OPEN ACCESS

Journal of Science & Cycling
Breakthroughs in Cycling & Triathlon Sciences

Original Article

Injuries in Elite British Paralympic Cyclists: A Longitudinal Investigation

Lee Pote [1], Katie Flatters [2], Heather Stephens [2], Ben Mac Donald [3], Stuart Mourton [1], Tom Outram [1], Jack Parker [1] and James Keenan [1]

Received: 9 October 2025 **Accepted:** 14 May 2026 **Published:** 27 July 2026

[1] University of Derby, School of Sport and Exercise Science, Kedleston Road Campus

[2] British Cycling; Great Britain Cycling Team, Manchester

[3] Chelsea Football Club, Cobham, London

Correspondence

Lee Pote

University of Derby, School of Sport and Exercise Science, Kedleston Road Campus

l.pote@derby.ac.uk

Abstract

The purpose of the Investigation was to determine the nature and incidence of injuries in elite British Paralympic cyclists. The sample consisted of 39 para-cyclists (mean age: 33.7 ± 7.60 years; mean elite cycling experience: 8.81 ± 5.32 years). Time loss injury data, for B, C, H and T classes, were collected over a four-year period which included: class, impairment, age, event group (sprint or endurance), site of injury, tissue, pathology, diagnosis, onset (acute or chronic), when the injury occurred (training or competition), the type of training or competition session, the mechanism of the injury, whether the injury was new or reoccurring, and the modified days. Data were analysed using a custom written MATLAB software (Version 8) script. Ninety-three injuries were recorded over the data collection period with C-class, para-endurance athletes, accounting for the highest incidence of injuries in the squad. The mechanism for injury occurrence was highest in gym-based activities making up 25.92% of all injuries. Within this category, trap bar deadlift was the most frequent gym-based activity for injury occurrence. The sacroiliac joint sustained the most injuries of any body part and had the highest incidence of index and re-injuries; the mechanism was largely influenced by non-cycling gym-based activities. Endurance athletes are most prone to injuries specifically, at the lower back and sacroiliac joint. While the inciting event has been identified as the load bearing exercises in the gym this is most likely due to other factors such as sub-optimal program design, spikes in acute workload, and technical incompetencies.

Keywords

Paracycling; Injuries; Paralympics; Injury Prevention

1 Introduction

Since the first competition in 1948, the Paralympic games has undergone a rapid evolution with increasing numbers of competitors; more than 4000 athletes took part at the London Paralympic Games in 2012.[1-3] The games have the second biggest number of competitors for a sporting event worldwide, behind only the Olympic games.[4] Additionally, paracycling is a growing discipline comprising of three different disciplines (bicycling, tricycling and handcycling) contested in two categories; track and road races.[5-7] These developments have made it increasingly important to understand the risk of sport-related injuries.[2] The International Paralympic Committee (IPC) also state that there is a duty of care in protecting the health of athletes and reducing injury risk.[3] However, despite an increase in the workloads of cyclists, there is a distinct lack of injury specific data and analysis.[5 8 9]

Of the limited literature available, acute injuries seem to be the most common in para-cyclists.[6 10] A study investigating cyclists at the 2012 London Paralympic games indicated that 75% of track and 71% of road injuries were acute[10]; a trend shown in other studies involving para-cyclists.[5 6] This tendency is also consistent with literature regarding able-bodied cyclists, showing most injuries to be acute and caused by crashes and falls.[11-14] The most common types of acute injuries (for able-bodied and para-cyclists) include abrasions, bruising, and fractures.[5 6 13-15] Although not as common, chronic injuries also occur in para-cyclists with research suggesting the back, neck/shoulder, and knee joint being the most prevalent sites of overuse; the same is shown in able-bodied cyclists.[5 6 12] Research suggests that, in general, para-cyclists suffer 5.8-10.5 injuries and illnesses per 1000 athlete days.[3 16 17] Track para-cyclists tend to have a slightly higher injury incidence when compared to road para-cyclists (9.3 as opposed to 6.7 injuries per 1000 athlete hours).[10] This is however a lot less than able-bodied cyclists where it has been reported that injury incidence can be as high as 54.8 injuries per 1000 athlete hours.[14]

While there is some literature available with regards to injuries in para-cyclists, most studies have investigated this as part of a larger, broader study, focusing on all Paralympic sports.[3 14 16 17] Furthermore, this research has investigated acute injuries over short periods of time (typically 3-23 days), and there remains a lack of longitudinal data to better understand the epidemiology of gradual onset injuries to inform injury statistics and prevention practices.[18] Lastly, no study has looked at para-cycling injuries from a multi-factorial perspective, comparing factors such as discipline, and event over an extended period.[9] This is important as the collection and analysis of ongoing epidemiological data, is a key step in the development of effective injury prevention programs.[3 17] Therefore, the purpose of this study was to investigate the nature and incidence of injuries in elite British paralympic cyclists over a four-year period. This analysis will identify areas of high injury risk which could help with session design and activity selection.

2 Material and Methods

This was a retrospective, longitudinal investigation examining injuries in elite paralympic cyclists over a four-year sequence. Overall, injury data was captured over a period of 1406 days.

2.1 Participants

The sample consisted of 36 cyclists (22 male, 14 female), with a mean age of 33.7 ± 7.60 years (male=36.4 ± 5.41; female=31.83 ± 9.06 years), and a mean elite cycling experience of 8.81 ± 5.32 years (male=10.80 ± 4.49, female=6.83 ± 4.62 years). The sample breakdown between classes and events can be observed in Table 1.

Table 1. Squad sample size according to class (B, C, H, T, Guide), event (para-sprint, para endurance) and sex (male, female)

	Para-Sprint		Para-Endurance	
	Male	**Female**	**Male**	**Female**
B class	2	3	1	2
C class	3	2	6	3
H class	0	0	2	1
T class	0	0	2	0
Guide/pilot	5	1	1	2
Total	**10**	**6**	**12**	**8**

According to the *Union Cycliste Internationale* (the world governing body for sports cycling) these classes can be defined as:

- Tandem division (B class): athletes with visual impairments riding in tandem with a sighted guide or pilot. Athletes can be classified between B1-3, and all compete together in one class.
- Bicycle division (C class): athletes riding a standard two-wheeled bicycle which could have adaptions according to the athlete's impairment. Impairments include range of motion limitations, impaired muscle power or limb deficiency. Athletes can be classified between C1-5.
- Handcycle division (H class): athletes that are impaired in the lower limbs due to upper limb impairments in the vertebrae, including paraplegics and amputees. Athletes can be classified between H1-H5.
- Tricycle division (T class): athletes who are unable to ride a bicycle due to lack of balance and/or severe restriction in pedalling due to spasticity, ataxia, athetosis, and dystonia. Athletes can be classified between T1-2.

"Guides" or "Pilots", for those athletes with visual impairments, were also included in the sample. Ethical approval was granted by the University of Derby Ethics Committee (ETH2223-1242).

2.2 Data Collection

Data were collected and recorded by the physiotherapists within the Great Britain Cycling Team (GBCT) medical team. The data set was created based upon the categories outlined in the "*International Olympic Committee consensus statement: methods for recording and reporting of epidemiological data on injury and illness in sport*".[19] Only time loss injuries were collected; the medical team would meet weekly to cross reference the collated data. Once the athlete returned to non-modified training, the numbers of days lost due to injury were recorded. Since multiple individuals were involved in the data collection process, the data were cleaned and sorted. This was to detect, diagnose, and edit faulty data.[20] Furthermore, the data were sorted into a standardised unit or group to avoid any human error that may have caused statistical errors.[21] Lastly, the clarification of data recording was cross referenced with the medical documentation database used by GBCT.

2.3 Injury Definition

The definition for "time loss injury" as utilised in this investigation was in accordance with the "*International Olympic Committee consensus statement: methods for recording and reporting of epidemiological data on injury and illness in sport*".[19] The statement defines a time loss injury as a "health problem that results in a player being unable to complete the current or future training session or competition".[19] For this study the following variables were collected: class, impairment, age, years in elite cycling, event group (sprint or endurance), site of injury, tissue, pathology, diagnosis, onset (acute or chronic), when the injury occurred (training or competition), the type of training or competition session, the mechanism of the injury, whether the injury was new or reoccurring, and the total modified days (time loss).

2.4 Data Analysis

Data were collected in MS Excel before being analysed using a custom written MATLAB software (Version 8) script. Initially injury distribution, mechanism, and site of injury were analysed in isolation before multi-factorial analysis were completed to provide greater insight into the nature and incidence of injury. Data were reported as the total number of injuries relating to each factor.

3 Results

3.1 Total Injuries and Injury Distribution

A total of 93 injuries were recorded in the four-year period (Table 2). Twenty-six of the overall squad sustained an injury (72%), 11 in the para-sprint (eight athletes and three guides) and 15 in the para-endurance group (13 athletes and two guides). Thirty-four injuries were sustained by female participants (nine athletes) and 54 injuries by male participants (17 athletes). Within events, 35 injuries were sustained in the para-sprint group (11 athletes) and 58 in para-endurance participants (15 athletes). Despite making up only 25% of the overall squad, C-class athletes sustained the most injuries (55.91%); para-endurance athletes accounted for the highest incidence of injuries in the squad (40.86%). In addition, C-class, para-endurance athletes were the only class where every member of the group sustained an injury. The second highest injury rate was observed in guides (22.58%).

3.2 Mechanism of Injury

The mechanism for injury occurrence was highest in gym-based activities making up 25.92% (n=27) of all injuries (Figure 1). Within this category, trap bar deadlift was the most frequent gym-based activity for injury occurrence (n=7). Crashes contributed to 21.12% (n=22) of all injuries and had a higher incidence rate in para-endurance athletes (n=17). Starts contributed to 13.44% of injury occurrences and was exclusive to track activities with an even distribution between para-sprint and para-endurance athletes. Intensity and duration as injury mechanisms were almost exclusively observed in para endurance (100% and 83% respectively).

Index (new) injuries made up 68% of all injuries (n=63), with re-injury (18%; n=17) and exacerbation (14%; n=13) making up the remainder of the injuries. Forty-six injuries were classified as acute sudden onset, 44 as repetitive gradual onset and three planned surgeries that led to cessation of normal training/competition. Training accounted for the highest injury incidence (n=74).

Table 2. Injury distribution for the four-year period by class and event

Class	Event	Athletes injured / class (n)	Injuries / class (n)	% of overall squad injured	% of total injuries in class
B	Para-sprint	4/5	10	11.11	10.75
	Para-endurance	2/3	7	5.56	7.53
C	Para-sprint	4/5	14	11.11	15.05
	Para-endurance	9/9	38	25.00	40.86
H	Para-sprint	0/0	0	0.00	0
	Para-endurance	1/3	1	2.78	1.08
T	Para-sprint	0/0	0	0.00	0
	Para-endurance	1/2	2	2.78	2.15
Guide	Para-sprint	3/6	11	8.33	11.83
	Para-endurance	2/3	10	5.56	10.75

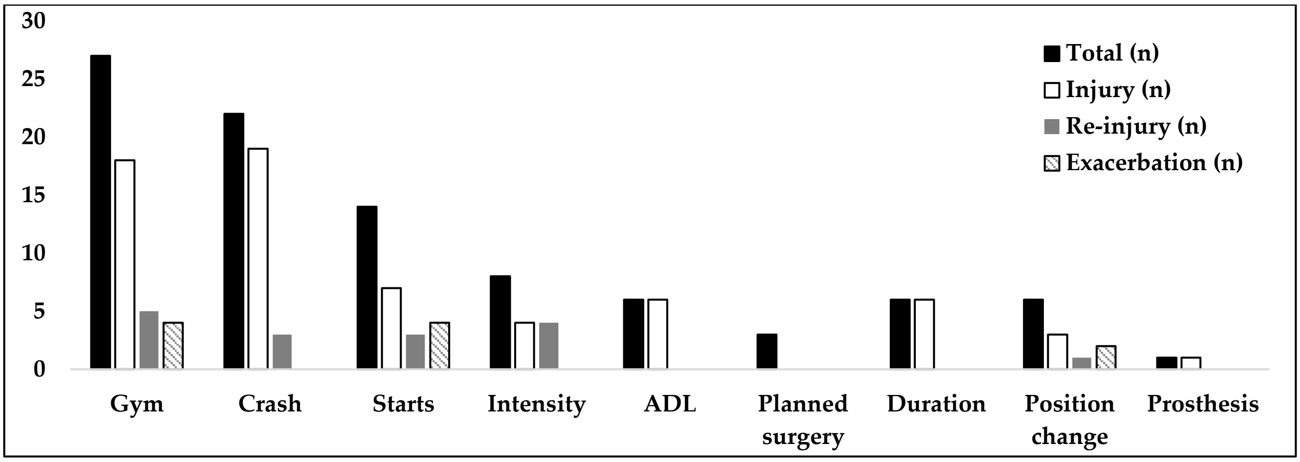

Figure 1. Mechanisms of total injuries, re-injuries, and exacerbations.
ADL=activities of daily living; exacerbation=injury because of existing symptoms

3.3 Site of Injury

The sacroiliac joint (SIJ) sustained the most injuries of any body part (n=27) as well as the highest incidence of index and re-injuries (Figure 2). Acute sudden onset and repetitive gradual onset for SIJ/Lumbar injuries were evenly distributed (n=14 and 13 respectively), however the mechanism was largely influenced by non-cycling gym-based activities; this accounted for 44% (n=12) of all injuries. The trap bar deadlift and squat accounted for 83% of gym based SIJ/Lumbar injuries (n=7 and 3 respectively). The second highest reported mechanism for SIJ/lumbar was due to starts in track-based activities (n=6).

The knee sustained 15 of the 93 injuries, these were primarily overuse injuries classified as repetitive gradual onset (n=10). Acute sudden onset knee injuries were all due to crashes or falls (n=3). A wide range of mechanisms for knee injuries were observed (intensity=4, duration=2, starts=2, leg press=2, planned surgery=2). The shoulder accounted for 13 injuries, the primary mechanism due to crashes and falls (n=6).

Injuries to the hip/groin accounted for 10 injuries and the onset was distributed between both acute and repetitive exposures to activities (n=4 and 5 respectively), with one planned surgery. The mechanism was primarily due to gym-based activities with 60% of injuries occurring in this setting while performing trap bar deadlifts (3), cleans (2) and squats (1). Injuries to the head and extremities accounted for 6.72% of injuries for each location, the mechanism of injury for these body parts were almost exclusively due to crashes.

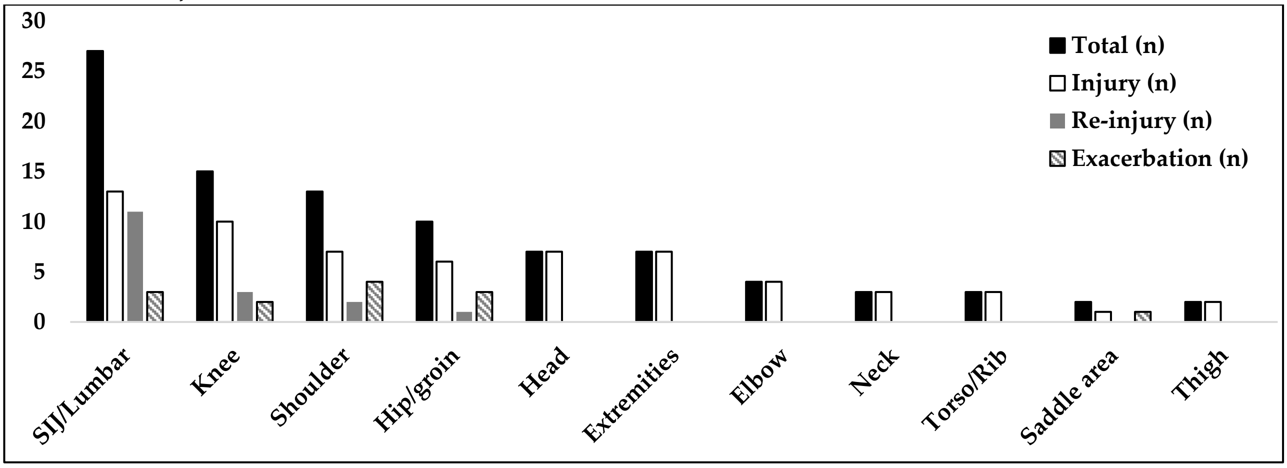

Figure 2. Site of total injuries, re-injuries and exacerbations.
SIJ=sacroiliac joint; Extremities= ankle, foot, hand, wrist, stump. Exacerbation=injury because of existing symptoms

3.4 Days Modified

Total days modified due to injury were the highest for the head area (78.43 ± 107.17 days) followed by the hip/groin (48.00 ± 69.30 days), shoulder (35.15 ± 32.21 days), elbow (33.25 ± 17.08 days) and neck (33.00 ± 49.49 days) (Table 3). The lowest days modified were shown for injuries in the saddle area (7.50 ± 0.71 days). Noteworthy is the large ranges observed for days modified at each injury site (Table 3).

Table 3. Total days modified and range per injury site

Body part/site	Days modified (n ± SD)	Days modified range (n)
Head	78.43 ± 107.17	5 - 291
Hip/groin	48.00 ± 69.30	4 – 233
Shoulder	35.15 ± 32.21	2 – 103
Elbow	33.25 ± 17.08	12 – 53
Neck	33.00 ± 49.49	3 – 90
Knee	26.47 ± 41.44	3 – 126
SIJ/Lumbar	24.15 ± 37.55	3 – 167
Extremities	18.71 ± 14.47	2 – 45
Torso/Rib	12.67 ± 13.61	2 – 28
Thigh	12.00 ± 8.49	6 – 18
Saddle area	7.50 ± 0.71	7 – 8

4 Discussion

The findings of this study are unique in that chronic and repetitive gradual onset injuries were observed to be the most prevalent in para-cycling. This contrasts existing literature which has previously demonstrated that acute injuries are most common in para-cyclists and highlights the importance of longitudinal study designs.[5 6 10] The most important finding of this investigation was that, in the C-class, every member (100%) of the para-endurance group sustained an injury and overall, the highest number of injuries were also observed within this group (n=58) (Table 1). Additionally, the sacroiliac joint and lumbar region of the spine sustained the most injuries for both acute sudden onset and repetitive gradual onset injuries in the para-endurance group (Figure 2).

The results showed that gym-based activities such as the squat and trap bar deadlift are the inciting events for most injuries at this joint (Figure 1). Therefore, sub-optimal lifting technique, and additional load to tissues concurrently with time training in flexed riding positions could be causing an increased risk of lumbopelvic injuries. This is also supported by the fact that 18 of the 22 sacroiliac joint injuries also had signs of instability and weakness. This strength deficiency and instability around the lumbopelvic region could increase load to other tissues (tendons and joints) around the hip and groin during high force activities in the gym and on the bike. Therefore, it is important to ensure that cyclists are familiar with the correct lifting techniques and form to reduce the risk of injury in the gym. It is well known that the sacroiliac joint is capable of substantial bending moments, but vulnerable to shear forces which can cause injury.[22] This can occur when squatting and deadlifting high loads which requires higher trunk muscle activity to counteract the anterior shear forces on the sacroiliac joint.[23 24] Additional exercises may also be implemented to strengthen the lower limbs while reducing injury risk by minimising shear forces at the SIJ. Furthermore, it has been suggested that non-contact injuries, such as those at the SIJ, are not caused by the training as such, but more likely by inappropriate program design, or the athlete not sticking to the prescribed program.[25 26] Excessive and rapid increases or spikes in training load are responsible for many non-contact soft tissue injuries and therefore it is important to consider optimal program design to ensure a balance between acute and chronic loads.[25] Having a holistic periodised approach to workload linking time on bike and gym-based exposures to the lumbar region is important for riders to build tolerance to specific positions (both in the gym and on the bike) and provide overload and progression needed to perform optimally.

The frequency of SIJ and lumbar spine injuries may be related to the position adopted by riders on the bike and to the time spent in the saddle. Aggressive, aerodynamic bike positions often adopted by track riders where the trunk is horizontal can expose the lumbar spine and ligamentous structures of the SIJ to high levels of mechanical stress.[27] High volumes of training in prolonged flexed posture such as this can also exacerbate the risk of injury to the spine.[28] Furthermore, the lumbar and SIJ sites may already be compromised joint/areas for C-class athletes who were particularly susceptible to spinal injuries. C-class athletes have range of motion limitations and impaired muscle function which may result in reduced strength and endurance of the spinal muscles, increase anterior pelvic tilt, and contribute to increased risk of lower back injury.[9 29-31] Furthermore, rider position on the bike was traditionally less aggressive compared to the more modern-day posture adopted during both training and competition. Therefore, it is essential that position optimisation of riders is considered for injury risk and that appropriate trunk stability, strengthening and pelvic floor muscle training are performed.[28 32 33] However, other intrinsic factors, for example, training load and impairment limitations also need to be considered for optimal bicycle configuration[34], an area that requires further research and perhaps a collaborative approach between the coach, physiotherapist, strength and conditioning coach and biomechanist.

Crashes were the second most common cause of injury, also most prevalent in para-endurance cyclists (Figure 1), with the shoulder and the knee joint most impacted by this type of event. This is similar to previous research in both para- and able-bodied cyclists with injuries including fractures (specifically of the clavicle), abrasions, and bruises.[13 14] The fact that para-endurance athletes are most prone to crashes, however, is most likely due to an increased frequency of outdoor riding and exposure to external, uncontrollable factors, when compared with sprinters who almost exclusively ride in a more controlled indoor environment. The next most frequent cause of injury was overuse, particularly at the knee joint. This is similar to previous literature[5 6] which has shown that likely causes include increased medial projection of the patellofemoral joint and altered activation of the vastus lateralis and vastus medialis muscles.[35] Furthermore, it has been shown that knee injury risk is exacerbated by long durations on the bike, inadequate preparation, inappropriate equipment set-up, and poor technique.[36] It is important to consider these factors multi-factorially when preparing athletes for competition, especially those that are long in duration. Standing starts accounted for 13.44% of injuries which is most likely due to high force exertion during this activity.[37] Lastly, training accounted for the most injuries in the four-year period. This is to be expected as athletes spend more time training than competing.

5 Practical Applications

The findings of this study have key practical applications. The para-athletes sustain a number of overuse gradual onset injuries, particularly of the SIJ/Lumbar spine area. Identifying the mechanisms of injury and problematic areas of weakness could lead to mitigating interventions such as, preconditioning and prehabilitation with individualised changes to the athlete's programme. This would include the multidisciplinary team around the athlete and the athlete themselves. Additional consideration is needed to ensure the athletes have a bespoke program which considers their personal altered physicality and biomechanics.

6 Conclusions

This is the first longitudinal study to quantify the nature and incidence of injuries in elite paralympic cyclists from a holistic perspective. Most importantly, endurance athletes are most prone to injuries specifically, at the lower back and sacroiliac joint. While the inciting event has been identified as the load bearing exercises in the gym, this is most likely due to other factors such as sub-optimal program design, spikes in acute workload (load monitoring errors), and technical incompetencies and techniques. Practitioners and coaches should consider these factors when implementing training programs as well as strengthen the muscles around the lumbopelvic hip complex. Furthermore, trainers need to consider training frequency, intensity, and duration to avoid repetitive gradual overuse injuries which also occur at the knee joint. Lastly, it is important that athletes undergo a position optimisation process to avoid compromised positions for long periods of time.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Webborn N, Emery C. Descriptive Epidemiology of Paralympic Sports Injuries. *Am J Phys Med Rehabil* 2014;6:s18-s22.

2. Slocum C, Blauwet CA, Anne Allen JB. Sports Medicine Considerations for the Paralympic Athlete. *Cuur Phys Med Rehabil Rep* 2015;3:25-35.

3. Derman W, Runciman P, Schwellnus M, *et al.* High precompwtition injury rate dominates the injury profile at the Rio 2016 Summer Paralympic Games: a prospective cohort study of 51 198 athlete days. *Br J Sports Med* 2017a;52:24-31.

4. Nyland J, Snouse S, Anderson M, *et al.* Soft Tissue Injuries to USA Paralympians at the 1996 Summer Games. *Arch Phys Med Rehabil* 2000;81:368-373.

5. Kromer P, Sommer K, Konstantinidis L, *et al.* Acute and overuse injuries in elite paracycling-an epidemiological study. *Sportverletz Sportschaden* 2011;25:167-172.

6. Hanief YL, Umar F. The characteristics of Indonesian para-cycling athletes' injuries. *Adv Rehab* 2020;34:37-46.

7. Liljedahl JB, Bjerkfors A, Arndt A, *et al.* Para-cycling race performance in different sport classes. *Disabil Rehabil* 2021;43:3440-3444.

8. Kubosch EJ, Fassbender K, Steffen K, *et al.* Implementation of an injury and illness surveillance system in paralympic athletes (ISSPA)-a study in German paracycling athletes. *Br J Sports Med* 2017;51:347.

9. Heneghan NR, Collacott E, Martin P, *et al.* Lumbosacral injuries in elite paralympic athletes with limb deficiency: a retrospective analysis of patient records. *BMJ Open SEM* 2021;15:e001001.

10. Willick SE, Webborn N, Emery C, *et al.* The epidemiology of injuries at the London 2012 Paralympic games. *Br J Sports Med* 2013;47:426-432.

11. Barrios C, Sala D, Terrados N *et al.* Traumatic and overuse injuries in elite professional cyclists. *Sports Exerc Injury* 1997;3:176-179.

12. De Bernardo N, Barrios C, Vera P, *et al.* Incidence and risk for traumatic and overuse injuries in top level road cyclists. *J Sports Sci* 2012;30:1047-1053.

13. Heaberle HS, Navarro SM, Power EJ, *et al.* Prevalence and epidemiology of injuries among elite cyclists in the Tour de France. *Orthop J Sports Med* 2018; 6:eCollection.

14. Edler C, Droste JN, Anemuller R, *et al.* Injuries in elite road cyclists during competition in one UCI World Tour season: a prospective epidemiological study of incidence and injury burden. *Phys Sportsmed* 2021;eCollection.

15. Bagherian S, Rahnama N. Epidemiology of injury in professional cyclists. *Br J Sports Med* 2010;44: 1-i82.

16. Derman W, Schwellnus MP, Jordaan E, *et al.* Sport, sex and age increase risk of illness at the Rio 2016 Summer Paralympic Games: a prospective cohort study of 51 198 athlete days. *Br J Sports Med* 2017b;52:17-23.

17. Derman W, Runciman P, Eken M. Incidence and burden of injury at the Tokyo 2020 Paralympic Games held During the Covid-19 pandemic: a prospective cohort study of 66 045 athlete days. *Br J Sports Med* 2022;57:63-70.

18. Derman W, Badenhorst M, Blauwet C, *et al.* Para sport translation of the IOC consensus on recording and reporting of data for injury and illness in sport. *Br J Sports Med* 2021;55:1068-1076.

19. Bahr R, Clarsen B, Derman W, *et al*. International Olympic Committee consensus statement: methods for recording and reporting of epidemiological data on injury and illness in sport 2020 (including STROBE Extension for Sport Injury and Illness Surveillance (STROBE-SIIS). *Br J Sports Med* 2020;54:372-389.

20. Van den Broeck J, Cunningham SA, Eeckels R, *et al.* Data cleaning: detecting, diagnosing, and editing data abnormalities. *PLoS Med* 2005;2:966-970

21. Barchard KA, Pace LA. Preventing human error: The impact of data entry methods on data accuracy and statistical results. *Comput Hum Behav* 2011;27:1834-1839.

22. Snijders CJ, Vleeming A, Stoeckart R. Transfer of lumbosacral load to iliac bones and legs. Part 1: biomechanics of self-bracing of the sacroiliac joints and its significance for treatment and exercise. *Clin Biomech* 1993;8:285-294.

23. Hartmann H, Wirth K, Mickel C, *et al.* Stress for vertebral bodies and intervertebral discs with respect to squatting depth. *J Funct Morphol Kinesiol* 2016;1:254-268.

24. Edington C, Greening C, Kmet N, *et al.* The effect of set up position on EMG amplitude, lumbar spine kinetics, and total force output during maximal isometric conventional-stance deadlifts. *Sports* 2018;6:90-100.

25. Gabbett T. The training-injury prevention paradox: should athletes be training smarter and harder? *Sports Medicine* 2016;50:273-280.

26. Impellizzeri FM, Menaspa P, Couts AJ, *et al.* Training load and its role in injury prevention, Part I: back to the future. *Journal of Athletic Training* 2020;9:885-892.

27. McEvoy M P, Wilkie K, Williams. Anterior pelvic tilt in elite cyclists – A comparative matches pairs study. *Phys. Ther. Sport.* 2007;8:22-29.

28. Galindo-Martinez A, Lopez-Valenciano A, Albaladejo-Garcia C, *et al.* Changes in trunk and lower extremity kinematics due to fatigue can predispose to chronic injuries in cycling. *Int J Environ Res Public Health* 2021;18:1-12.

29. Ehde DM, Smith DG, Czerniecki JM, *et al.* Back pain as a secondary disability in persons with lower limb amputations. *Arch Phys Med Rehabil* 2001;82:731-734.

30. Abdul-Satter A. Amputation related back pain: prevalence, associated risk factors and correlation with functional disability. *Egypt Rheumatol Rehab* 2007;34:183-196.

31. Sadowski PK, Battista S, Leuzzi G, *et al.* Low back pain in people with lower limb amputation: a cross sectional study. *Spine* 2022;47:1599-1606.

32. Pel JJM, Spoor CW, Pool-Goudzwaard AL, *et al.* Biomechanical analysis of reducing sacroiliac joint shear load by optimisation of pelvic muscle and ligament forces. *Ann Biomed Eng* 2008;36:415-424.

33. Bucke J, Mattiussi A, May K, *et al.* The reliability, variability, and minimal detectable change of multiplanar isometric trunk strength testing using a fixed digital dynamometer. *Sports Medicine and Biomechanics* 2024;9:840-846.

34. Swart J, Holliday W. Cycling biomechanics optimization- the R evolution of bicycle fitting. *Current Sports Medicine reports* 2019;2:490-496.

35. Bini RR, Bini AF. Potential factors associated with knee pain in cyclists: a systematic review. *J Sports Med* 2018;9:99-106.

36. Wanich T, Hodgkins C, Columbier JA, *et al.* Cycling injuries in the lower extremity. *J Am Acad Orthop Surg* 2007;15:748-756.

37. Padulo J, Haffaye G. Bertucci W, *et al.* Optimisation of starting conditions in track cycling. *Sport Sci Health* 2014;10:189-198.