-loss. All statistical analyses were performed in Stata (Stata/SE 16.1, StataCorp., USA).

## 3. Results

Sixty-three individual athletes (43 female, 20 male) were eligible across the four-season surveillance period. Almost half (47.6 %) of the athletes participated across all four seasons, 20.6 % three seasons, 15.9 % two seasons, and 15.9 % one season. A total of 188 athlete seasons, 57 male athlete seasons, (mean age = 18.7, range = 10 to 33), and 131 female athlete seasons (mean age 18.3, range = 10 to 29), equivalent to a total of 65,206 athlete days (Table 1) were included for analysis.

Four hundred and twenty-one medical attention injuries were reported (female = 292, male = 129), at an IIR of 2.36 (95 % CI = 2.14–2.60) injuries per 365 athlete days. An increasing trend was observed in the medical attention IIR across each successive season, ranging from 2.04 (2018–19) to 2.59 (2021–22), however, this was not statistically significant (incidence rate ratio = 1.09, 95 % CI = 0.97–1.22, $p$ = 0.161). The median number of days spent injured per injury was 36, with an inter-quartile range (IQR) of 15–95. Of the 421 injuries, 283 (67.2 %) resulted in a period of time-loss from training or competition occurring at an IIR of 1.58 (95 % CI = 1.41–1.78) per 365 athlete days. The median number of time-loss days per injury was 17 (IQR = 7–56). The overall injury burden for the surveillance period was 90.80 days of absence (95 % CI = 81–102) per 365 athlete days.

**Table 1**
Distribution of injuries across four scholarship seasons (2018–19, 2019–20, 2020–21, 2021–22).

| | 2018–19 | | 2019–20 | | 2020–21 | | 2021–22 | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Male | Female | Male | Female | Male | Female | Male | Female | Male | Female |
| Total athletes (n) | 12 | 30 | 15 | 35 | 16 | 33 | 14 | 33 | 20 | 43 |
| Total injured athletes (n) | 9 | 23 | 11 | 24 | 13 | 24 | 13 | 27 | 20 | 41 |
| Period prevalence (%) | 75 | 77 | 73 | 69 | 81 | 73 | 93 | 82 | 100 | 95 |
| Total injuries (n) | 23 | 60 | 30 | 75 | 37 | 79 | 39 | 78 | 129 | 292 |
| Median number of injuries (IQR) | 2 (0.5–3) | 2 (1–3) | 1 (0–3) | 2 (0–3) | 2 (1–4) | 2 (0–4) | 2.5 (2–4) | 2 (1–4) | 5 (3–9) | 6 (2–12) |
| Range | 0–6 | 0–9 | 0–9 | 0–8 | 0–7 | 0–7 | 0–5 | 0–6 | 1–17 | 0–25 |
| Injury incidence rate[a] | 1.92 | 2.08 | 2.11 | 2.33 | 2.31 | 2.61 | 2.79 | 2.50 | 2.30 | 2.38 |
| 95 % CI for injury incidence rate | 1.28–2.89 | 1.61–2.68 | 1.48–3.02 | 1.86–2.92 | 1.67–3.19 | 2.09–3.25 | 2.04–3.82 | 2.00–3.12 | 1.94–2.73 | 2.12–2.67 |
| Total time loss injuries (n) | 18 | 41 | 15 | 55 | 25 | 50 | 27 | 52 | 85 | 198 |
| Injury incidence rate | 1.50 | 1.42 | 1.06 | 1.71 | 1.56 | 1.65 | 1.93 | 1.67 | 1.51 | 1.61 |
| 95 % CI injury incidence rate | 0.95–2.38 | 1.05–1.93 | 0.64–1.76 | 1.31–2.23 | 1.05–2.31 | 1.25–2.18 | 1.32–2.81 | 1.27–2.19 | 1.22–1.87 | 1.40–1.85 |
| Injury severity[c] | | | | | | | | | | |
| Mild (1–7 days) (n) | 1 | 8 | 5 | 13 | 10 | 20 | 9 | 16 | 25 | 57 |
| Moderate (8–28 days) (n) | 6 | 16 | 2 | 24 | 9 | 16 | 8 | 15 | 25 | 71 |
| Severe (>28 days) (n) | 11 | 17 | 8 | 18 | 6 | 15 | 10 | 20 | 35 | 70 |
| Total non-time loss injuries (n) | 5 | 19 | 15 | 20 | 12 | 29 | 12 | 26 | 44 | 94 |
| Exposure (days) | 4381 | 10,505 | 5178 | 11,732 | 5840 | 11,069 | 5110 | 11,391 | 20,509 | 44,697 |
| Injury burden[b] | 151.41 | 65.08 | 67.07 | 82.66 | 51.98 | 87.45 | 126.24 | 119.41 | 95.31 | 89.07 |
| 95 % CI for injury burden | 95.39–240.32 | 47.92–88.39 | 40.43–111.25 | 63.31–107.93 | 35.12–76.93 | 66.28–115.38 | 86.57–184.08 | 90.83–156.43 | 77.06–117.89 | 77.66–102.42 |

n = number; % = percentage; IQR = interquartile range; CI = confidence interval; > greater than.

[a] Injuries per 365 athlete days.

[b] Days of absence per 365 athlete days.

[c] Sub-categories for injury severity are for time-loss injuries only.

The most frequently reported body site injured was the lumbar spine (n = 77; 18.3 %), followed by the wrist and hand (n = 49; 11.6 %), shoulder (n = 44; 10.5 %), and neck (n = 37; 8.8 %). Of the 283 time-loss injuries reported, the lumbar spine (n = 58, 20.5 %), wrist and hand (n = 33, 11.7 %) and shoulder (n = 27, 9.5 %) accounted for two fifths of all time-loss injuries. Injuries reported to the head (n = 12/15; 80.0 %), trunk and abdomen (n = 7/9; 77.8 %), foot (n = 14/18; 77.8 %), and lumbar spine (n = 58/77; 75.3 %) were the body sites with the highest proportion of time-loss injuries. The most burdensome injuries according to body site were the lumbar spine (n = 21.4, 95 % CI = 16.5–27.7), wrist and hand (n = 17.6, 95 % CI = 12.5–24.8), and shoulder (n = 10.0, 95 % CI = 6.9–14.6). When considering the specific clinical diagnostic codes allocated by the health professionals, lumbar spine facet joint pain/stiffness (n = 21, 5.0 %), triceps muscle strain (n = 17, 4.0 %), wrist (radiocarpal joint) sprain (n = 16, 3.8 %), posteromedial shin periostitis (n = 13, 3.1 %), and concussion (n = 8, 1.9 %) were the most frequently reported.

With respect to the specific tissue injured, almost a quarter of all injuries were reported as joint sprains (n = 105; 24.9 %), followed by muscle injuries (n = 91, 21.6 %), and impingement type injuries (n = 57, 13.5 %). Joint sprains (n = 72, 25.5 %), muscle injuries (n = 55, 19.5 %), and impingement type injuries (n = 34, 12.1 %) were also the most common reported type of time loss injuries (Appendix A). Injury burden according to body site and tissue type was highest in wrist joint injuries (Fig. 1).

Considering athlete sex, over the 4-year surveillance period, 129 injuries were reported for male athletes at an IIR of 2.30 (95 % CI = 1.94–2.73) per 365 athlete days, whilst 292 injuries were reported for female athletes at an IIR of 2.38 (95 % CI = 2.12–2.67) per 365 athlete days. The IIR between female and male athletes was comparable (incidence rate ratio = 0.97; 95 % CI = 0.73–1.27, p = 0.807). The injury burden was similar between males (95.31 days of absence [95 % CI = 77.06–117.89] per 365 athlete days) and females (89.07 days of absence [95 % CI = 77.66–102.42] per 365 athlete days). The most frequently reported body sites injured were similar across athlete sexes. For males, injuries were most frequently reported at the lumbar spine (n = 22; 17.1 %), wrist and hand (n = 18; 14.0 %), shoulder (n = 15; 11.6 %), and knee (n = 15; 11.6 %), whereas in females the lumbar spine (n = 55; 18.8 %), wrist and hand (n = 31; 10.6 %), lower leg (n = 31; 10.6 %), and shoulder (n = 29; 9.9 %) were most frequently reported.

Injury occurrence varied according to the different diving disciplines. Athletes participating in the 10 m platform discipline were the most likely to be injured, with 202 injuries reported at an IIR of 3.02, 95 % CI = 2.63–3.47 per 365 athlete days. The reported IIRs were lower in both the 3 m springboard discipline (IIR = 2.20, 95 % CI = 1.90–2.55), and in the group of athletes who competed in both the 3 m springboard and 10 m platform (IIR = 1.30, 0.95–1.79). Springboard and platform diving athletes were most likely to report an injury to the lumbar spine; however, platform diving athletes had a higher IIR to the wrist and hand, shoulder, and upper arm, compared to springboard diving athletes who had a higher IIR to the knee and lower leg (Fig. 2). Springboard diving athletes who reported a stress fracture suffered the greatest mean days of time loss compared to any other tissue type (Fig. 2).

Almost all injuries occurred within the daily training environment (n = 373, 88.6 %), with competition environments featuring the least (n = 24, 5.7 %). Injuries related to diving practice sessions (n = 334) were reported substantially more often compared to in-competition injuries (n = 10). A small number of injuries were reported to occur during weight training sessions (n = 20, 4.8 %), warm-up activities (n = 15, 3.6 %), and during competition (n = 10, 2.4 %). Of the sport specific diving activity details recorded, 59.3 % (n = 233) of injuries were reported as occurring during pool/water training, 11.2 % (n = 44) during dryland training, and 9.7 % (n = 38) from weight training and conditioning. The mechanism of injury was most frequently reported as either water entry (30.4 %), or the take-off phase of the dive (27.8 %). (Table 2)

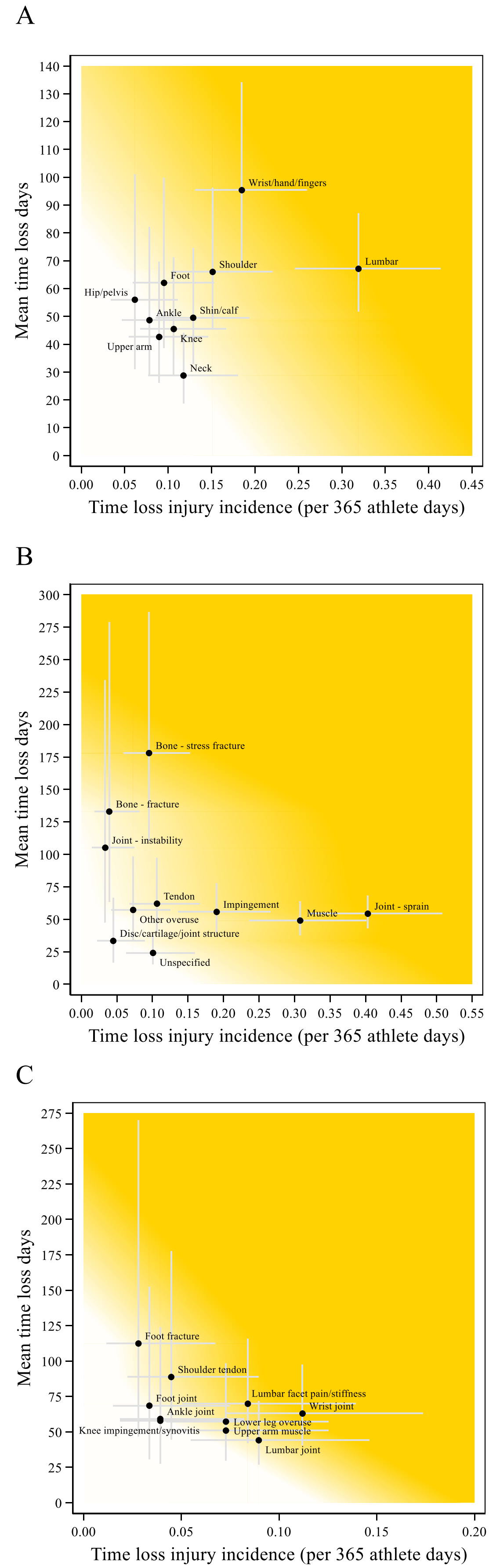


**Fig. 1.** Injury burden in competitive diving athletes by (A) body site, (B) tissue type, and (C) body site and tissue type.

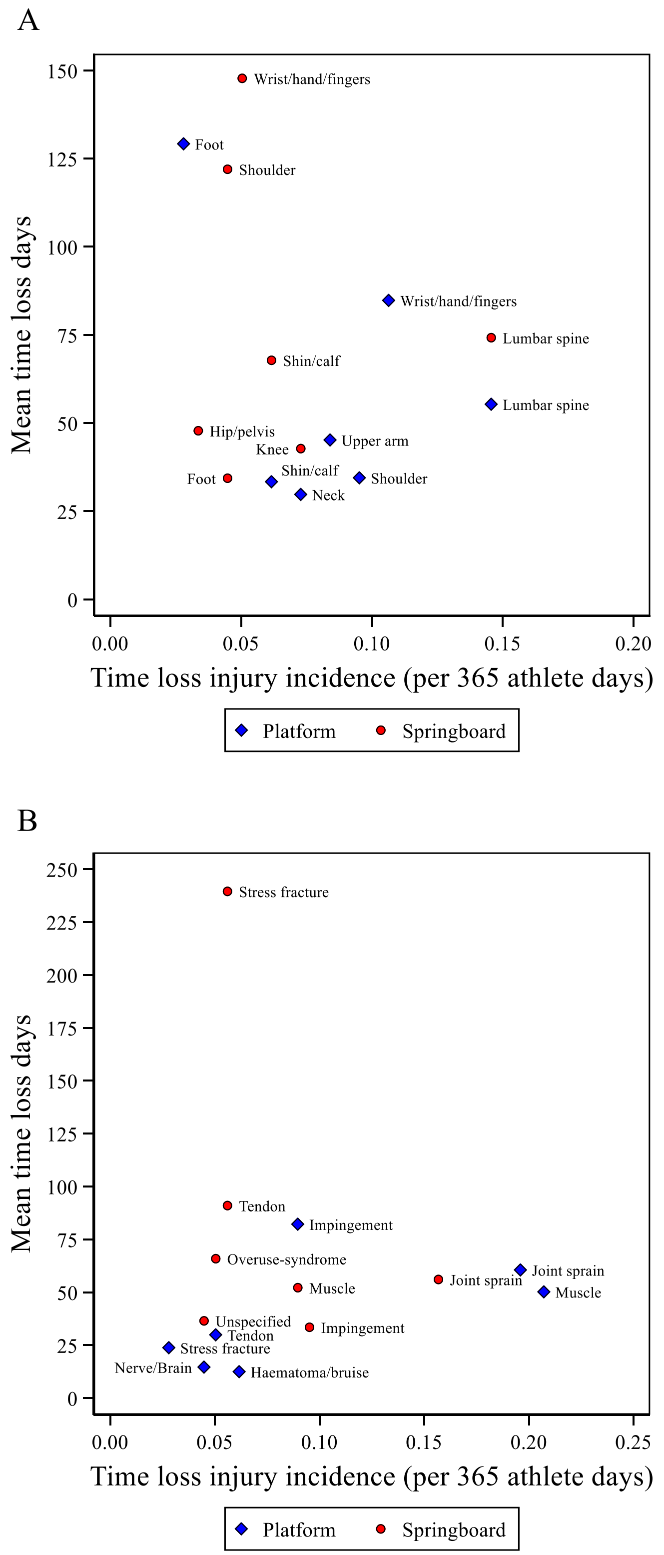


**Fig. 2.** Injury burden in competitive diving athletes by diving discipline and (A) body site, and (B) tissue type.

## 4. Discussion

This is the first study of male and female competitive diving athletes to report on injury prevalence, incidence, and burden, and provide comparisons between training and competition, diving discipline and mechanism of injury in an elite athlete cohort. This study identified injury diagnoses in competitive diving athletes, the injury severity and burden, and that injuries in diving athletes occur substantially more in training than in competition. The study further identified that injuries in diving athletes most commonly occur to the lumbar spine, wrist, and shoulder, that injuries most commonly occur in pool/water related diving activity, and the rate of injuries was found to be higher in platform compared to springboard diving athletes.

This study identified injury burden in competitive diving athletes to be high. Reported injury burden in this study was more than two times that reported across multiple sports within an Australian sports academy.[19] Within this study, the lumbar spine, and wrist/hand body sites were identified to have high injury burden in both springboard and platform diving disciplines. Development of prevention strategies targeting these body sites should be considered to reduce injury burden in competitive diving.

Injury occurrence in competitive diving has previously been reported as low; however, results from the present study suggest that could be a result of reporting bias, with almost all data reported on competition only surveillance periods. The present study identified that diving athletes are often injured, with injuries most commonly reported during diving training sessions compared to in-competition, which likely relates to greater training exposure for the development of new skills. Consistent with previous literature from cohort studies at multi-sport events, new injuries during competition were not common in this cohort. Interestingly, when the type of injury activity data is examined, two and a half times as many injuries were reported to occur in weight training compared to competition. These findings contrast with previous literature that reports injuries in diving are infrequent and suggest that whilst diving athletes are less likely to sustain an injury within competition surveillance periods, injuries do frequently occur in the daily training environment. It has been previously reported that diving athletes present to competition with pre-existing injuries, supporting the notion that diving athletes sustain injuries during training, and that these injuries impair training performance in the lead-up to competition.[6,7] Developing a deeper understanding of how and why injuries occur in training, and establishing the impact that injury and athlete availability for training has on performance would provide an opportunity to develop targeted interventions to reduce training related injuries.

The lumbar spine was reported as the body site with the highest injury incidence in diving athletes, consistent with the literature. The present study further identified that, whilst being the most frequent body site injured, the nature of lumbar spine injuries in competitive diving athletes varies, as does the impact on athlete availability. For example, lumbar joint pain and/or stiffness was the most frequently reported lumbar spine injury, yet other injuries to the lumbar spine such as lumbar joint sprain and lumbar bone stress fracture carried higher injury severity. Recent literature from other sports suggests that less severe injuries with no associated time loss can lead to subsequent time loss injuries.[20] In order to assess and develop strategies to counter this process within diving athletes, sporting organisations should ensure quality injury surveillance that enables health providers to record all injuries and monitor both non time-loss and time-loss injuries.

The results from the present study confirm the outcomes of previous research that upper extremity injuries are common in competitive diving athletes and contribute considerable time loss. This is consistent with existing cohort studies in Olympic Games[3–5] and FINA World Championships.[6,7,9] The upper extremity is susceptible to injury as diving athletes fall at a speed close to 60 km/h, breaking the water with their hands (both wrists and elbows in full extension) to enter the water, with the athlete experiencing a sudden decrease in velocity of 53 % within milliseconds of water entry.[2,13] This adopted hand position minimises the amount of splash, but results in forceful wrist extension that causes injuries at the wrist and hand.[21] Rapid joint movements of shoulder abduction and internal rotation occur under the water, placing significant joint torques on the upper extremity.[13] Targeted prevention strategies should be designed and implemented with the aim of reducing the incidence of upper extremity injuries in diving athletes. It has been suggested that strength training exercises aimed at the rotator cuff may help in the prevention of shoulder injuries in overhead female athletes,[22] whilst a primary prevention strategy, such as protective equipment in the form of wrist guards/braces could reduce the incidence of wrist and hand injuries,[23] and secondary prevention strategies aimed at early identification and intervention could be investigated to reduce the injury severity and injury burden of triceps muscle strains.[24]

Research into the epidemiology of sport-related concussion has continued to increase over recent years. This study identified that concussion does occur in competitive diving athletes, contributing 1.9 % (n = 8) of injuries reported within this athlete cohort. To date, only two studies have previously reported concussion in a diving population, with both studies having small athlete sample sizes and a small number of concussions reported. The incidence proportion of concussion in competitive diving athletes has been reported as high as 8.1 % in collegiate level female athletes.[10] Established return to play protocols for concussion suggest that all diagnosed concussions require a period of no training and/or competition, thus all become classified as time-loss injuries with periods between 7 and 14 days.[25] Whilst evidence concerning concussion continues to emerge, understanding of how often it occurs in different sporting populations remains important. Further research into the causative factors of concussion injuries in competitive diving athletes is required to help guide preventative strategies.

Notable differences in injury profiles between the 3 m springboard and 10 m platform diving disciplines were identified in the present study. Injury incidence rates were 35 % higher in athletes competing in the 10 m platform discipline than those competing in the 3 m springboard discipline, whilst also identifying that bone stress injuries were found to have the highest discipline specific injury burden in springboard diving athletes. Despite there only being a small number of case studies that have provided evidence for the types of injuries specific to either diving discipline previously,[26–28] the present study confirms the findings that lower limb injuries are common in springboard diving athletes,[27] whereas platform diving athletes are more likely to sustain an injury to the upper limb.[26,28] It has been suggested that the repetitive, high energy, axial loading during training and competing in the springboard diving discipline may lead to joint forces being dissipated through the lower limb, causing more lower limb overuse injuries in springboard diving athletes.[27] Forces attenuated by the upper limb and lumbar spine may be increased by the dive height, with large joint torque forces acting on the wrist and hand, and lumbar spine at the point of water entry.[29] Given this research has found that injuries occur in athletes competing in the 10 m platform diving discipline at 1.35 times of their springboard diving peers, targeted interventions to reduce the most common injuries in 10 m platform diving athletes should be prioritised. Interventions aimed at reducing bone stress injuries in diving athletes could be designed at a group level for springboard diving athletes, and these could include approaches to monitoring training load and athlete exposure, nutritional support, and further assessment of all health problems that contribute to poor bone health in athletes. As the lumbar spine is the most common injured body site in both springboard and platform diving athletes, injury prevention interventions could be applied across each diving discipline to streamline implementation.

**Table 2**
Frequency and proportion of injuries reported by diving athletes by injury activity, training type, diving injury activity, diving discipline, and mechanism of injury.

| | No. of injuries (%) | | | | |
|---|---|---|---|---|---|
| | 2018–19 | 2019–20 | 2020–21 | 2021–22 | Total |
| *General injury onset*[a] | | | | | |
| Overuse | 45 (54.22) | 64 (60.95) | 61 (62.59) | 65 (55.56) | 235 (55.82) |
| Traumatic | 27 (32.53) | 26 (24.76) | 52 (44.83) | 51 (43.59) | 156 (37.05) |
| Other | 11 (13.25) | 15 (14.29) | 3 (2.59) | 1 (0.85) | 30 (7.13) |
| *Injury activity*[a] | | | | | |
| Training | 66 (79.52) | 85 (80.95) | 99 (85.34) | 84 (71.79) | 334 (79.33) |
| Competition | 4 (4.82) | 2 (1.90) | 0 (0.00) | 4 (3.42) | 10 (2.38) |
| Other | 9 (10.84) | 10 (9.52) | 8 (6.90) | 15 (12.82) | 42 (9.98) |
| Warm-up | 2 (2.41) | 2 (1.90) | 5 (4.31) | 6 (5.13) | 15 (3.56) |
| Weight training | 2 (2.41) | 6 (5.71) | 4 (3.45) | 8 (6.84) | 20 (4.75) |
| *General location*[a] | | | | | |
| Training | 71 (85.54) | 94 (89.52) | 110 (94.83) | 98 (83.76) | 373 (88.60) |
| Competition | 9 (10.84) | 5 (4.76) | 2 (1.72) | 8 (6.84) | 24 (5.70) |
| Other | 3 (3.61) | 6 (5.71) | 4 (3.45) | 11 (9.40) | 24 (5.70) |
| *Diving injury activity*[b] | | | | | |
| Pool/water training | 38 (69.09) | 60 (57.14) | 69 (59.48) | 66 (56.41) | 233 (59.29) |
| Dryland | 7 (12.73) | 9 (8.57) | 16 (13.79) | 12 (10.26) | 44 (11.20) |
| Weight training & conditioning | 3 (5.45) | 9 (8.57) | 13 (11.21) | 13 (11.11) | 38 (9.67) |
| Other | 7 (12.73) | 27 (25.71) | 18 (15.52) | 26 (22.22) | 78 (19.85) |
| *Diving discipline*[a] | | | | | |
| Platform | 45 (54.22) | 49 (46.67) | 59 (50.86) | 49 (41.88) | 202 (47.98) |
| Springboard | 32 (38.55) | 46 (43.81) | 48 (41.38) | 55 (47.01) | 181 (42.99) |
| Both (springboard and platform) | 6 (7.23) | 10 (9.52) | 9 (7.76) | 13 (11.11) | 38 (9.03) |
| *Diving mechanism of injury*[c] | | | | | |
| Water (take off) | 16 (32.00) | 24 (22.86) | 29 (25.00) | 39 (33.33) | 108 (27.84) |
| Water (entry) | 17 (34.00) | 31 (29.52) | 40 (34.48) | 32 (27.35) | 120 (30.93) |
| Other | 17 (34.00) | 50 (47.62) | 47 (40.52) | 46 (39.32) | 160 (41.24) |

[a] % of overall injuries n = 421.
[b] % of 393 injuries.
[c] % of 388 injuries.

Understanding mechanisms of injury in competitive diving athletes had yet to be explored in the literature. The dive is often broken into three components: take-off (approach), aerial manoeuvre, and water entry. Our results reported that more than 50 % of injuries reported during pool sessions occurred during either the take-off or water entry phase of the dive. Existing case studies suggest that the water entry[30–32] and take-off[27] phases are common phases for injury to occur in competitive diving athletes. Diving athletes complete high numbers of training dives, most of which load their hands on entry to the water, with previous work identifying an increase in wrist and hand injuries with a flat hand in full wrist extension.[13] Biomechanical analysis of water entry positions has identified that this wrist position creates an area in the water for the body to move through that reduces the amount of created splash from the dive, thus improving performance outcomes.[33] Future research investigating the mechanism of injury in competitive diving athletes needs to be conducted to understand how factors such as, the board height, hurdle-leg, differing take-off approaches, the direction of the rotation/twist, and the direction of the dive (dive type) might contribute to injury.

Capturing quality athlete exposure level data in diving is difficult. It is noted that the use of athlete attendance/scholarship days as a measure of athlete exposure has limitations. A range of measures of athlete exposure have been described in the literature, including training hours,[11] and number of completed training sessions.[10] Future research is required to define and validate refined measures to quantify diving exposure. This study only included injuries that were recorded in the AMS by the treating sports and exercise physician and physiotherapists. Whilst the use of a medical attention definition allows for refined diagnostic information to be captured, it is acknowledged that athletes may not have presented to a medical practitioner for minor injuries and hence these would not have been recorded and included in the study.

## 5. Conclusion

This study provides new evidence that enables injury prevention strategies to be designed to target the most commonly occurring injuries within each competitive diving discipline. The findings of this study contrast to previous literature that suggests injury occurrence in diving is low, with more than seven out of ten diving athletes reported being injured each season. Injuries related to diving training sessions were reported substantially more often compared to in-competition. Notable differences in the injury profile between platform and springboard competitive diving athletes were observed, which warrants consideration for the future development of injury prevention strategies.

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## Confirmation of ethical compliance

Ethics approval for this study was granted by the Australian Institute of Sport Ethics Committee (approval number 20200205.R2), with cross-institutional ethics approval granted by the University of Canberra Human Research Ethics Committee (approval number 6905).

## CRediT authorship contribution statement

BC: Conceptualisation, Methodology, Investigation, Software, Data curation, Writing — Original draft preparation; MH: Conceptualisation, Writing — Reviewing and editing; GW: Conceptualisation, Writing — Reviewing and editing; NB: Writing — Reviewing and editing; MD: Conceptualisation, Writing — Reviewing and editing; JW: Writing — Reviewing and editing; LT: Conceptualisation, Software, Visualisation, Supervision, Writing — Reviewing and editing.

## Declaration of interest statement

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Co-author previously was the editor-in-chief at the journal to which we are submitting. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendices. Supplementary data

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