Prevalence and incidence of injuries in para athletes: a systematic review with meta-analysis and GRADE recommendations

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ABSTRACT

Objective To investigate prevalence, incidence and profile of musculoskeletal injuries in para athletes.

Design Systematic review.

Data sources Searches were conducted in MEDLINE, EMBASE, AMED, SPORTSDiscus, CINAHL and hand searching.

Eligibility criteria Studies were considered if they reported prevalence or incidence of musculoskeletal injuries in para athletes. Study selection, data extraction and analysis followed the protocol. Meta-analyses were conducted to estimate the prevalence and incidence rate among studies and subgroup analyses investigated whether methodological quality and sample size of the studies influenced on the estimated injury prevalence and incidence. The Grading of Recommendations Assessment, Development and Evaluation system determined the strength of evidence.

Results Forty-two studies were included. The prevalence of musculoskeletal injuries was 40.8% (95% CI 32.5% to 49.8%). Because of imprecision, indirectness and inconsistency, the strength of evidence was very low quality. The incidence of musculoskeletal injuries was 14.3 injuries per 1000 athlete-days (95% CI 11.9 to 16.8). The strength of evidence was low quality because of imprecision and indirectness. The subgroup analyses revealed that the sample size influenced on estimated injury prevalence and methodological quality influenced on estimated incidence. Injuries were more prevalent in the shoulder, for non-ambulant para athletes, and in the lower limbs, for ambulant para athletes.

Summary/conclusion Para athletes show high prevalence and incidence of musculoskeletal injuries. Current very low-quality and low-quality evidence suggests that future high-quality studies with systematic data collection, larger sample size and specificities of para athletes are likely to change estimates of injury prevalence and incidence in para athletes.

PROSPERO registration number CRD42020147982.

INTRODUCTION

Since the first Paralympic Games in Rome in 1960, with 400 athletes with spinal cord injury from 23 countries,[1] the number of athletes with disabilities competing at major sports events has grown exponentially, reaching 4328 athletes from 160 countries in 22 sports at the Rio 2016 Summer Paralympic Games.[2] Especially for individuals with a disability, sports practice has a positive impact on cardiovascular fitness, self-efficacy, self-perceived quality of life and community participation.[3 4] Although sport participation is beneficial, it also comes with a risk of musculoskeletal injuries.[5 6]

Comparison of the injury incidence rates between Paralympic Games and the Olympic Games shows to which extent sports injuries need attention in athletes with disabilities, henceforward defined as para athletes. During the 2016 summer Paralympic Games, a total of 510 injuries were reported in 441 athletes, with an injury incidence rate of 10 injuries per 1000 athlete-days.[7] This incidence rate was almost twice as high when compared with the 5.7 injuries per 1000 athlete-days during the 2016 summer Olympic Games.[8] In addition to a high incidence rate, the profile of Paralympic sports injuries is extremely variable.[9] The different levels of para athletes' classification favour the participation of athletes with different types and degrees of disabilities in the same sport modality. This wider presentation of disability may help explain the great variety of injury profiles in Paralympic sports.[10 11]

The consequences of injuries in para athletes are often not limited to sports time loss or reduced sports performance. Injuries also frequently pose an additional barrier to activities of daily living in para athletes.[6] For example, an upper limb muscle injury in a disabled wheelchair javelin thrower can also affect his or her ability for independent locomotion during daily living.[4] Thus, to prevent these injuries, the first step is to understand the extent of the sports injury problem.[12] Weiler *et al*[13] conducted a systematic review of sports injuries in athletes with disabilities but the wide variability in reported injury rates prevented the authors to conduct a meta-analysis. The inclusion of studies without clear definition of sports injury might have contributed to this wide variability. Furthermore, another methodological shortcoming in this area is that estimates of prevalence and incidence comes from studies with small samples. Since the publication of this previous review in 2016,[13] new large studies on Paralympic sports injuries have been conducted, including longitudinal studies. Therefore, the primary aim of this systematic review with meta-analysis was to

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investigate the prevalence, incidence and profile of musculoskeletal injuries in para athletes. As a secondary aim, we investigated whether methodological quality and sample size influenced the prevalence and incidence reported.

METHODS

Search strategy

For this systematic review, we followed recommendations from the Joanna Briggs Institute Reviewers' Manual,[14] the Cochrane Collaboration[15] and Preferred Reporting Items for Systematic Reviews and Meta-Analyses reporting guidelines.[16] The review's protocol was registered at PROSPERO (CRD42020147982). Search strategies were conducted in August 2019 and updated in May 2020 in MEDLINE, EMBASE, AMED, SPORTSDiscus and CINAHL. In addition, we handsearched the reference list of previous reviews on the topic. There was no date or language restriction. Our sensitive search strategy included the combination of the following terms 'prevalence', 'incidence', 'epidemiology', 'injury' and 'para athlete'. Online supplemental material 1 shows a detailed search strategy for each database.

Eligibility criteria

We included published studies that reported the prevalence or incidence of musculoskeletal injuries in para athletes, including prospective, and retrospective cohort studies, without language, sample size, age or publication date restrictions. Para athlete is a general term used for athletes with an impairment who participate at any competitive level.[10] To be included, studies should report the prevalence or incidence of musculoskeletal injury in para athletes, along with a clear definition of musculoskeletal injury. Given that definitions of musculoskeletal injuries are extremely variable in the literature, any type of definition was accepted. When studies reported data from the same cohort or event, with similar methodology and the same definition of injury, only the study with global data on prevalence and incidence of injury was included.

Study selection and data extraction

Two reviewers (LSPP and FOM) independently screened titles and abstracts and assessed potential full texts. A third reviewer (RR) solved any between-reviewer disagreements.

Two reviewers (LSPP and FOM) also independently extracted descriptive and outcome data of all included studies. A third reviewer (RR) solved any discrepancies between data extractions. Descriptive information included data collection setting, sample characteristics (eg, sex, age, sport, disability, years of practising in para sports), injury characteristics (eg, injury definition, professional responsible for injury diagnosis and record, number of sports injuries), the prevalence and incidence rate of injuries with 95% CIs per study. When these data were not provided, we estimated prevalence and incidence rate using the number of athletes injured, reported number of injuries, total sample and time frame of the competition. For incidence rate, if the time frame of the competition was not reported we contacted authors or performed an internet search to clarify the start and closing dates of the competition, considering the number of days of the competition. When a study reported more than one competition, the injury incidence rate was calculated for each competition. Prevalence was estimated as the proportion of athletes affected by injury at any given time,[17] and incidence rate was estimated as the number of injuries divided by the total person-time at risk (athlete exposures).[18]

Assessment of the methodological quality

Two independent reviewers (LSPP and FOM) assessed the methodological quality of included studies using 'The Joanna Briggs Institute Prevalence Critical Appraisal Tool'.[14] A third reviewer (RR) solved potential disagreements regarding the risk of bias scoring. Each item was rated as 'yes', 'no', 'unclear' or 'not applicable' according to information available in each study, with a maximum score of nine points. One of the items in this tool is sample size. To evaluate if the sample size of each included study was appropriate, we used the following equation: sample size$=\frac{Z_{1-\alpha/2}}{d^2}^{2}p(1-p)$

where p was the expected prevalence (12.1%), defined based on a previous study,[7] Z was the confidence level (1.96), and d was the precision (5.0%).[19] The sample size estimation resulted in a minimum required sample size of 163 participants. A third reviewer (RR) solved potential disagreements regarding the risk of bias scoring.

Data analysis

Descriptive statistics were used to summarise data in meta-analysis. The prevalence and in incidence rate estimated from individual studies were pooled, using a random-effects model.[15] Studies that reported injury prevalence and incidence from the same subgroups of a larger sample during the same competitive event were excluded from the analysis. I^2 was used to explain what proportion of the observed variance was attributed to the variance in true effects rather than to sampling error.[20] A prediction interval was used to access the heterogeneity, that is, how much effect size varies across studies.[20]

Quality of evidence

To summarise the overall quality of the evidence the Grading of Recommendations Assessment, Development and Evaluation (GRADE system)[21] was used for the meta-analysis pooling prevalence and incidence data from all included studies. Scoring of evidence started at high-quality evidence which was downgraded one level if one of the following prespecified criteria was present: (1) poor methodological quality (downgraded if ≥25% of the studies included in the meta-analysis used inappropriate sampling method or statistical analyses (ie, items 2 and 8 in The Joanna Briggs Institute Prevalence Critical Appraisal Tool)); (2) imprecision (downgraded if ≥25% of the included studies did not present minimum required sample size of 163 participants); (3) indirectness (downgraded if ≥25% of the included studies did not use valid and reliable methods for data collection, for example, validated questionnaires previously described in the literature or standardised systems for recording sports injuries) and (4) inconsistency (downgraded if prediction interval has a variation ≥0.5 between upper and lower limits). These prespecified criteria were defined considering the items of Joana Briggs that correspond to the GRADE system criterion, for example, items 2 and 8 for poor methodological quality, and the corresponding index of the meta-analysis, such as the prediction interval for indirectness criterion.

We performed subgroup analyses to investigate whether methodological quality and sample size influenced overall estimates of prevalence and incidence. For the subgroup analysis, the criteria used to classify studies in high and lower methodological quality was the median score of The Joanna Briggs Institute Prevalence Critical Appraisal Tool. Studies that presented median risk of bias ≤6 points out of 9 were pooled as lower methodological quality. For the sample size subgroup analysis, the cut-off sample of 163 para athletes were used to classify studies into small and

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large sample size. For the subgroup analyses, if there was no overlap between 95% CIs between subgroups, we interpreted that each subgroup provided different estimates. All analyses were performed using Comprehensive Meta-Analysis, V.2.0 (Biostat, Englewood, New Jersey, USA).

RESULTS

Flow of studies

The electronic search strategy identified 4092 records from the selected databases after excluding duplicates. After screening titles, abstracts and reference lists, 74 potentially relevant records underwent full-text review, including one additional study found by handsearching. Twenty-three studies failed to meet the inclusion criteria, eight studies did not provide information after contact and one study was excluded because it reported data from the same event, using similar methodology, and using the same injury definition than another included study. Thereby, 42 studies were included in this review. Figure 1 shows the flow chart of studies through the review.

Characteristics of included studies

Twenty-five out of 42 studies included reported both injury prevalence and incidence rates,[7 22–45] 7 studies only reported prevalence data[46–52] and 10 studies only reported incidence rates.[3 53–61] Of the 35 studies with incidence data, 20 studies reported injury incidence rate per days,[3 22–29 33 39 41–44 53 55–58] 5 studies reported incidence per hours,[31 32 34 59 60] 5 studies reported injury incidence rate in different competitions,[35–37 45 54] three studies differentiated the injury incidence rate between precompetitive and competitive periods,[7 30 40] one study reported injury incidence rate per 1000 athlete exposures,[61] and one study reported injury incidence rate per 100 athlete competitions.[38] The number of participants ranged from 11[32] to 3657,[7] with a mean of 390.9 participants and median of 135.5. Regarding sex, 2 (4.8%) studies were conducted with females,[47 50] 4 (9.5%) with males[22 33 36 58] and 36 (85.7%) with both sexes.[3 7 23–32 34 35 37–46 48 49 51–57 59–61] Six studies were performed with wheelchair para athletes,[22 27 33 47 50 59] 11 studies with ambulant para athletes[25 32 34–38 41 44 52 58] and 25 studies with both wheelchair

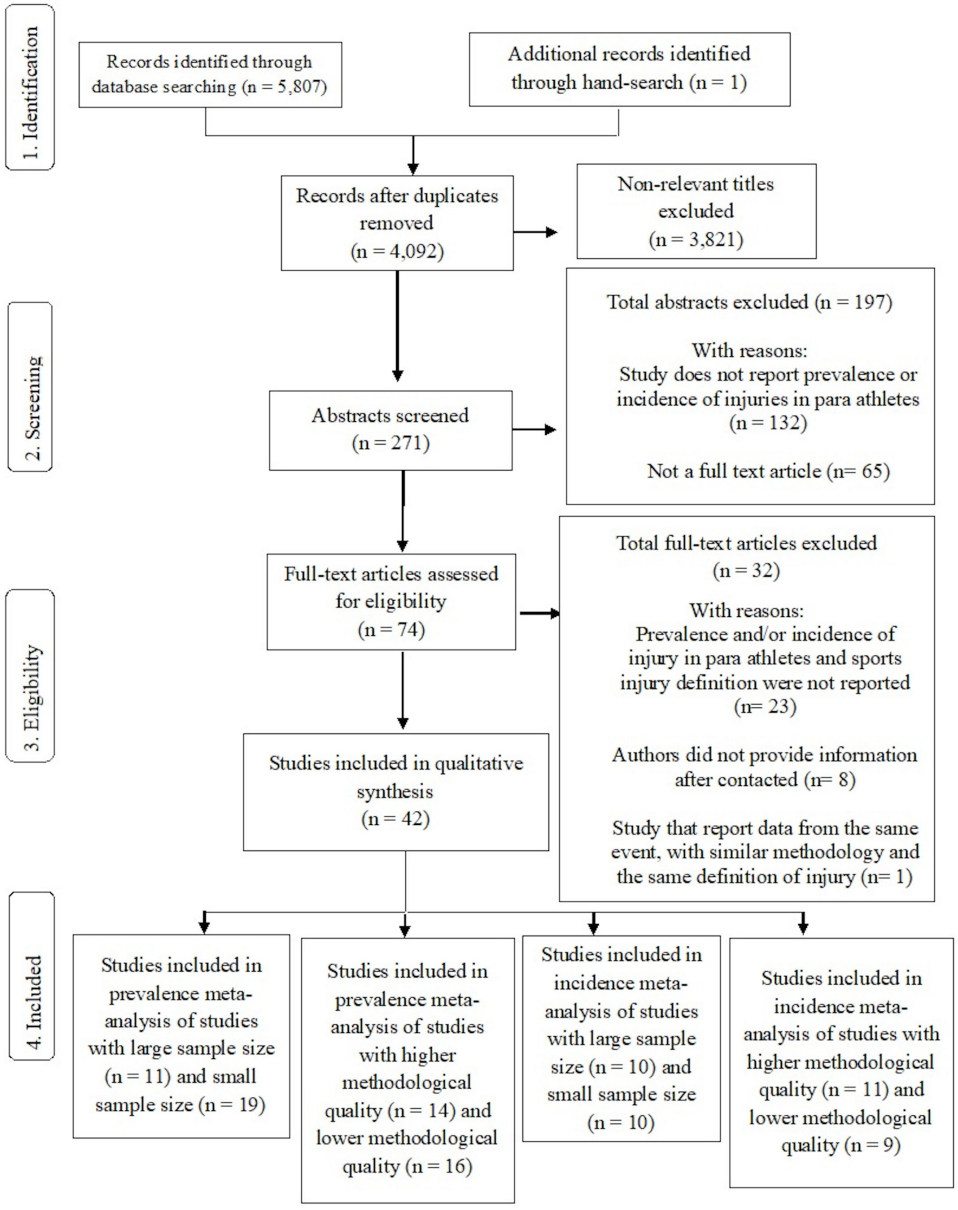

Figure 1 PRISMA flow chart of studies through the review. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

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Table 1 Methodological quality of the included studies (n=42)

Study	1	2	3	4	5	6	7	8	9	Overall score (0–9)
Antonietti *et al*, 2008[22]	Y	Y	N	Y	Y	Y	Y	Y	Y	8
Bauerfeind *et al*, 2015[33]	Y	Y	N	Y	N	Y	U	Y	N	5
Bernardi *et al*, 2003[46]	Y	Y	Y	Y	Y	Y	Y	Y	Y	9
Blauwet *et al*, 2016[3]	Y	Y	Y	Y	Y	Y	Y	Y	Y	9
Chung *et al*, 2012[59]	Y	Y	N	Y	N	U	U	Y	N	4
Curtis *et al*, 1999[47]	Y	Y	N	Y	U	Y	U	Y	U	5
Derman *et al*, 2016[39]	Y	Y	Y	Y	Y	Y	Y	Y	Y	9
Derman *et al*, 2018[7]	Y	Y	Y	Y	Y	Y	Y	Y	Y	9
Derman *et al*, 2020[40]	Y	Y	Y	Y	Y	Y	Y	Y	Y	9
Fagher *et al*, 2019[41]	Y	Y	N	Y	Y	Y	Y	Y	Y	8
Fagher *et al*, 2020[48]	Y	Y	N	Y	Y	Y	Y	Y	Y	8
Fagher *et al*, 2020[31]	Y	Y	N	Y	Y	Y	Y	Y	Y	8
Ferrara *et al*, 1992[53]	Y	Y	N	Y	N	U	N	U	U	3
Ferrara *et al*, 1992[42]	Y	Y	Y	Y	U	Y	Y	Y	U	7
Ferrara and Davis, 1994[43]	Y	Y	Y	Y	Y	Y	U	Y	U	7
Ferrara and Buckley, 1996[61]	Y	Y	Y	Y	Y	Y	U	Y	U	7
Ferrara *et al*, 2000[54]	Y	Y	Y	U	U	U	U	U	U	3
Gajardo *et al*, 2019[44]	Y	Y	N	Y	Y	N	Y	Y	Y	7
Gawroński *et al*, 2013[45]	Y	Y	N	Y	Y	Y	U	Y	U	6
Haykowsky *et al*, 1999[32]	Y	Y	N	Y	N	Y	U	N	N	4
Hollander *et al*, 2019[55]	Y	Y	N	Y	Y	Y	Y	Y	U	7
Kubosch *et al*, 2017[23]	Y	Y	N	Y	U	Y	Y	Y	U	6
Lankhorst *et al*, 2019[34]	Y	Y	N	Y	Y	N	Y	Y	Y	7
Magno e Silva *et al*, 2013[35]	Y	Y	N	Y	Y	N	U	Y	U	5
Magno e Silva *et al*, 2013[36]	Y	Y	N	Y	Y	N	U	Y	U	5
Magno e Silva *et al*, 2013[37]	Y	Y	N	Y	Y	N	U	Y	U	5
Marqueta *et al*, 2005[24]	Y	Y	N	Y	N	U	U	N	U	3
McCormick *et al*, 1990[25]	Y	Y	Y	Y	Y	Y	U	Y	N	7
Nyland *et al*, 2000[56]	Y	Y	Y	Y	Y	N	N	Y	U	6
Ona Ayala *et al*, 2019[26]	Y	Y	Y	Y	Y	Y	Y	Y	U	8
Patatoukas *et al*, 2011[49]	Y	Y	N	Y	U	N	N	Y	U	4
Ramirez *et al*, 2009[60]	Y	Y	Y	Y	Y	N	N	Y	Y	7
Saffarian *et al*, 2019[38]	Y	Y	Y	Y	U	N	N	Y	N	5
Shimizu *et al*, 2017[50]	Y	Y	N	Y	Y	Y	U	Y	N	6
Taylor and Williams, 1995[27]	Y	Y	N	Y	N	U	N	Y	U	4
Tenforde *et al*, 2019[51]	Y	Y	Y	Y	Y	N	U	Y	N	6
Webborn *et al*, 2006[29]	Y	Y	Y	Y	N	N	U	N	N	4
Webborn *et al*, 2012[57]	Y	Y	Y	U	U	U	U	Y	U	4
Webborn *et al*, 2016[58]	Y	Y	Y	U	Y	Y	Y	Y	Y	8

Continued

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Table 1 Continued

Study	1	2	3	4	5	6	7	8	9	Overall score (0–9)
Willick *et al*, 2013[30]	Y	Y	Y	Y	Y	Y	Y	Y	U	8
Willick *et al*, 2016[28]	Y	Y	Y	Y	Y	Y	Y	Y	U	8
Zwierzchowska *et al*, 2020[52]	Y	Y	N	Y	Y	N	U	Y	Y	6
Total 'yes' scores	42	42	20	39	28	24	18	37	14	

1. Was the sample frame appropriate to address the target population?
2. Were study participants sampled in an appropriate way?
3. Was the sample size adequate?
4. Were the study subjects and the setting described in detail?
5. Was the data analysis conducted with sufficient coverage of the identified sample?
6. Were valid methods used for the identification of the condition?
7. Was the condition measured in a standard, reliable way for all participants?
8. Was there appropriate statistical analysis?
9. Was the response rate adequate, and if not, was the low response rate managed appropriately?

N, no; NA, not applicable; U, unclear; Y, yes.

and ambulant para athletes.[3 7 23 24 26 28–31 39 40 42 43 45 46 48 49 51 53–57 60 61] Twenty studies were sport-specific,[3 22–24 26–28 32 33 35–37 41 44 47 50 52 53 55 59] 19 were multisport[7 25 29–31 38–40 42 43 45 46 48 49 54 56–58 60] and 3 studies did not report para sport modality.[34 51 61] Ten studies did not report para athlete disabilities,[26 28–30 39 42 54 57 59 61] 22 studies presented information about classification level of para athletes,[3 7 22 24 26 32 63 135–41 43 44 48 50 52 55 57–59] 23 studies specified the assistive devices used by para athletes,[3 7 22 24 26–28 30 31 33 39 40 46–48 50 51 53 55–57 59 60] and in 30 studies the injury diagnosis was confirmed by a medical practitioner.[3 7 23 25 26 28–31 33–40 45 46 48 50 51 54–61] Only five studies presented longitudinal prospective design,[23 31 34 59 60] while 37 studies reported retrospective or competitive events data.[3 7 22 24–30 32 33 35–58 61] Online supplemental material 2 shows the characteristics of the included studies and demonstrates the level of inconsistency in injury definitions and the report of para athletes' exposure (days, hours or competition).

Quality assessment

Methodological quality issues are reported in table 1. None of the studies had a negative or unclear answer to item 2, 22 studies did not present appropriate sample size,[22–24 27 31–37 41 44 45 47–50 52 53 55 59] 18 studies did not use valid methods for data collection or did not clearly present the methods used for data collection,[24 27 29 34–38 44 49 51–54 56 57 59 60] and 5 studies had a negative or unclear answers to item 8.[24 29 32 53 54] Twenty-one studies scored ≤6 out of 9.[23 24 27 29 32 33 35–38 45 47 49–54 56 57 59] Mean (SD) methodological quality of the included studies was 6.3 (1.8) out of 9 (ranging from 0 to 9).

Prevalence of musculoskeletal injuries in para athletes

The pooled prevalence estimates including data from 30 studies (n=12 151)[7 22–25 27 29–52] found was 40.8% (95% CI 32.5% to 49.8%; I^2: 97.7%; prediction interval: 0.1–0.8). The overall quality of evidence was rated as very low quality (ie, downgraded due to imprecision, indirectness and inconsistency) (table 2). The subgroup analysis based on higher and lower methodological quality revealed no significant difference. The pooled estimate for studies with higher methodological quality (n=10 408)[7 22 25 30 31 34 39–44 46 48] was injury prevalence of 34.7% (95% CI 25.4% to 45.4%; I^2: 98.2%; prediction interval: 0.1–0.8) and for studies with lower methodological quality (n=1743)[23 24 27 29 32 33 35–38 45 47 49–52] was 47.4% (95% CI 32.1% to 63.3%; I^2: 95.8%; prediction interval: 0.1–0.9) (figure 2). For the subgroup analysis based on study sample size, studies with large sample size showed significantly lower prevalence estimate than studies with small sample size. While studies with large sample size (n=11 068)[7 25 29 30 38–40 42 43 46 51] showed injury prevalence of 18.5% (95% CI 12.7% to 26.1%; I^2: 98.3%; prediction interval: 0.1–0.6), the prevalence estimate from studies with small sample size (n=1083)[22–24 27 31–37 41 44 45 47–50 52] was 58.3% (95% CI 48.2% to 67.8%; I^2: 88.1%; prediction interval: 0.2–0.9) (online supplemental material 3).

Incidence rate of musculoskeletal injuries in para athletes

For incidence rate, the pooled estimate including data from 20 studies (n=11 608)[7 22–25 27 29 30 33 39–45 53 55–57] that reported injury incidence rate per days and also the number of injuries, sample size and exposure in days. The incidence rate was 14.3 injuries per 1000 athlete-days (95% CI 11.9 to 16.8; I^2: 98.4%; prediction interval was 0.1–0.2). The overall quality of evidence was rated as low quality (ie, downgraded due to imprecision and indirectness) (table 2). The subgroup analysis showed a significant lower incidence rate in studies of higher methodological quality

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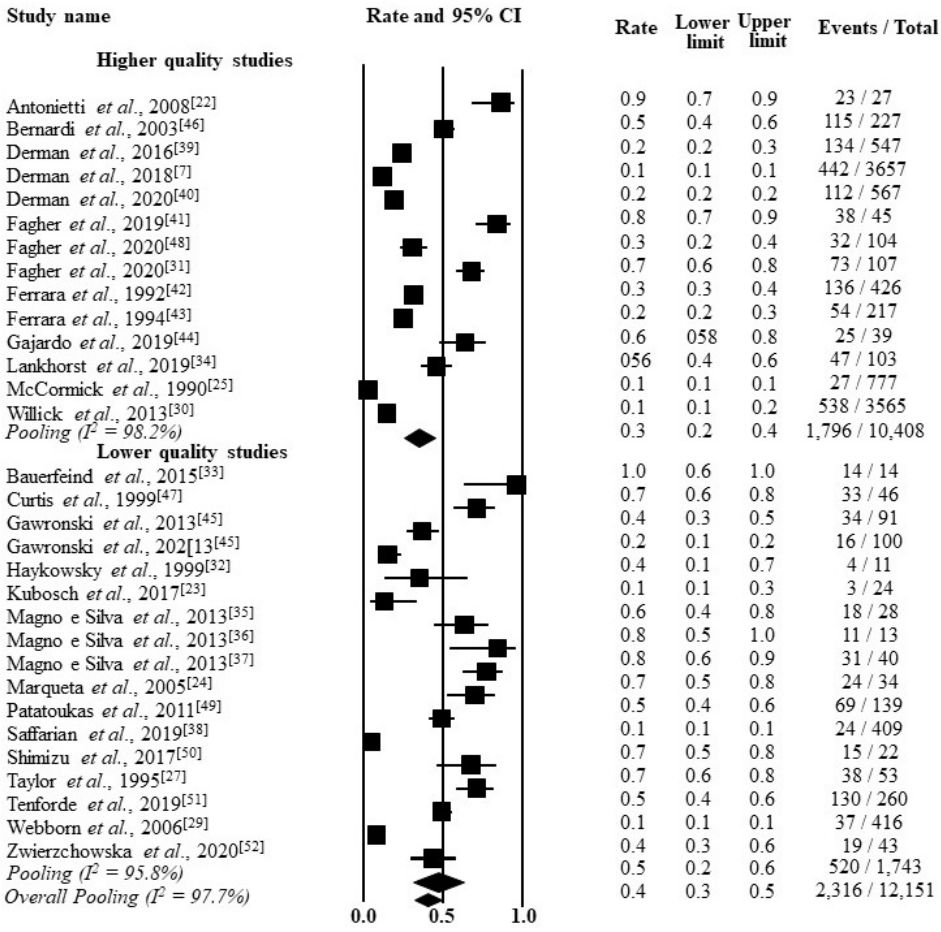

Figure 2 Meta-Analysis for overall injuries prevalence in para athletes and subgroup analysis for studies with higher and lower methodological quality.

as compared with studies with lower methodological quality. The pooled estimate for studies with higher methodological quality (n=9999)[7 22 30 39–44 55] was injury incidence rate of 11.7 per 1000 athlete-days (95% CI 8.9 to 14.5; I^2: 98.6%; prediction interval was 0.1–0.4) and pooling of 1609 para athletes from studies with lower methodological quality[23 24 27 29 33 45 53 56 57] estimated the injury incidence of 23.1 per 1000 athlete-days (95% CI 17.1 to 29.2; I^2: 98.4%; prediction interval was 0.1–0.4) (figure 3). The subgroup analysis showed no clear difference with regards to sample size. While studies with large sample size (n=10 981)[7 25 29 30 39 40 42 43 56 57] estimated an injury incidence rate of 14.4 per 1000 athlete-days (95% CI: 11.1 to 17.7; I^2: 98.8%; prediction interval was 0.1–0.2) studies with small sample size (n=627)[22–24 27 33 41 44 45 53 55] showed an incidence rate of 14.7 per 1000 athlete-days (95% CI: 11.1 to 18.5; I^2: 97.4%; prediction interval: 0.1–0.3) (online supplemental material 4).

Injury profile in para athletes

Eighteen studies found that the shoulder was the body location most frequently affected by injuries,[7 22 23 26 28 30–33 39–42 44 46–48 59] mainly in sports with non-ambulant para athletes, like wheelchair basketball,[22] wheelchair rugby,[33] wheelchair foil fencer[59] and powerlifting.[26 28] In other four studies, most of the injuries occurred in upper limbs.[27 52 53 61] Nine studies reported that lower limbs injuries were the most common for ambulant para athletes,[24 34 36–38 43 51 58 60] and in three studies, the trunk was the most frequently injured region.[35 54 55] Four studies found similar prevalence of upper and lower limb injuries,[3 29 56 57] and four studies did not report injuries by body location.[25 45 49 50] In general, strain, sprains and contusions were the most common injuries in para athletes.[3 24 25 29 31 33–38 41 45 46 49 52 54 55 59–61] Most of the studies that included sudden and gradual onset injuries reported that sudden onset injuries are more frequent than

Table 2 Evidence table for outcome measure

Outcomes	Risk of bias*	Imprecision†	Indirectness‡	Inconsistency§	No of para athletes	Quality
Injuries prevalence in para athletes	No serious risk of bias	Serious imprecision	Serious indirectness	Serious inconsistency	12 151	Very low quality
Injuries incidence rate in para athletes	No serious risk of bias	Serious imprecision	Serious indirectness	No serious inconsistency	11 608	Low quality

*More than 25% of studies with a risk of bias (ie, inappropriate sampling method or statistical analyses).
†More than 25% of studies with small sample size.
‡More than 25% of studies did not use valid and reliable methods for data collection.
§Heterogeneity across the studies (prediction interval has a variation ≥0.5 between upper and lower limits).

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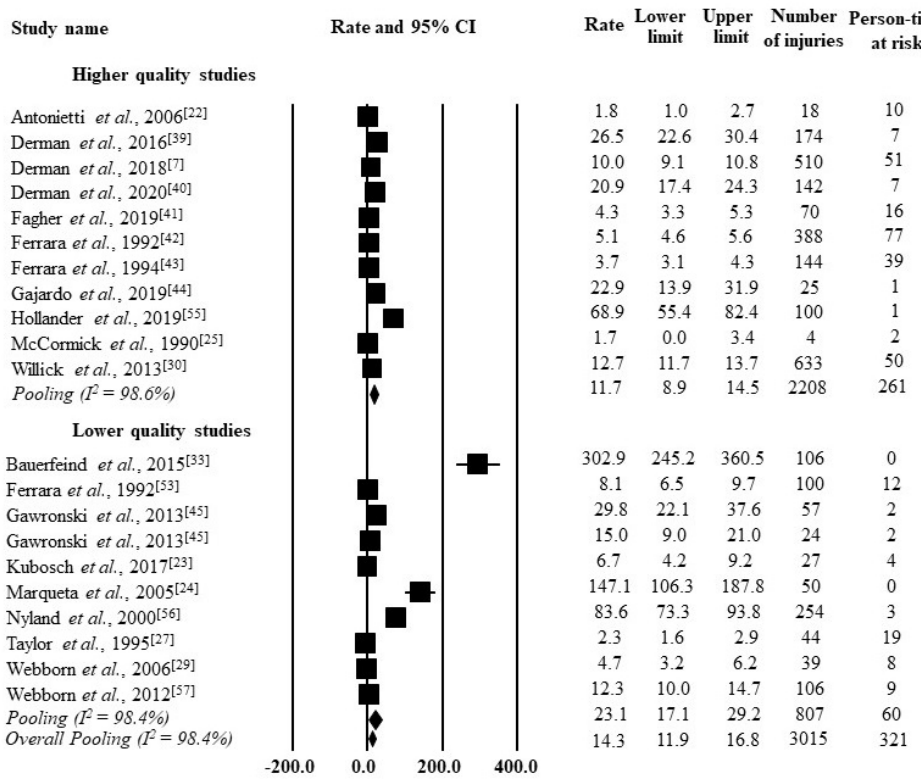

Figure 3 Meta-Analysis for overall injuries incidence rate in para athletes and subgroup analysis for studies with higher and lower methodological quality.

gradual onset injuries and only one study reported similar data for gradual and sudden onset injuries.[45] Between winter sports, para alpine skiing/snowboard had a higher incidence rate of injuries,[39 40] while between summer sports, football 5-a-side had the highest injury incidence rates[7 30] (online supplemental material 5).

DISCUSSION

The purpose of this systematic review with meta-analysis was to investigate the prevalence, incidence and profile of musculoskeletal injuries, including body location, type of injury and sports with the highest number of injuries, in para athletes. Our findings showed that musculoskeletal injury prevalence in para athletes was 40.8% (95% CI 32.5% to 49.8%) and musculoskeletal injury incidence rate was 14.3 injuries per 1000 athlete-days (95% CI 11.9 to 16.8). According to the GRADE system, pooling of studies on injury prevalence in para athletes provided very low-quality evidence, and pooling of studies on injury incidence rate provided low-quality evidence. The subgroup analysis based on study sample size showed a significant lower injury prevalence (18.5%, 95% CI 12.7% to 26.1%) in studies of large sample size in comparison to studies with small sample size (58.3%, 95% CI 48.2% to 67.8%). The subgroup analysis based on methodological quality showed a significant lower injury incidence (11.7 per 1000 athlete-days, 95% CI 8.9 to 14.5) in studies of higher methodological quality as compared with studies with lower methodological quality (23.1 per 1000 athlete-days, 95% CI 17.1 to 29.2). Sudden-onset injuries were more frequent than gradual onset injuries. Strains, sprains and contusions were the most common injury type and the body regions most frequently affected were the shoulder for wheelchair athletes and the lower limbs for ambulant para athletes.

Prevalence and incidence rates of musculoskeletal injuries in para athletes are higher than in able-bodied athletes. For example, during the last summer Paralympic Games (Rio 2016), the prevalence of injuries was 12.1%,[7] while in the Olympic Games in the same year it was 8%.[8] Incidence of injuries followed the same pattern, with 10 injuries per 1000 athlete-days in Paralympic Games[7] and 5.7 injuries per 1000 athlete-days during the Olympic Games.[8] The high injury prevalence and incidence rates in para athletes show that the mechanisms of occurrence of musculoskeletal injuries in this population need to be better understood. Para athletes can be categorised in different groups, varying between para athletes with loss of muscle strength and para athletes with intellectual impairment.[11] Then, these different profiles of para athletes require different approaches to treat and prevent the occurrence of musculoskeletal injuries. Furthermore, para athletes use different equipment to compete, such as a wheelchair or prosthetic devices, which increases the complexity of strategies designed to reduce injury risk.[4] Sports injuries in para athletes, unlike able-bodied athletes, can also be related to their own disability or to the assistive device they use in their daily lives. For this reason, to better understand para athletes' injuries and related factors, full knowledge of the specificities of the sport modality and the para athlete classification level are required to design and implement more individualised approaches. However, some studies still do not report this type of information.[13 62 63] Although most of the included studies reported the type of disability (76%) and had injury diagnosis confirmed by a medical practitioner (70%), almost half did not provide information about the para athlete classification level or the use of assistive devices. One of the few studies that provided this information demonstrated that para athletes that did not use any assistive devices had a higher injury

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prevalence.[48] Thus, future studies should report this information to allow better understanding on para athlete injuries profile and related factors.

The subgroup analysis showed that the estimated prevalence and incidence of musculoskeletal injuries in para athletes was influenced by the studies' sample size and methodological quality, respectively. More specifically, studies with small sample size overestimated the injury prevalence (58.3%) in comparison to studies with large sample sizes (18.5%). For injury incidence rate, studies with higher methodological quality showed significantly lower incidence (11.7 per 1000 athlete-days) than studies with lower methodological quality (23.1 per 1000 athlete-days). This also was observed in previous systematic review with athletes with disability that reported a lower injury risk in studies with larger sample populations and higher methodological quality.[13] There are fewer large competitions in para athlete sports in comparison to able-bodied sports, which may help to explain the small number of studies with appropriate sample size to estimate prevalence and incidence of musculoskeletal injuries in para athletes.[64] Most of these large sample studies were performed during Paralympic games,[7 29 30 39 40] which might not represent injuries rates in non-elite para athletes. Large para athletes training centres and national organisations are key to the development of future studies with large samples, high methodological quality and including prospective data collection throughout different seasons, which will provide more consistent information regarding musculoskeletal injuries in para athletes. Nevertheless, the high prevalence and incidence rates data showed by the present review highlight the need to better understand and hopefully prevent the occurrence of musculoskeletal injuries in para athletes.

The shoulder was the most affected body region in wheelchair para athletes, which can be explained by the higher demands of the upper limbs in their daily activities[4] and during sports practice. Studies that assessed scapular kinematics in wheelchair para athletes demonstrated scapular asymmetries during wheelchair propulsion[65 66] that, along with muscle imbalance and excessive training load, may increase the occurrence of shoulder injuries.[67 68] Most of the ambulant para athletes were from sport modalities that have the highest injury incidence rates in summer Paralympic Games, such as football 5-a-side and athletics, which might help to explain why the lower limbs were the body regions most frequently affected in these para athletes.[7 30] In the present review, sudden onset injuries were more frequent than gradual onset injuries. This may be related to the fact that gradual-onset injuries are often under-reported, since most of the injury definitions are based on 'time-loss' or 'medical attention'[13] and few studies performed a longitudinal follow-up,[23 31 34 59 60] so consequently might not detect most of the gradual-onset injuries.

Our results regarding location and type of musculoskeletal injuries are in agreement with the results of non-systematic reviews.[9 10 69] The heterogeneity in para sports, due to a large number of modalities and also to the different athlete classification levels for the same modality, increases the inconsistency of information about prevalence and incidence of musculoskeletal injuries in para athletes. In addition, the heterogeneity in the methods used by studies with para athletes, compromises pooling of data. One of the main problems is the different musculoskeletal injury definitions. Similar to Olympic sports, para sports also has a wide variety of injuries definition.[70] As an attempt to solve this problem, the International Olympic Committee very recently established a consensus statement about methods for recording and reporting of epidemiological data on injury and illness in sport.[71] A similar consensus should be developed for Paralympic sports and their specificities. Finally, most of the studies used different procedures to report prevalence and incidence rate data, did not mention a clear definition of these variables, and did not present all information used to compute these data, such as number of injuries, number of athletes injured, the total number of athletes and exposure.[18] As well as data records, studies should use valid and reliable methods to assess injuries rate, such as the Oslo Sports Trauma Research Center Questionnaire on Health Problems .[23 72]

Weiler *et al*[13] conducted a systematic review of sports injuries in athletes with disabilities and also demonstrated high variability in reported injury rates. They suggested that future studies should better define injury, use standardised methods of data collection and report para athletes demographic data to improve quality of injury epidemiological data. Following these steps and focusing on para athletes specificities, future researches will allow the construction of a more consistent and robust knowledge about musculoskeletal injuries in para athletes that will allow para athletes, sport teams and institutional boards to elaborate more effective approaches to the injury in para sport problem.

This study had some limitations. First, age or level of sports participation were not defined as exclusion criteria, which allowed a wider range of included studies and consequently increased heterogeneity levels in the data. However, as studies with para athletes are less common, we had to use less restricted inclusion criteria to review data on musculoskeletal injuries in this population. Level of competition, classification levels, injury severity and type of injury might also influence on estimated prevalence and incidence rates of injuries in para athletes and were not controlled in this review. However, this was not possible because most of the studies did not report this information. The strength of the current evidence was downgraded due to imprecision, indirectness and inconsistency about injury prevalence and downgraded due to imprecision and indirectness about injury incidence rate in para athletes, presenting very low-quality and low-quality evidence, respectively.

Future high-quality studies with consistent information on the parameters used to calculate the injury prevalence and incidence rate, and valid and reliable methods for data collection are likely to impact on the estimated prevalence and incidence of musculoskeletal injuries in para athletes. To improve the quality of injury epidemiological data in para athletes, studies must properly define injury, including their type of presentation (sudden or gradual onset), severity and also follow the recommendations in the scientific literature regarding the appropriate methods to report athlete exposure and to inform about injuries risk and burden.[71] In addition, studies should report para athlete's demographic data, including type of disability, equipment used for sport practice or during daily activities, level of competition and other relevant daily demands, such as side jobs. Finally, more prospective studies that investigate the relationship between modifiable factors and injuries occurrence in para athletes, such as use of equipment and training and competition volume and intensity may form the basis for the design of more effective strategies to prevent and manage injuries in para athletes.

CONCLUSION

The reviewed studies demonstrated that musculoskeletal injury prevalence in para athletes was 40.8% (95% CI 32.5% to 49.8%) and injury incidence rate was 14.3 injuries per 1000 athlete-days (95% CI: 11.9 to 16.8). The subgroup analysis based on study sample size showed a significant lower injury prevalence

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in studies of large sample size as compared with studies with small sample size. For the incidence rate, studies with higher methodological quality showed a significant lower injury incidence rate in comparison to studies with lower methodological quality. Sudden-onset injuries are more frequent than gradual onset injuries in para athletes. Shoulder was the body region most commonly injured for non-ambulant para athletes, while lower limbs were the most frequently injured region for ambulant para athletes. The heterogeneity between para athletes and the poor methodological quality of the studies promote greater inconsistency in the information on the injury prevalence and incidence in para athletes. Therefore, current very low-quality and low-quality evidence suggests that prevalence and incidence rate, respectively, are likely to change with future high-quality studies, observing a large sample size, systematic data collection with reliable and validated methods and with attention to the specificities of para athletes. Findings of this systematic review demonstrate that para athletes, sports teams and para sport institutional boards should be aware of the high prevalence and incidence levels of musculoskeletal injuries in para athletes.

What is already known

- The heterogeneity in para sports increases the inconsistency of information about prevalence and incidence of musculoskeletal injuries in para athletes.
- There is still a need for consensus on epidemiological research methodology, including sports injury definition in para sports.
- In para athletes, shoulder is the most frequently affected body location by injuries in non-ambulant para athletes, and lower limbs injuries are the most common in ambulant para athletes.

What are the new findings

- This was the first systematic review with meta-analysis on injury prevalence and incidence in para athletes that uses Grading of Recommendations Assessment, Development and Evaluation recommendations to assess the overall quality of evidence.
- The subgroup analyses revealed that the sample size influenced the estimated injury prevalence and methodological quality influenced the injury incidence rate.
- Between winter sports, para alpine skiing/snowboard had the highest incidence of injuries, while between summer sports, football 5-a-side had the highest incidence of injuries.

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Supplementary material 1

Search strategy conducted in August 2019 and updated in May 2020

OVID (Medline, Embase, AMED)

1. incidence.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
2. prevalence.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
3. epidemiology.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
4. rate*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
5. 1 or 2 or 3 or 4
6. injur*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
7. trauma.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
8. 6 or 7
9. (adaptive adj sport). mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
10. para*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
11. disab*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
12. impairment*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]

13. 9 or 10 or 11 or 12
14. athlet*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
15. player*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
16. sport*.mp [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
17. 14 or 15 or 16
18. 5 and 9 and 14 and 18

EBSCO (SPORTDiscus and CINAHL)

S18 S14 AND S15 AND S16 AND S17

S17 S11 OR S12 OR S13

S16 S7 OR S8 OR S9 OR S10

S15 S5 OR S6

S14 S1 OR S2 OR S3 OR S4

S13 sport*

S12 player*

S11 athlet*

S10 impairment*

S9 disab*

S8 para*

S7 adaptive and sport

S6 trauma

S5 injur*

S4 rate*

S3 epidemiology

S2 prevalence

S1 incidence

Supplementary material 2

Characteristics of the included studies (n = 42)

Study, year, setting, injury record	Sample size, sex, age	Sport, mean practice duration	Disability	Injury definition	Exposure (days)	Sports injuries	Prevalence	Incidence rate (95% CI)
Studies reporting on both prevalence and incidence rates (n = 25)								
Antonietti *et al.*, 2008[22] Location: Brazil Sample selection: convenience Injury record: Physiotherapy students	n* = 27 Sex: male Average age: 30.1 (SD 10.6) years	Sport: wheelchair basketball Mean practice duration: 48.9 (SD 62.5) months	Spinal cord injury	Some participants presented injury with pathological diagnosis established by prior medical evaluation. Those who had no previous pathological diagnosis, it was considered pain as a complaint and injury was considered non-specific.	365	18	86.6% (23**)	1.8 (95% CI,1.0–2.7) injuries per 1000 athlete-days[a]
Bauerfeind *et al*., 2015[33] Location: Poland Sample selection: convenience Injury record: National Team physiotherapists and medical histories of the athletes	n* = 14 Sex: male Average age: 29.5 (SD 5.7) years	Sport: wheelchair rugby Mean practice duration: 6.68 (SD 3.66) years	Spinal cord injury and others	Sports injuries were defined as bodily injuries that arise during training or competition, and stopped, limited or modified participation in sports activities for one day or more	Mean of training and tournament days = 25 (SD 5.6) days	106	100% (14**)	302.8 (95% CI, 245.2–360.5) injuries per 1000 athlete-days[a]

Derman *et al.*, 2016[39] Location: Sochi 2014 Winter Paralympic Games Sample selection: convenience Injury record: ATOS system supplied to the medical staff employed by the Sochi Organising Committees of the Olympic and Paralympic Games (SOCOG) and WEB-IISS	n* = 547 Sex: both sex Average age: from 13 years	Sport: alpine skiing/ snowboarding, cross-countryskiing / biathlon, ice sledge hockey, wheelchair curling Mean practice duration: not reported	Not reported	Injury was specifically defined as 'any newly acquired injury as well as exacerbations of pre-existing injury that occurred during training and/or competition in the games period of the Sochi 2014 Winter Paralympic Games'	12	174	24.5 % (134**)	26.5 (95% CI, 22.7–30.8) injuries per 1000 athlete-days
Derman *et al.*, 2018[7] Location: Rio 2016 Summer Paralympic Games Sample selection: convenience Injury record:	n* = 3657 Sex: both sex Average age: from 12 years	Sport: archery, boccia, canoe, cycling (track and road), equestrian, football 5-a-side, football 7-a-side, goalball, judo, para athletics, para powerlifting, para swimming,	Limb deficiency (amputation, dysmelia, congenital deformity), visual impairment, spinal cord injury, central neurological injury (cerebral palsy, traumatic brain injury, stroke, other	Injury was specifically defined as 'any newly acquired injury as well as exacerbations of pre-existing injury that occurred during training and/ or competition in the games period of the	Overall: 14 Pre-competition: 3 Competition: 11	Overall: 510 Pre-competition: 141 Competition: 369	Overall: 12.1% (441**) Pre-competition: 3.7% (134**) Competition: 8.9% (325**)	Overall: 10.0 (95% CI, 9.1–10.9) injuries per 1000 athlete-days Pre-competition: 12.9 (95% CI, 10.9–15.2) injuries per 1000 athlete-days Competition: 9.2 (95% CI, 8.3–10.2) injuries per 1000 athlete-days

WEB-IISS		rowing, sailing, shooting para sport, sitting volleyball, table tennis, triathlon, wheelchair basketball, wheelchair fencing, wheelchair rugby and wheelchair tennis Mean practice duration: not reported	neurological impairment), other, *Les autres* (non-spinal polio myelitis, ankylosis, leg shortening, joint movement restriction, nerve injury resulting in local paralysis), intellectual impairment, unknown, short stature	Rio 2016 Summer Paralympic Games'				
Derman *et al.*, 2020[40] Location: Pyeongchang 2018 Paralympic Winter Games Sample selection: convenience Injury record: Polyclinic datasets and WEB-IISS	n* = 567 Sex: both sex Average age: 32.1 (SD 10.3) years	Sport: para alpine skiing, para snowboard, para Nordic skiing (combining para cross-country skiing and para biathlon), para ice hockey and wheelchair curling Mean practice duration: not reported	Limb deficiency (amputation, dysmelia and congenital deformity), spinal cord injury, visual impairment, central neurologic injury (cerebral palsy, traumatic brain injury, stroke and other neurological impairments), *Les autres*, unknown	Injury was defined as 'any newly acquired injury as well as exacerbations of pre-existing injury that occurred during training and/or competition in the games period of the Pyeongchang 2018 Paralympic Winter Games'	Overall: 12 Pre-competition: 3 Competition: 9	Overall: 142 Pre-competition: 33 Competition: 109	Overall: 19.8% (112**) Pre-competition: 5.5% (31**) Competition: 16.8% (95**)	Overall: 20.9 (95% CI, 17.4–25.0) injuries per 1000 athlete-days Pre-competition period: 19.4 (95% CI, 13.6–27.6) injuries per 1000 athlete-days Competition: 21.4 (95% CI, 17.4–26.3) injuries per 1000 athlete-days
Fagher *et al*., 2019[41] Location:	n* = 45 Sex: both sex Average age:	Sport: judo Mean practice duration: not	Visual impairment	Sports injury was defined and questioned to the	365	70	84% (38**)	4.3 (95% CI, 3.3–5.3) injuries per 1000 athlete-days[a]

United Kingdom Sample selection: convenience Injury record: Bachelor student	from 18 years	reported		athletes as: 'Have you had any new musculoskeletal pain, feeling or injury during the past year that caused changes in normal training or competition to the mode, duration, intensity, or frequency, regardless of whether or not time is lost from training or competition?'				
Ferrara *et al.*, 1992[42] Location: USA Sample selection: convenience Injury record: investigator	n* = 426 Sex: both sex Average age: 25.6 years	Sport: track, field, weightlifting, swimming and others Mean practice duration: 5.8 years	Not reported	The definition of injury was 'any trauma to the participant that occurred during any practice training, or competition session that caused the athlete stop, limit, or modify participation for 1 d or more'	180	388	32% (137**)	5.1 (95% CI, 4.5–5.7) injuries per 1000 athlete-days[a]
Ferrara *et al.*, 1994[43] Location: USA Sample selection: convenience Injury record:	n* = 217 Sex: both sex Average age: 24.2 (SD 7.8) years	Sport: track, field, weightlifting, soccer, cycling, wheelchair team handball, boccia, slalom, equestrian,	Cerebral palsy	The definition of injury was 'any trauma to the body that occurred during a practice, training, or competition session that caused	180	144	25% (54**)	3.7 (95% CI, 3.1–4.3) injuries per 1000 athlete-days[a]

investigator		bowling and cross-country Mean practice duration: 6.2 (4.1) years		the athlete to stop, limit, or modify participation in sports for 1 or more days'				
Gajardo *et al*., 2019[44] Location: Southern Championship of the National Goalball League of Chile 2017. Sample selection: convenience Injury record: Kinesiology students	n* = 39 Sex: both sex Average age: 41 (SD 14.9) years	Sport: goalball Mean practice duration: not reported	Visual impairment	Physical injury or ailment was defined as 'any musculoskeletal or neurological ailment related to sport and generating alterations in training / competition'	28	25	64% (25**)	22.9 (95% CI, 13.9–31.9) injuries per 1000 athlete-days[a]
Gawroński *et al.,* 2013[45] Location: Beijing 2008 and London 2012 Sample selection: convenience Injury record: two team physicians	n* = 91 in Beijing and 100 in London Sex: both sex Average age: 32 (SD 11) years in Beijing and 32 (SD 10) years in London	Sport: equestrian, cycling, athletics, archery, swimming, powerlifting, shooting, wheelchair basketball, wheelchair fencing, wheelchair tennis, table tennis, rowing Mean practice	Amputation, spinal cord injury, *Les autres*, cerebral palsy, visual impairment, intellectual disability	Injury was defined as 'a newly acquired musculoskeletal symptom or an exacerbation of a pre-existing (chronic) injury that occurred during training and/or competition'	Beijing: 21 days London: 16 days	Beijing: 57 London: 24	Beijing: 37.4% (34**) London: 16% (16**)	Beijing: 29.8 (95% CI, 22.1– 37.6) injuries per 1000 athlete-days London: 15 (95% CI, 9.0–21.0) injuries per 1000 athlete-days

		duration: not reported						
Kubosch *et al.*, 2017[23] Location: Germany Sample selection: convenience Injury record: OSTRC questionnaire	n* = 24 Sex: both sex Average age: 36.5 (SD 9.7) years	Sport: paracycling Mean practice duration: not reported	Paraplegia, extremity disability, Injury Cerebral Palsy/skull injury, visual impairment and pilot	Acute injury was defined as 'any musculoskeletal complaint caused by previous acute trauma' and overload injuries were defined as 'musculoskeletal complaints that resulted in acute trauma or exacerbation of existing complaints, and persisted for days, weeks, or months without connection to a relevant event'	168	27	14% (3**)	6.7 (95% CI, 4.2–9.2) injuries per 1000 athlete-days[a]
Marqueta *et al.*, 2005[24] Location: Netherlands Sample selection: convenience Injury record: not reported	n* = 34 Sex: both sex Average age: 26.6 (range from 15 to 41) years	Sport: athletics Mean practice duration: not reported	Visual impairment, cerebral palsy, amputation, upper limb atrophy, brachial paralysis, superior limb agenesis, tetraplegia, paraplegia and Charcot-Marie-Tooth disease	Injury was defined as 'any circumstance that affecting the musculoskeletal system has motivated a consultation medical and / or assistance by both the doctor as by the physiotherapists of the selection'	10	50	70.5% (24**)	147.1 (95% CI, 106.3–187.8) injuries per 1000 athlete-days[a]
McCormick *et al.*, 1990[25]	n* = 777 Sex: both sex	Sport: soccer, equestrian, track /	Intellectual impairment	A sports injury was defined as 'an injury	3	4	3.5% (27**)	1.7 (95% CI, 0–3.4) injuries per 1000

Location: USA Sample selection: convenience Injury record: Paediatrician, paediatric resident trainee, or registered nurse	Average age: not reported	field, swimming / diving, gymnastics Mean practice duration: not reported		resulting directly from participation in a sports event'				athlete-days[a]
Ona Ayala *et al.*, 2019[26] Location: Rio 2016 Paralympic Games Sample selection: convenience Games Injury record: WEB-IISS	n* = 180 Sex: both sex Average age: range from 12 to 75 years	Sport: powerlifting Mean practice duration: not reported	Not reported	Injury was defined as 'any newly acquired injury as well as exacerbations of preexisting injury that occurred during training and/or competition of the 3-day pre-competition and 7-day competition period at the Rio 2016 Paralympic Games'	10	22	78% (141**)	15.6 (95% CI, 9.61–21.59) injuries per 1000 athlete-days
Taylor *et al.*, 1995[27] Location: England Sample selection: convenience Injury record: self-reported	n* = 53 Sex: both sex Average age: 59% of athletes were aged from 25 to 39 years	Sport: wheelchair race Mean practice duration: 3 years (interquartile range of 1-5.75)	The most commonly were spinal cord injuries and spina bifida	An injury was defined as 'pain in any part of the body that affected or prevented the athlete from training or competing for at least 1 day'	365	44	72% (38**)	2.3 (95% CI, 1.6–2.9) injuries per 1000 athlete-days[a]
Willick *et al.*,	n* = 163	Sport:	Not reported	Injury was defined as	7	38	23.3%	3.3 (95% CI, 24.0–42.6)

2016[28] Location: London 2012 Paralympic Games Sample selection: convenience Injury record: LOCOG and WEB-IISS	Sex: both sex Average age: range from 13 to 67 years	powerlifting Mean practice duration: not reported		'any newly acquired injury as well as exacerbations of preexisting injury that occurred during training and/or competition of the 14-day pre-competition and competition period of the London 2012 Paralympic Games'			(38**)	injuries per 1000 athlete-days
Webborn *et al.*, 2006[29] Location: 2002 Salt Lake Winter Paralympic Games Sample selection: convenience Injury record: authors of the study, team physicians and other medical personnel	n* = 416 Sex: both sex Average age: 33 (range from 17 to 58) years	Sport: alpine skiing, nordic skiing and sledge hockey Mean practice duration: not reported	Not reported	The authors considered important to describe all sport-related conditions that might conceivably medical personnel affect the performance or functional capacity of the winter Paralympic athlete	20	39	9% (39**)	4.7 (95% CI, 3.2–6.2) injuries per 1000 athlete-days[a]
Willick *et al.*, 2013[30] Location: London 2012 Paralympic	n* = 3565 Sex: both sex Average age: 30 (range from 13 to 67) years	Sport: football 5-a-side, powerlifting, goalball, wheelchair	Not reported	Injury was defined as 'any sport-related musculoskeletal or neurological complaint prompting	Overall: 14 Pre-competition: 3 Competitio	Overall: 633 Pre-competition: 158	15.1% (539**)	Overall: 12.7 (95% CI 11.7–13.7) injuries per 1000 athlete-days Pre-competition: 14.8 (95% CI, 12.6–17.3)

Games Sample selection: convenience Injury record: London Organizing Committee of the Olympic and Paralympic Games (LOCOG) and own teams medical staff, utilizing a web-based injury and illness surveillance system (WEB-IISS)		fencing, wheelchair rugby, athletics, judo, wheelchair tennis, table tennis, wheelchair basketball, football 7-a-side, seated volleyball, cycling track, equestrian, swimming, archery, boccia, cycling road, sailing, rowing, shooting Mean practice duration: not reported		an athlete to seek medical attention, regardless of whether or not the complaint resulted in lost time from training or competition'	n: 11	Competitio n: 475		injuries per 1000 athlete-days Competition:12.1 (95% CI, 11.0–13.3) injuries per 1000 athlete-days
Fagher *et al*., 2020[31] Location: Sweden Sample selection: convenience Injury record: an eHealth based self-report application adapted to Paralympic	n* = 107 Sex: both sex Average age: range from 18 to 63 years	Sport: cycling, para athletics, para cross-country skiing, triathlon, canoe, goalball, judo, para alpine skiing, para ice hockey, para swimming, table tennis, wheelchair basketball, wheelchair rugby,	Physical, visual and intellectual impairments, central neurological impairment, *les autres*, limb deficiency, spinal cord injury	Sports-related injuries and illnesses in Paralympic sport (SRIIPS) were defined as 'any new musculoskeletal pain, feeling, injury, illness or psychological complaint that caused changes in normal training or competition to the	365	179	68% (73**)	6.9 (95% CI, 6.0–8.0) per 1000 hours[c]

athletes		wheelchair tennis, boccia, equestrian, sailing, shooting para sport, wheelchair curling. Mean practice duration: 5.8 years		mode, duration, intensity, or frequency, regardless of whether or not time was lost from training or competition'				
Haykowsky *et al.*, 1999[32] Location: Canada Sample selection: convenience Injury record: not reported	n* = 11 Sex: both sex Average age: from 22 to 75 years	Sport: powerlifting Mean practice duration: 5 (range: 0.25-11) years	Visual impairment	Injury was considered as powerlifting-related injuries that required medical intervention (from a physician, chiropractor, or physical therapist) and that resulted in an interruption in training for more than one day	365	Not reported	36% (4**)	0.1 injuries per 100 hours of training[b]
Lankhorst *et al.*, 2019[34] Location: Netherlands Sample selection: convenience Injury record: Questionnaire based on recommendation	n* = 103 Group 0 (no participation in organized sport at all): 18 Group 1 (sports participation at sport club one time per week): 21 Group 2 (sports	Sport: not reported Mean practice duration: not reported	Cardiovascular, pulmonary, musculoskeletal, metabolic or neuromuscular disorders according to the classification of the American College of Sports Medicine	Injury was defined as 'any new musculoskeletal pain, feeling or injury which results from participation in recreational physical activity or sports and causes changes in physical activities including sports	360 (Cumulative hours of physical activity during 1 year per group – group 0: 10,674; group 2:	86 Group 0: 9 Group 1: 17 Group 2: 60	46% (47**)	Group 0: 0.84 (95% CI, 0.38–1.6) per 1000 h of physical activity[c] Group 1: 1.88 (95% CI, 1.1–3.1) per 1000 h of physical activity[c] Group 2: 1.33 (95% CI, 1.0–1.7) per 1000 h of physical activity[c]

s of the Dutch Ministry of Health, Welfare and Sport (VWS) and designed in an online web-based tool	participation at sport club two or more times per week): 64 Sex: both sex Average age: 14.4 (SD 2.7) years			activities, regardless of whether or not time is lost from physical activity, sports training or competition'	9,019; group 2: 44,937)			
Magno e Silva *et al.*, 2013[35] Location: Brazil Sample selection: convenience Injury record: multidisciplinary Brazilian medical team	n* = 28 Paralympic Games 2004: 3 athletes Pan American Games 2005: 23 athletes IBSA World Championships 2007: 14 athletes Pan American Games 2007: 13 athletes Beijing 2008: 3 athletes Sex: both sex Average age: 36.5 (SD 9.7) years	Sport: swimming Mean practice duration: not reported	Visual impairment	A reportable injury was defined as 'any injury that caused an athlete to stop, limit, or modify participation for 1 or more days'	Paralympic Games 2004: 12[a] Pan American Games 2005: 20[a] IBSA World Championships 2007: 13[a] Pan American Games 2007: 17[a] Beijing 2008: 12[a]	Overall: 41 Paralympic Games 2004: 4 injuries American Games 2005: 7 injuries IBSA World Championships 2007: 22 injuries Pan American Games 2007: 6 injuries Beijing 2008: 2 injuries	Overall: 64% (18**) Paralympic Games 2004: 100% (3**) Pan-American Games 2005: 35% (8**) World Championship International Blind Sports Federation 2007: 79% (11*) Para Pan-American Games 2007: 38%	Overall: 0.3 injuries per athlete per competition Paralympic Games: 111.1 (95% CI, 2.2–220.0) injuries per 1000 athlete-days[a] Pan American Games 2005: 15.2 (95% CI, 3.9–26.5) injuries per 1000 athlete-days[a] IBSA World Championships 2007: 120.9 (95% CI, 70.4–171.4) injuries per 1000 athlete-days[a] Pan American Games 2007: 27.2 (95% CI, 4.4–48.9) injuries per 1000 athlete-days[a] Beijing 2008: 55.6 (95% CI, 0–132.6) injuries per 1000 athlete-days[a]

							(5**) Paralympic Games 2008: 33% (1**)	
Magno e Silva *et al.*, 2013[36] Location: Brazil Sample selection: convenience Injury record: multidisciplinary Brazilian medical team	n* = 13 Paralympic Games 2004: 8 athletes Pan American Games 2005: 8 athletes IBSA World Championships 2007: 8 athletes Pan American Games 2007: 8 athletes Beijing 2008: 8 athletes Sex: male Average age: 36.5 (SD 9.7) years	Sport: football 5-a-side Mean practice duration: not reported	Visual impairment	A reportable injury was defined as 'any injury that caused an athlete to stop, limit or modify participation for one or more days'	Paralympic Games 2004: 12[a] Pan American Games 2005: 20[a] IBSA World Championships 2007: 13[a] Pan American Games 2007: 17[a] Beijing 2008: 12[a]	Overall: 35 Paralympic Games 2004: 12 injuries American Games 2005: 6 injuries IBSA World Championships 2007: 7 injuries Pan American Games 2007: 3 injuries Beijing 2008: 7 injuries	Overall: 84.6% (11**) Paralympic Games 2004: 87.5% (7**) IBSA Para Pan-American Games 2005: 62.5% (5**) IBSA World Championship 2007: 62.5% (5**) Para-Panamerican Games 2007: 37.5% (3**) Paralympic	Overall: 0.1 injuries per match Paralympic Games 2004: 125.0 (95% CI, 54.3–195.7) injuries per 1000 athlete-days[a] Pan American Games 2005: 37.5 (95% CI, 7.5–67.5) injuries per 1000 athlete-days[a] IBSA World Championships 2007: 67.3 (95% CI, 17.5–117.2) injuries per 1000 athlete-days[a] Pan American Games 2007: 22.1 (95% CI, 0–47.0) injuries per 1000 athlete-days[a] Beijing 2008: 72.9 (95% CI, 18.9–126.9) injuries per 1000 athlete-days[a]

							Games 2008: 50.0% (4**)	
Magno e Silva *et al*., 2013[37] Location: Brazil Sample selection: convenience Injury record: multidisciplinary Brazilian medical team	n* = 40 Paralympic Games 2004: 11 athletes Pan American Games 2005: 28 athletes IBSA World Championships 2007: 28 athletes Pan American Games 2007: 19 athletes Beijing 2008: 22 athletes Sex: both sex Average age: 36.5 (SD 9.7) years	Sport: athletics Mean practice duration: not reported	Visual impairment	A reportable injury was defined as 'any injury that caused an athlete to stop, limit, or modify participation for 1 ≥ d'	Paralympic Games 2004: 12[a] Pan American Games 2005: 20[a] IBSA World Championships 2007: 13[a] Pan American Games 2007: 17[a] Beijing 2008: 12[a]	Overall: 77 Paralympic Games 2004: 11 injuries American Games 2005: 16 injuries IBSA World Championships 2007: 28 injuries Pan American Games 2007: 11 injuries Beijing 2008: 11 injuries	Overall: 78% (31**) Paralympic Games 2004: 82% (9**) IBSA Para Pan-American Games 2005: 46% (13**) IBSA World Championship 2007: 61% (17**) Para Pan-American Games 2007: 47% (9**) Paralympic Games 2008: 36% (8**)	Average incidence rate of 0.4 injuries per athlete per competition Paralympic Games 2004: 83.3 (95% CI, 34.1–132.6) injuries per 1000 athlete-days[a] Pan American Games 2005: 111.1 (95% CI, 2.2–220.0) injuries per 1000 athlete-days[a] IBSA World Championships 2007: 76.9 (95% CI, 48.4–105.4) injuries per 1000 athlete-days[a] Pan American Games 2007: 34.1 (95% CI, 13.9–54.2) injuries per 1000 athlete-days[a] Beijing 2008: 41.7 (95% CI, 17.0–66.3) injuries per 1000 athlete-days[a]
Saffarian *et al*., 2019[38] Location: 2013	n* = 409 Sex: both sex Average age:	Sport: archery, badminton, basketball,	Dwarfism	An injury or illness was described as 'any symptom that	8	24	5.9% (24**)	0.78 injury per 100 athlete-competitions

World Dwarf Games (USA) Sample selection: convenience Injury record: Physician or athletic training staff	Futures (6 years and younger), Junior A (7–11 years old), Junior B (12–15 years old), Open (any age), and Masters (35 and older)	boccia, floor hockey, kurling, powerlifting, shooting, soccer, swimming, table tennis, track and field, and volleyball Mean practice duration: not reported		an athlete was experiencing that led them to seek medical consultation from either an athletic trainer or a physician present at the games'				
Studies reporting only on prevalence (n = 7)								
Bernardi *et al*., 2003[46] Location: Italy Sample selection: randomly Injury record: Sports physicians	n* = 227 Sex: both sex Average age: range from 12 to 64 years	Sport: wheelchair tennis, fencing, athletics, swimming, wheelchair basketball and others Mean practice duration: not reported	Spinal cord injury, amputation, cerebral palsy and *Les autres* (disorders resulting in locomotor disabilities that did not fit into the previously mentioned categories)	'Sport-related muscle pain' was defined as any muscle pain experienced during the past 12 months that occurred during sport activity (training or competition) and/or was reported as a consequence of physical exercise, causing discomfort for at least 1 d and not being related to systemic disease	365	Not reported	50.7% (115**)	Not reported
Curtis *et al.*, 1999[47] Location: USA Sample selection: convenience	n* = 46 Sex: female Average age: 33.2 (SD 9.1) years	Sport: wheelchair basketball Mean practice duration: not reported	Spinal cord injury, lower extremity musculoskeletal and neuromuscular disabilities, post-polio, spina bifida	Wheelchair User's Shoulder Pain Index (WUSPI) was used to measure shoulder pain	Not reported	Not reported	72% (33**) of the subjects reported shoulder pain since	Not reported

Injury record: assistants			and amputation				wheelchair use and 89.1% (41**) of the subjects reported upper extremity pain since beginning wheelchair use	
Fagher *et al*., 2020[48] Location: Sweden Sample selection: convenience Injury record: Sports physiotherapists	n* = 104 Sex: both sex Average age: 29 (Interquartile range 23-36) years	Sport: cycling, para athletics, para cross-country skiing, triathlon, canoe, goalball, judo, para alpine skiing, para ice hockey, para swimming, table tennis, wheelchair basketball, wheelchair rugby, wheelchair tennis, boccia, equestrian, sailing, shooting para sport, wheelchair curling. Mean practice	Limb deficiency (amputation, dysmelia, congenital deformity), spinal cord injury, *Les autres*, central neurological injury (cerebral palsy, traumatic brain injury, stroke, other neurological), intellectual impairment, visual impairment, wheelchair athletes	The definition of current sports-related injuries and illnesses in Paralympic sport (SRIIPS) was: 'any new musculoskeletal pain, feeling, injury, illness or psychological complaint that caused changes in normal training or competition to the mode, duration, intensity, or frequency, regardless of whether or not time is lost from training or competition'	365	Not reported	31% (32**)	Not reported

		duration: 10 (Interquartile range 5-16) years						
Patatoukas *et al*., 2011[49] Location: 2000 Panhellenic Championship for Athletes with Disabilities (Greece) Sample selection: convenience Injury record: not reported	n* = 139 Sex: both sex Average age: 32.8 (SD 8.6) years	Sport: wheelchair basketball, standing track & field, swimming, wheelchair field, gym, wheelchair track, powerlifting, wheelchair dancing, shooting Mean practice duration: 7.2 (SD 5) years	Spinal cord injury, poliomyelitis, cerebral palsy, acquired brain injury, amputation, other disabilities (arthrogryposis, dysmelias, dwarfism, etc) and *Les Autres*	Athletic injury was defined as 'any injury that caused an athlete to stop, limit or modify participation for 1 day or more'	Not reported	178	49.6% (69**)	Not reported
Shimizu et al., 2017[50] Location: 2014 Asian Para Games (Japan) Sample selection: convenience Injury record: two physicians	n* = 22 Sex: female Average age: 29.1 (SD 8) years	Sport: wheelchair basketball Mean practice duration: 8.6 (SD 5.8) years	Central nervous system disorders (spinal cord injurys, spina bifida, cerebral palsy) and skeletal system disorders (transtibial amputation, hip disorder, knee disorder and ankle disorder)	Deep tissue injury (DTI) was defined as 'a purple or maroon localized area of discolored intact skin or a blood-filled blister due to damage to the underlying soft tissue from pressure and/or shear forces'	Not reported	23	68.2% (15**)	Not reported
Tenforde *et al.*, 2019[51] Location: USA Sample selection:	n* = 260 Sex: both sex Average age: 31.7 (SD 11.5) years	Sport: not reported Mean practice duration: not reported	Spinal cord injury, lower limb amputee, neurological injury, visual impairment, cerebral palsy,	Bone stress injury was defined as 'either stress reaction or stress fracture'	Not reported	Not reported	50% (130**)	Not reported

convenience Injury record: authors of the study			others, upper limb amputee, musculoskeletal disorder, arthrogryposis					
Zwierzchowska *et al.*, 2020[52] Location: Goalball European Championship Sample selection: convenience Injury record: authors assisted by a coach and team interpreter	n* = 43 Sex: both sex Average age: 26 years	Sport: goalball Mean practice duration: 6 years	Visual impairment	Sports injury was defined as "damage to body tissue resulting from practicing a sport or exercise" and the authors also used the time of absence from training and competitions as a criterion for classification of injury	9	Not reported	44% (19**)	Not reported
Studies reporting only on incidence rates (n = 10)								
Blauwet *et al.*, 2016[3] Location: London 2012 Paralympic Games Sample selection: convenience Injury record: London Organizing Committee of the Olympic and	n* = 977 Sex: both sex Average age: from 13 years	Sport: athletics Mean practice duration: not reported	Amputation, visual impairment, cerebral palsy, short stature and other disorders	Injury was defined as any newly acquired injury as well as exacerbations of preexisting injury that occurred during training and/or competition of the 14 day pre-competition and competition period of the London 2012 Paralympic Games	10	216	Not reported	22.1 (95% CI, 19.5–24.7) injuries per 1000 athlete-days

Paralympic Games (LOCOG) and own teams medical staff, utilizing a web-based injury and illness surveillance system (WEB-IISS)								
Ferrara *et al*., 1992[53] Location: USA Sample selection: convenience Injury record: self-reported	n* = 68 Sex: both sex Average age: 29.6 (SD 9.5) years	Sport: skiing Mean practice duration: 6.7 (SD 4.5) years	Leg and arm amputation, spinal cord injury, visual impairment, spina bifida, multiple sclerosis, muscular dystrophy and undescribed impairments	The definition of injury was 'any trauma to the participant that occurred during any practice training, or competition session that resulted in the cessation, limitation, or modification of the athlete's participation in the sport for at least 24 hours'	182	100	Not reported	8.1 (95% CI, 6.5–9.7) injuries per 1000 athlete-days[a]
Ferrara *et al*, 2000[54] Location: 1990 World Games and Championship (WC) in Assen, Holland, 1991	n* = 1360 (overall) WC: 220 athletes PT: 345 athletes PGI: 360 athletes AC: 55 athletes	Sport: multi sports events ranged from 14 to 21 different sports Mean practice duration: not reported	Not reported	A reportable injury was defined as 'an injury/illness that was evaluated by the US Medical Staff during these competitions'	WC: 13[a] PT: 12[a] PGI: 24[a] AC: 7[a] PGII: 14[a]	Overall: 1037 WC: 52 PT: 170 PGI: 387 AC: 22 PGII: 406	Not reported	WC: 18.2 (95% CI, 13.2–23.1) injuries per 1000 athlete-days[a] PT: 41.1 (95% CI, 34.9–47.2) injuries per 1000 athlete-days[a] PGI: 44.8 (95% CI, 40.3–49.3) injuries per

US Paralympic Trials (PT) in Hempstead, New York, 1992 Paralympic Games (PGI) in Barcelona, Spain, 1994 World Athletics Championships (AC) in Berlin, Germany, and 1996 Paralympic Games (PGII) in Atlanta, USA Sample selection: convenience Injury record: medical staff	PGII: 380 athletes Sex: both sex Average age: not reported							1000 athlete-days[a] AC: 57.1 (95% CI, 33.3–81.0) injuries per 1000 athlete-days[a] PGII: 76.3 (95% CI, 68.9–83.7) injuries per 1000 athlete-days[a]
Hollander *et al*., 2019[55] Location: Wheelchair Basketball World Championships 2018 in Germany Sample selection: convenience	n* = 132 Sex: both sex Average age: 29.7 (SD 6.1) years	Sport: wheelchair basketball Mean practice duration: not reported	Spinal cord injury	Injury was defined as 'any newly incurred musculoskeletal complaint (traumatic or overuse) and/or concussion during the tournament receiving medical attention regardless of the consequences for participation'	11	100	Not reported	68.9 (95% CI, 55.4–82.4) injuries per 1000 athlete-days

Injury record: IOC injury surveillance system for multi-sports events								
Nyland *et al.*, 2000[56] Location: 1996 Paralympic Games (USA) Sample selection: convenience Injury record: United States Olympic Committee (USOC)	n* = 304 Sex: both sex Average age: not reported	Sport: athletics, wheelchair basketball, cycling, equestrian, fencing, boccie, goalball, judo, quad rugby, lawn bowling, powerlifting, soccer, swimming, table tennis, tennis, sitting volleyball, standing volleyball Mean practice duration: not reported	Physical disabilities, visual impairment, cerebral palsy, stroke, acquired or congenital motor dysfunction and spinal cord injury	Soft tissue injuries were operationally defined as strain, sprain, tendonitis, bursitis, or contusion	10	254	Not reported	83.6 (95% CI, 73.3–93.8) injuries per 1000 athlete-days[a]
Webborn *et al.*, 2012[57] Location: 2010 Vancouver Paralympic Games Sample selection:	n* = 505 Sex: both sex Average age: not reported	Sport: alpine skiing, nordic skiing (include biathlon), ice sledge hockey and wheelchair curling Mean practice	Not reported	Injury was defined as ‘any sports-related musculoskeletal complaint that caused the athlete to seek medical attention during the study period,	17	106 injuries (actual injuries reported as 120 but need to remove 14 as states	Not reported	12.4 (95% CI, 10.0–14.7) injuries per 1000 athlete-days[a]

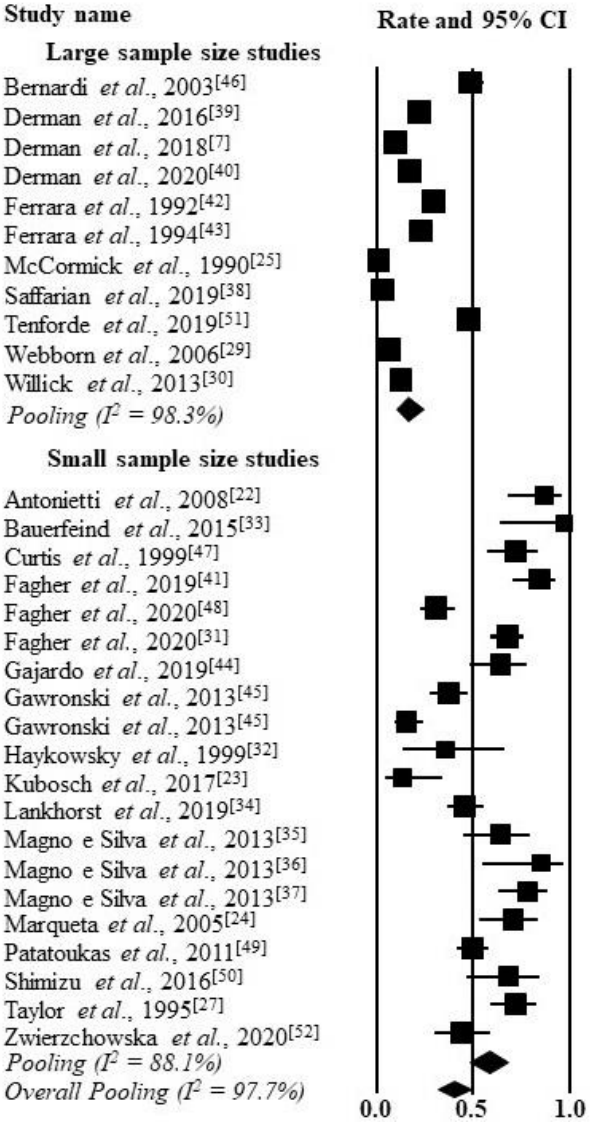
convenience Injury record: staff at the Polyclinics and venue medical		duration: not reported		regardless of the athlete's ability to continue with training or competition'		were not sports related)		
Webborn *et al*., 2016[58] Location: London 2012 Paralympic Games Sample selection: convenience Injury record: LOCOG and WEB-IISS	n* = 70 in Football 5-a-side and 96 in Football 7-a-side Sex: male Average age: not reported	Sport: football 5-a-side and football 7-a-side Mean practice duration: not reported	Visual impairment and central neurologic injury (cerebral palsy and traumatic brain injury)	Injury was defined as 'any newly acquired injury, as well as exacerbations of pre-existing injury that occurred during training and / or competition of the 14-day pre-competition and competition period of the London 2012 Paralympic Games'	14	Football 7-a-side: 22 Football 7-a-side: 14	Not reported	Football 5-a-side: 22.4 (95% CI, 14.1–33.8) injuries per 1000 athlete-days Football 7-a-side: 10.4 (95% CI, 5.4–15.5) injuries per 1000 athlete-days
Chung *et al.*, 2012[59] Location: China Sample selection: convenience Injury record: Physiotherapists	n* = 14 Sex: both sex Average age: 28.6 (SD 6.8) years	Sport: wheelchair foil fencers Mean practice duration: 10.1 (SD 5.3) years	Not reported	Injury was defined as trauma that occurred during a training / competition and prevented the athlete from continuing fencing activity for at least 1 day	24664 hours[b]	95	Not reported	3.9 per 1000 athlete hours (95% CI, 3.1–4.7)[c]
Ramirez *et al.*, 2009[60] Location: USA Sample selection:	n* = 210 Sex: both sex Average age: 18 (range from 10 to 23) years	Sport: adapted basketball, field hockey, soccer and softball Mean practice	Autism, emotional disturbance, learning disability, mental retardation orthopedic disability,	Injury episodes were defined as 'events resulting in immediate removal of the athlete from	19012 hours[a,b]	38	Not reported	2.0 injuries per 1000 athlete hours (95% CI, 1.4–2.6)[a,c]

convenience Injury record: study data collectors		duration: not reported	sensory disability, multiple disability, other health impairment	the session and medical treatment by school staff or transport to a hospital'. Injury diagnoses were defined as 'the physical trauma sustained to the body region of an athlete during the injury event'				
Ferrara *et al.*, 1996[61] Location: USA Sample selection: convenience Injury record: Athletes With Disabilities Injury Registry (ADIR) staff	n* = 319 Sex: both sex Average age: 31.6 (SD 9.3) years	Sport: not reported Mean practice duration: 7.8 (SD 6.5) years	Not reported	An injury was defined when 'a scheduled practice or competition was modified, missed, or interrupted due to an injury, illness, or pain for 1 day or more'	From April 1990 until September 1992	102	Not reported	9.4 injuries per 1000 athlete-exposures

CI: confidence interval
SD: standard deviation
n*: sample size
**Corresponds to the absolute prevalence of injury in para athletes
[a] Deduced or calculated from the study
[b] Exposure in hours
[c] Incidence Rate per 1000 h exposure

Supplementary material 3

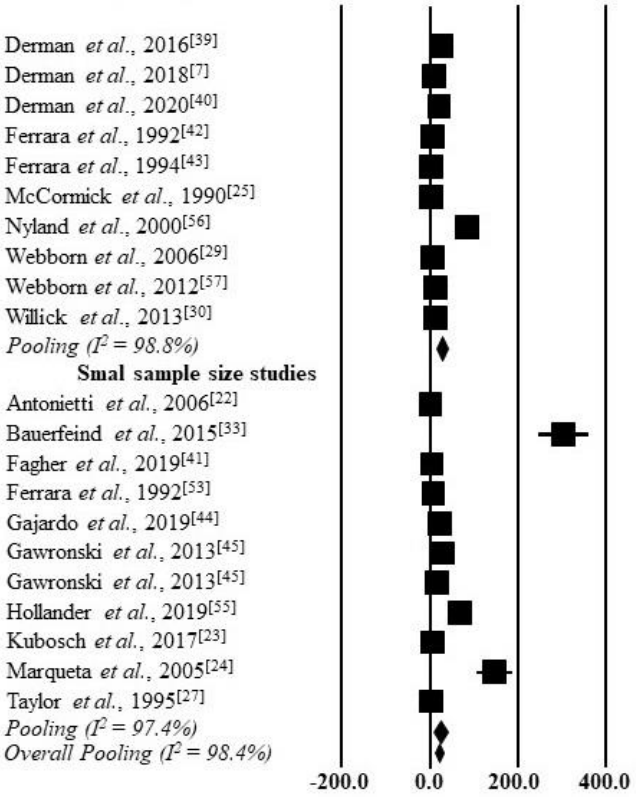
Meta-analysis for overall injuries prevalence in para athletes and subgroup analysis for studies with large and small sample size



Study name	Rate	Lower limit	Upper limit	Events / Total
Large sample size studies				
Bernardi *et al.*, 2003[46]	0.5	0.4	0.6	115 / 227
Derman *et al.*, 2016[39]	0.2	0.2	0.3	134 / 547
Derman *et al.*, 2018[7]	0.1	0.1	0.1	442 / 3657
Derman *et al.*, 2020[40]	0.2	0.2	0.2	112 / 567
Ferrara *et al.*, 1992[42]	0.3	0.3	0.4	136 / 426
Ferrara *et al.*, 1994[43]	0.2	0.2	0.3	54 / 217
McCormick *et al.*, 1990[25]	0.1	0.1	0.1	27 / 777
Saffarian *et al.*, 2019[38]	0.1	0.1	0.1	24 / 409
Tenforde *et al.*, 2019[51]	0.5	0.4	0.6	130 / 260
Webborn *et al.*, 2006[29]	0.1	0.1	0.1	37 / 416
Willick *et al.*, 2013[30]	0.1	0.1	0.2	538 / 3565
Pooling (I^2 = 98.3%)	0.2	0.1	0.3	1,749 / 11,068
Small sample size studies				
Antonietti *et al.*, 2008[22]	0.9	0.7	1.0	23 / 27
Bauerfeind *et al.*, 2015[33]	1.0	0.6	1.0	14 / 14
Curtis *et al.*, 1999[47]	0.7	0.6	0.8	33 / 46
Fagher *et al.*, 2019[41]	0.8	0.7	0.9	38 / 45
Fagher *et al.*, 2020[48]	0.3	0.2	0.4	32 / 104
Fagher *et al.*, 2020[31]	0.7	0.6	0.8	73 / 107
Gajardo *et al.*, 2019[44]	0.6	0.5	0.8	25 / 39
Gawronski *et al.*, 2013[45]	0.4	0.3	0.5	34 / 91
Gawronski *et al.*, 2013[45]	0.2	0.1	0.2	16 / 100
Haykowsky *et al.*, 1999[32]	0.4	0.1	0.7	4 / 11
Kubosch *et al.*, 2017[23]	0.1	0.1	0.3	3 / 24
Lankhorst *et al.*, 2019[34]	0.5	0.4	0.6	47 / 103
Magno e Silva *et al.*, 2013[35]	0.6	0.4	0.8	18 / 28
Magno e Silva *et al.*, 2013[36]	0.8	0.5	1.0	11 / 13
Magno e Silva *et al.*, 2013[37]	0.8	0.6	0.9	31 / 40
Marqueta *et al.*, 2005[24]	0.7	0.5	0.8	24 / 34
Patatoukas *et al.*, 2011[49]	0.5	0.4	0.6	69 / 139
Shimizu *et al.*, 2016[50]	0.7	0.5	0.8	15 / 22
Taylor *et al.*, 1995[27]	0.7	0.6	0.8	38 / 53
Zwierzchowska *et al.*, 2020[52]	0.4	0.3	0.6	19 / 43
Pooling (I^2 = 88.1%)	0.6	0.5	0.7	567 / 1,083
Overall Pooling (I^2 = 97.7%)	0.4	0.3	0.5	2,316 / 12,151

Supplementary material 4

Meta-analysis for overall injuries incidence rate in para athletes and subgroup analysis for studies with large and small sample size



Rate	Lower limit	Upper limit	Number of injuries	Person-time at risk
26.5	22.6	30.4	174	7
10.0	9.1	10.8	510	51
20.9	17.4	24.3	142	7
5.1	4.6	5.6	388	77
3.7	3.1	4.3	144	39
1.0	0.0	3.4	4	2
83.6	73.3	93.8	254	3
4.7	3.2	6.2	39	8
12.3	10.0	14.7	106	9
12.7	11.7	13.7	633	50
14.4	11.1	17.7	2394	252
1.8	1.0	2.7	18	10
302.9	245.2	360.5	106	0
4.3	3.3	5.3	70	16
8.1	6.5	9.7	100	12
22.9	13.9	31.9	25	1
29.8	22.1	37.6	57	2
15.0	9.0	21.0	24	2
68.9	55.4	82.4	100	1
6.7	4.2	9.2	27	4
147.1	106.3	187.8	50	0
2.3	1.6	2.9	44	19
14.7	11.1	18.5	621	69
14.3	11.9	16.8	3015	321

Supplementary material 5

Studies that reported injury profile in para athletes

		Studies
Most affected body location	**Shoulder**	Antonietti *et al*., 2008[22], Bauerfeind *et al*., 2015[33], Bernardi *et al*., 2003[46], Chung *et al*., 2012[59], Curtis *et al*., 1999[47], Derman *et al*., 2016[39], Derman *et al*., 2018[7], Derman *et al*., 2020[40], Fagher *et al.*, 2019[41], Fagher *et al*., 2020[31], Fagher *et al.*, 2020[48], Ferrara *et al*., 1992[42], Gajardo *et al*., 2019[44], Haykowsky *et al*., 1999[32], Kubosch *et al*., 2017[23], Ona Ayala *et al*., 2019[26], Willick *et al*., 2013[30], Willick *et al*., 2016[28]
	Upper limbs	Ferrara *et al*., 1992[53], Ferrara *et al*., 1996[61], Taylor *et al*., 1995[27], Zwierzchowska *et al*., 2020[52]
	Lower Limbs	Ferrara *et al*., 1994[43], Lankhorst *et al*., 2019[34], Magno e Silva *et al*., 2013[37], Magno e Silva *et al*., 2013[36], Marqueta *et al*., 2005[24], Ramirez *et al.*, 2009[60], Saffarian *et al*., 2019[38], Tenforde *et al*., 2019[51], Webborn *et al*., 2016[29]
	Trunk	Ferrara *et al.*, 2000[54], Magno e Silva *et al*., 2013[35], Hollander *et al.*, 2019[55]
Type of injury	**Soft tissue injury**	Bauerfeind *et al*., 2015[33], Bernardi *et al*., 2003[46], Blauwet *et al*., 2016[3], Chung *et al*., 2012[59], Fagher *et al.*, 2019[41], Fagher *et al.*, 2020[31], Ferrara *et al*., 1996[61], Ferrara *et al.*, 2000[54], Gawroński *et al.*, 2013[45], Hollander *et al.*, 2019[55], Lankhorst *et al*., 2019[34], Magno e Silva *et al*., 2013[35], Magno e Silva *et al*., 2013[37], Magno e Silva *et al*., 2013[36], Marqueta *et al*., 2005[24], McCormick *et al*., 1990[25], Patatoukas *et al.*, 2011[49], Ramirez *et al.*, 2009[60], Saffarian *et al*., 2019[38], Webborn *et al*., 2006[29], Zwierzchowska *et al*., 2020[52]
Injury presentation	**Sudden onset**	Antonietti *et al*., 2008[22], Bernardi *et al*., 2003[46], Blauwet *et al*., 2016[3], Derman *et al*., 2016[39], Derman *et al*., 2018[7], Derman *et al*., 2020[40], Fagher *et al.*, 2019[41], Ferrara *et al.*, 2000[54], Magno e Silva *et al*., 2013[36], Marqueta *et al*., 2005[24], Nyland *et al*., 2000[56], Saffarian *et al*., 2019[38], Tenforde *et al*., 2019[51], Webborn *et al*., 2006[29], Webborn *et al*., 2016[58], Willick *et al*., 2013[30], Zwierzchowska *et al*., 2020[52]
	Gradual onset	Bauerfeind *et al*., 2015[33], Fagher *et al.*, 2020[31], Fagher *et al.*, 2020[48], Ferrara *et al*., 1992[42], Ferrara *et al.*, 1992[53], Kubosch *et al*., 2017[23], Hollander *et al.*, 2019[55], Magno e Silva *et al*., 2013[35], Magno e Silva *et al*., 2013[37], Ona Ayala *et al*., 2019[26], Taylor *et al*., 1995[27], Webborn *et al.*, 2012[57], Willick *et al*., 2016[58]