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Injuries in weightlifting and powerlifting: an updated systematic review

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ABSTRACT

Objective To systematically review the literature on the incidence, prevalence, anatomical injury localisation and risk factors in Olympic weightlifting and powerlifting.

Design Updated systematic review, PROSPERO registration (CRD42022382364).

Data sources Four databases (PubMed, Embase, SPORTDiscus and Web of Science) were searched on 19 February 2024.

Eligibility Reports assessing injury incidence and prevalence in Olympic weightlifting and powerlifting, published between January 2015 and February 2024, were included in addition to reports from a previous systematic review. The 'Quality Assessment Tool for Observational Cohort and Cross-sectional Studies' was used to assess methodological quality.

Results Of 1765 screened records, eight new reports were found, resulting in 17 reports in the review. 12 reports covered weightlifting and seven covered powerlifting, with two of the reports included in both categories as they addressed both sports. In weightlifting, the period prevalence of injuries during competitions was 10.7%–68%, the incidence was 2.4–3.3 injuries/1000 hours of training, and the most common injury sites were the knee, lower back, shoulder and hands/fingers. In powerlifting, one report showed a point prevalence of 70%. Injury incidence was 1.0–4.4 injuries/1000 hours of training, and the most common injury sites were the lower back/pelvis, shoulder and elbow/upper arm. Both sports showed a high prevalence of pelvic floor dysfunction (eg, urinary incontinence) among females (50%) compared with males (9.3%).

Conclusions This updated systematic review supports the conclusions of previous reviews and shows new findings that pelvic floor dysfunction is very common in both sports. Due to the distinctly different study designs and settings, further direct comparisons between sports were difficult. In weightlifting, reports mainly focused on injuries during competitions. In powerlifting, injury incidence was low, but injury prevalence was high when defining injury as a painful condition that impairs training/competition.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ The injury incidence in both sports is considered low, and injuries commonly occur in the spine, knee and shoulder areas.
⇒ Mechanisms of injuries and risk factors have been hypothesised but still not established.

WHAT THIS STUDY ADDS

⇒ Weightlifting had a clearly higher proportion of injuries to the knee and hands/fingers, and powerlifting had a higher proportion of injuries to the elbow/upper arm. Both sports had similarly high proportions of injuries to the lower back/pelvis region and shoulder region. Pelvic floor dysfunction seem highly prevalent in both sports, more so in female lifters.
⇒ This review shows that injury rates in both sports are still relatively low. However, depending on the time frame of injury registration and definition of injury, the injury prevalence can be considered high.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This review suggests that the acute and chronic load on different body regions might be more important as risk factors than the specific movements performed in respective sports since both sports display similar proportions of shoulder and low back injuries, despite differences in absolute loads and biomechanical demands between sports.
⇒ This review indicates a need for a more homogenous study design in both sports, with prospective studies conducted according to current sports injury epidemiology guidelines.

INTRODUCTION

Olympic weightlifting (hereafter named weightlifting) and powerlifting are two popular strength sports that focus on lifting the most weight in one repetition.[1 2] Weightlifting involves two events: the snatch and the clean and jerk.[1] Powerlifting involves three events: the squat, bench press and deadlift.[2] Over the past decade, both weightlifting and powerlifting have experienced a significant increase in participation, with lifters competing at various levels, from local to international.[1 2]

While both sports share a common objective of lifting the heaviest weight in their respective events, there are differences in their techniques and training methodologies.

Powerlifting includes higher maximal loads relative to body weight[2] and focuses on maximal force production. Conversely, weightlifting movements occur faster and require a greater range of motion and focus on maximal power production, that is, being able to generate force rapidly within a short time frame.[3]

Although a previous systematic review[4] concluded that both sports have a relatively low risk of injury (2.4–3.3 injuries/1000 hours for weightlifting and 1.0–4.4 injuries/1000 hours of powerlifting training), injuries during heavy lifting while training or competing is a recognised problem in both sports. Potential risk factors for injuries include excessively heavy loads in extreme joint positions that require a large range of motion. For instance, Bengtsson *et al*[5] and Gross *et al*[6] describe the bench press and the snatch as exercises that are generally considered risk factors for injuries to the shoulder area because of the high loads in outer range positions. Further, Kujala *et al*[7] proposed that performing deep squat movements could potentially elevate the risk of developing osteoarthritis, an exercise incorporated into the training regimens of weightlifters and powerlifters. Even though several theories exist on the injury mechanisms in both sports, there is a lack of evidence to support these hypotheses.

The definition of sports injuries can vary between studies, making it challenging to get an accurate overview of these injuries. Some definitions will be restricted to consequences of sudden, damaging events such as strains and lacerations.[8] Other definitions can be classified as having any type of pain or physical impairment that would impact the normal training of the athlete.[9] The previous systematic reviews on injury epidemiology in weightlifting and powerlifting were published in 2017, but the reviews were searched for articles until April/September 2015.[4,10] Also, two more recent reviews have been conducted, but none have been as comprehensive as the two by Aasa *et al*[4] and Keogh *et al*[11] For example, one review[12] included only three reports on powerlifting and the other[13] included study designs and populations not relevant to investigating injury rates and risk factors. Several reports on injuries in weightlifting and powerlifting have been published since, and both sports have continued to grow and undergone changes in their organisation and practice. Thus, there was a need for an updated synthesis of the literature. Understanding the injury incidence, prevalence and risk factors of injuries in powerlifting and weightlifting can help inform injury prevention strategies and help coaches, lifters and therapists better tailor training programmes to reduce the risk of injury. The purpose of this study was to systematically review the most recent literature on the incidence, prevalence, anatomical injury localisation and risk factors in Olympic weightlifting and powerlifting, thereby updating prior research.

METHODS

The methods were according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses.[14] The review was preregistered in PROSPERO before starting the search process (CRD42022382364) (https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42022382364).[15]

Eligibility criteria

Inclusion criteria

Reports from peer-reviewed and peer-reviewed observational studies published after 1 January 2015 were included. This cut-off date was chosen because the previous systematic reviews[4,10] had searched for articles until April/September 2015. In addition, the reports from Aasa *et al*[4] were also included in the present review. The eligibility criteria were based on the PECO (population, exposure, comparator, outcome) strategy, considering observational studies in competitive weightlifters and/or powerlifters (P), which were (E) or not (C) injured to identify the point or period prevalence and/or incidence of injury (O).

Exclusion criteria

Reports that included lifters defined as recreational lifters, lifters from other strength sports (eg, CrossFit, bodybuilding or strongman) or reports including lifters in federations without random drug testing were excluded. Additionally, reports that included weightlifting and/or powerlifting athletes with a disability were excluded as they do not participate in all the events of weightlifting/powerlifting, and the study population would not be generalisable to the majority of lifters. Further, reports that did not include all events from powerlifting and/or weightlifting were excluded. Also, reports with the following study designs were excluded: narrative, scoping, systematic reviews or clinical trials.

Information sources

The literature search was initially performed in December 2022 and updated on 19 February 2024 using the following databases: PubMed, Embase, SPORTDiscus and Web of Science.

Search strategy

The search strategy included terms for describing the individual sports (ie, weightlifting and powerlifting) and the events of the sports. Further, search terms describing occurrence and risk are also included, as well as terms describing risk factors for injury and specific terms for injuries (online supplemental Data 1). Grey literature, that is, dissertations, theses and conference abstracts, were not searched for or sought after.

Selection process

The screening process consisted of two steps: first, titles and abstracts were reviewed for relevance by two independent reviewers (MT and GL), and second, the full texts of selected records were independently assessed by the same reviewers to determine their suitability for inclusion. Authors of primary studies were not contacted to clarify eligibility. In both stages, Rayyan software[16] was used by two authors to analyse studies independently (MT and GL). In each step, when a consensus could not be reached, two additional authors (ADL and LB) participated and helped in coming to a conclusion. Additionally, all reports from the previous review were added.[4] Reference lists of included reports were also screened for relevant titles and screened for eligibility. The screening process was performed manually without the use of automated or semiautomated approaches.

Data collection process

Two authors (MT and GL) extracted available data from reports by creating individual tables to analyse outcomes. Next, both authors (MT and GL) combined their individual data tables to minimise the risk of missing any relevant information. When any uncertainties were met, two additional authors (ADL and LB) participated and helped reach a conclusion. In case multiple reports were included from the same study, data were extracted from each report separately and then presented across multiple tables.

Data items

The following data were sought and tabulated from each report: aim, study type, population, injury incidence (injuries/1000 hours), prevalence (%), injury type, injury severity, onset of injury, time-loss due to injury, injury localisation and exposure. No assumptions were made about missing or unclear information, and effect measures were not calculated to avoid any potential bias.

Study risk of bias assessment

The Quality Assessment Tool for Observational Cohort and Cross-sectional Studies was used to assess the quality of included reports.[17] Each of the four authors independently reviewed the reports and compared their findings. Disagreements were resolved through discussion until a consensus was reached. After, each report received an overall quality rating score of either 'poor', 'fair' or 'good'.[17] The assessment tool does not provide a set guide for the appraisal of the overall quality. Therefore, the assessors must evaluate the risk of bias of each report on its own in relation to how each criterion of the assessment tool would affect the overall quality and the internal validity of the reports.[17] In this review, based on the assessment tool criteria, each report was assigned a quality rating of 'good' if it addressed question nine, 'Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?' and four other questions; 'fair' if it addressed between four and five questions and 'poor' if it addressed less than three questions. Criteria 12 and 13 were not applicable to the aims of this review, so these criteria were not considered a flaw in the methodology of the reports.

Synthesis methods

All data sought (see data items) were extracted to tables, including each report and the available data presented in those reports. In the following synthesis of results, data was presented and grouped by reports reporting the prevalence and/or incidence of injuries. Moreover, all results were transformed into percentages to facilitate easier comparison across multiple reports. Due to the heterogeneity of study designs, we did not combine the data for analysis. In case a report did not have all outcomes available for data extraction, this was noted.

Equity, diversity and inclusion statement

The analysis and interpretation of the review's results examined the differences between females and males, focusing on highlighting the implications of one of the main findings for female lifters. The review excluded athletes living with disability in order to generalise the results to lifters without disabilities. The review did not limit the language of articles to English, thus enabling a diversity of international research. The investigation team comprised four men from diverse career stages and clinical disciplines, representing three different countries—the USA, Sweden and Hong Kong.

RESULTS

The systematic review process was performed in accordance with the preregistered protocol, and no amendments were made except for the inclusion of reports from the previous review by Aasa *et al*[4]

Study selection

The systematic literature search yielded a total of 2786 potentially relevant records, which were screened for eligibility. The results are presented in figure 1. In addition, nine reports[8 11 18–24] were included from the previous review by Aasa *et al*.[4] A list of all excluded full-texts and reasons for exclusion is provided in online supplemental Data 2. In total, 17 reports, representing 16 samples, met the inclusion criteria and were assessed for risk of bias.

Risk of bias in studies

Five reports were of 'good'[11 25–28] quality, while six were considered 'fair'[8 20 21 24 29 30] and six were considered 'poor'.[18 19 22 23 31 32] The full breakdown of results from the quality assessment is presented in online supplemental Data 3. This represents a notable improvement compared with the previous systematic review by Aasa *et al*,[4] which identified only one[11] out of nine reports of 'good' quality. As seen in online supplemental Data 3, criteria pertaining to describing the objectives, population, recruitment, definition of exposure measures and including an analysis of potential confounding factors in the statistical analysis were done well across most reports (criteria one, two, three, nine and 14). Conversely, criteria pertaining to power calculation of sample size, blinding of assessors and several criteria related to the time frame of reports (ie, a prospective design would have improved quality) were not fulfilled adequately (criteria five, six, seven, 10, 12 and 13). Additionally, related to the risk of bias, data on injury

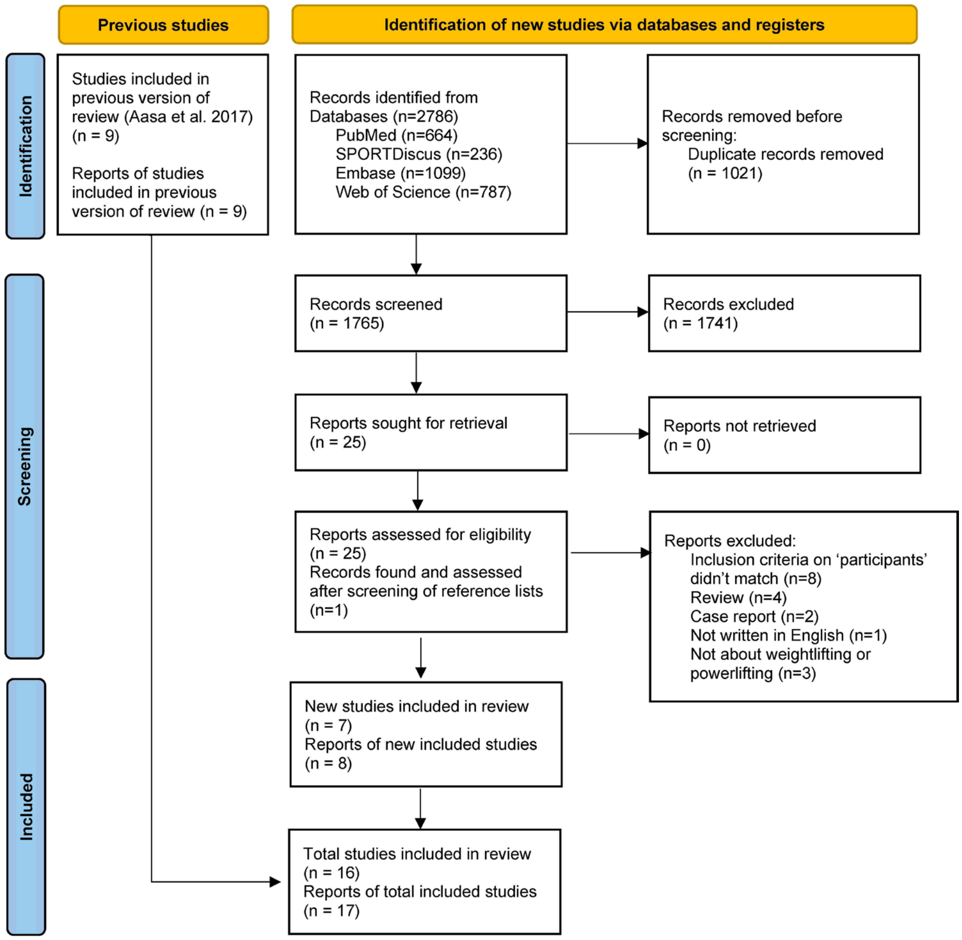

Figure 1 Flow chart of the literature screening according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).

prevalence in the report by Müller *et al*[31] were only presented in a figure, and data were therefore approximated.

Study characteristics

In total, 3062 lifters were analysed in the 17 included reports[8 11 18–32] which represented 16 samples. These were further broken down into 2161 weightlifters and 901 powerlifters. The reports from Ashikaga *et al*[30] and Soligard *et al*[27] both examined data from the same population of weightlifters as part of the 2020 Olympic Games. The reports from Raske *et al*[24] and Skaug *et al*[25] included both powerlifters and weightlifters. The competitive experience of all the lifters varied from 1 year experience to elite national-level lifters (participated in at least one national championship) to international lifters (participated in at least one international competition), except for two reports by Brown *et al*[22] and Müller *et al*,[31] where adolescent competitors were included. Basic characteristics, including injury incidence, prevalence and exposure measures in each report, are presented in online supplemental Data 4.

Results of individual studies

Definition and classification of injuries

The definition and classification of injuries varied among the included reports. For instance, five reports classified injury as any physical impairment that prevented training as an injury with/without the addition of physical damage or incident leading as the cause of injury.[11 23 24 26 32] In contrast, Brown *et al*[22] and Jonasson *et al*[20] defined injury as having a pain condition, and Müller *et al*[31] defined injury as acute pain experienced in the back within the last 7 days. A scale for measurement was used: none, little, moderate, strong and maximum. The report from Ashikaga *et al*[30] classified an injury as any case handled by an athletic trainer, physical therapist, nurse or attending physician. Five reports[8 21 27–29] classified an injury as any new or recurring medical condition incurred during a specific competition period, either in training or during actual competition, regardless of the consequences with respect to absence from lifting. The report from Skaug *et al*[25] considered any pelvic floor dysfunction (PFD) as an injury involving urinary incontinence (UI), anal incontinence (AI) or pelvic organ prolapse (POP), using the definitions provided by the International Urogynecological Association and International Continence Society.

The reports from Kulund *et al*[18] and Calhoon *et al*[19] did not provide a definition of injury. Injuries were not categorised uniformly in all reports. Some did not categorise injuries at all, and the others categorised in terms of their time from debut (acute, chronic, recurrent) or in which situation the injury debuted (contact, non-contact, training or competition) (online supplemental Data 5).

Weightlifting

Prevalence, incidence and risk factors

12 of the included reports reported injuries in weightlifting, and the study design, population, prevalence, incidence and exposure are presented in the online supplemental Data 5.[8 18–21 24 25 27–31] Six reports[8 21 27–30] presented data on period prevalence during the competition (eg, Olympic Games), and the other six investigated injury point prevalence and incidence using questionnaires.[18–20 24 25 31] Notably, Müller *et al*[31] only investigated the prevalence of back pain, and Skaug *et al*[25] investigated exclusively PFD and presented point prevalence data of PFD (ie, AI, UI and POP). Six reports[8 21 27–30] reported a period prevalence of injuries during competitions of 10.7%–68%, and two reports[19 24] showed an incidence of 2.4–3.3 injuries/1000 hours of training. Skaug *et al*[25] was the only report identifying risk factors for injuries (PFD) in weightlifting.

Anatomical localisations of injuries

Six reports[18 19 21 27 28 30] on weightlifting reported total injuries and their anatomical localisation in numbers, thus enabling the calculation of the proportion of injuries in different locations in relation to the total number of injuries. The highest proportion of injuries were at the knee (21%), lower back (19%), hand/fingers (15.3%) and shoulder (15.3%) regions. As mentioned, Müller *et al*[31] only investigated back pain among adolescent lifters, and Skaug *et al*[25] reported pelvic floor injury dysfunctions. The report by Lhee *et al*[29] did not examine the localisations of injuries when they investigated injuries during the Asian Games. Data on the anatomical localisation of injuries in all reports are presented in table 1.

Injury onset, types of injuries, severity and time-loss due to injury

All available data on injury onset, type, severity and time-loss due to injury are presented in online supplemental Data 5). Four[19 21 27 28] out of 12 reports categorised injury onset as acute or gradual, and two reports[8 21] categorised injury onset in relation to training or competition. Notably, the report by Calhoon *et al*[19] and the reports conducted during the Olympic Games[21 27 28] showed a higher proportion of injuries with acute onset. The other eight did not report injury onset. Four reports[19 21 27 28] described injury types/severity based on the tissue mechanism related to the injury (eg, strain, sprain, fracture, etc), and the report by Ashikaga *et al*[30] classified injury severity based on the type of medical attention required. Muscle strains and pulls were the dominant type of injury in these reports. Five reports[8 19 21 29] included data on time-loss due to injury measured in days, and the report by Skaug *et al*[25] reported the consequence of injury, such as avoiding training due to injury.

Powerlifting

Prevalence, incidence and risk factors

Seven of the included reports investigated injuries among powerlifters, and the study design, population, prevalence, incidence and exposure are presented in online supplemental Data 4).[11 22–26 32] All reports collected data through questionnaires asking about current injuries and/or previous injuries. One retrospective report asked about injuries during the powerlifters' whole career.[22] Five reports[11 22–24 32] presented injury incidence based on retrospective questionnaires, and two[25 26] reported point prevalence of injuries. One report[26] showed a point prevalence of 70%, and five reports[11 22–24 32] reported an incidence between 1.0 and 4.4 injuries/1000 hours of training. Three reports presented the analysis of risk factors for injuries. Reichel *et al*[32] identified low training frequency as a potential risk factor for injuries because of 'undertraining'. The report by Stromback *et al*[26] showed that there was a significant association between powerlifters with low back pain experiencing the injury onset during deadlift training and the onset of shoulder injuries during bench press training. The report by Skaug *et al*[25] also identified risk factors for PFD.

Anatomical localisations of injuries

Five reports[11 22 23 26 32] on powerlifting reported total injuries and their anatomical localisation in numbers, thus enabling the calculation of the proportion of injuries in different locations in relation to the total number of injuries. The highest proportion of injuries were in the lower back (30.8%), shoulder (19.6%) and elbow/upper arm (8.0%) regions. Further, the report by Stromback *et al*[26] found a significantly higher percentage of males sustained injuries to the lumbopelvic region, whereas females had a significantly higher incidence of injuries in the neck/cervical and thoracic areas. Data on the anatomical localisation of injuries in all reports are presented in table 1.

Injury onset, types of injuries, severity and time-loss due to injury

All available data on injury onset, type, severity and time-loss due to injury are presented in online supplemental Data 5). Three out of the seven reports categorised injury onset as acute or gradual, and the results were inconsistent. Stromback *et al*[26] described that 70% of injuries had a gradual onset, and the other two[11 32] found that acute onset was slightly more common than gradual. Notably, Stromback *et al*[26] was the only study in which powerlifters were asked about their current injuries (online supplemental Data 4). Two reports[22 32] described injury types/severity based on tissue mechanisms related to the injury (eg, pulls, cramps, inflammation, etc) and showed that acute muscular injuries were most frequent. Three reports[25 26 32] included data on time-loss/consequences of injuries in either the duration (days) needed to be spent

Table 1 Summary of number of injuries in total and for each anatomical location (n) and per cent of injuries for each anatomical location (%)

Study	Population	Number of injuries	Foot, leg	Knee	Thigh	Hip, groin	Hand, fingers	Elbow, upper arm	Shoulder girdle	Low back and pelvis	Thoracic and cervical spine	Other
Kulund *et al* 1978[18]	Olympic weightlifting	115	4, (3.5%)	26, (22.6%)	5, (4.3%)	3, (2.6%)	25, (21.7%)	11, (9.6%)	26, (22.6%)	8, (7%)	3, (2.6%)	Haemorrhoids 3, (2.6%), hernia 1, (0.9%)
Brown *et al* 1983[22]	Powerlifting	98	2, (2%)	8, (8.2%)	3, (3.1%)	4, (4.1%),	4, (4.1%)	8, (8.1%)	6, (6.1%)	49, (50%)	4, (4.1%)	Chest 7, (7.1%), abdomen 3, (3.1%)
Calhoon *et al* 1999[19]	Olympic weightlifting	560	30, (5.4%)	107, (19.1%)	31, (5.5%)	29, (5.2%)	56, (10%)	14, (2.5%)	99, (17.7%)	130, (23.1%)	57, (10.2%)	Head 4, (0.7%), chest 2, (0.4%), abdomen 1, (0.2%)
Raske *et al* 2002[24]	Olympic weightlifting and powerlifting	124	1, (0.8%)	24, (19%)	NA	9, (7%)	10, (8%)	9, (7%)	30, (24.2%)	26, (21%)	15, (12%)	NA
Keogh *et al* 2006[11]	Powerlifting	118	NA	11, (9.3%)	7, (5.9%)	2, (1.7%)	NA	16, (13.5%)	43, (36.1%)	28, (23.7%)	2, (1.7%)	Chest 4, (3.4%), other 5, (4.2%)
Junge *et al* 2009[8]	Olympic weightlifting	43	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Jonasson *et al* 2011†[20]	Olympic weightlifting	NA	27%	25%	NA	31%	NA	35%	50%	59%	44%	NA
Siewe *et al* 2011†[23]	Powerlifting	106	NA	NA	NA	NA	31, (12.7%)	NA	40, (16.3%)	37, (15.1%)	NA	Lower extremity, 34, (13.9%)
Engebretsen *et al* 2013[21]	Olympic weightlifting	44	4, (9.1%)	6, (13.6%)	2, (4.5%)	2, (4.5%)	3, (6.8%)	11, (25%)	5, (11.4%)	7, (15.9%)	3, (6.8%)	Other, 1, (2.3%)
Müller *et al* 2017†[31]	Olympic weightlifting	NA	NA	NA	NA	NA	NA	NA	NA	12%	NA	NA
Soligard *et al* 2017[28]	Olympic weightlifting	34	1, (2.9%)	3, (8.8%)	5, (14.7%)	NA	5 (14.7%)	7, (20.6%)	6, (17.6%)	6, (17.6%)	1, (2.9%)	NA
Stromback *et al* 2018‡[26]	Powerlifting	129 current	5, (3.9%)	9, (7%)	11, (8.5%)	20, (15.5%)	4, (3.1%)	5, (3.9%)	21, (16.3%)	25, (19.4%)	19, (14.7%)	Forearm 7, (5.4%), chest 3, (2.3%)
Reichel *et al* 2019[32]	Powerlifting	224	NA	NA	NA	NA	NA	25, (11.2%)	22, (9.8%)	69, (30.8%)	NA	NA
Skaug *et al* 2020[25]	Olympic weightlifting and powerlifting	379 pelvic floor	NA	NA	NA	NA	NA	NA	NA	NA	NA	*Female:* 90 UI, 144 AI, *Male:* 19 UI, 126 AI
Lhee *et al* 2021[29]	Olympic weightlifting	6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ashikaga *et al* 2022*[30]	Olympic weightlifting	112	7, (6.3%)	40, (35.7%)	5, (4.5%)	NA	46, (.1%)	12, (10.7%)	NA	2, (1.8%)	NA	NA
Soligard *et al* 2023*[27]	Olympic weightlifting	21	2, (9.5%)	4, (19%)	3, (14.3%)	NA	1, (4.8%)	3, (14.3%)	NA	6, (28.6%)	1, (4.8%)	Abdomen 1, (4.8%)

*Ashikaga *et al* (30) and Soligard *et al* (27) both investigated injuries during the 2020 Summer Olympics.
†Incomplete reporting,
‡Data acquired from authors (26).
NA, not available; AI, anal incontinence; UI, urinary incontinence.;

away from participating in the sports or simply to what extent the injury hindered the powerlifter from participating in the sports (eg, refraining partly or completely from training or competition).

PFD in weightlifting and powerlifting

The report from Skaug *et al*[25] was the only report that investigated the prevalence of PFD in both weightlifters and powerlifters but did not differentiate between the two sports. Their findings highlighted a high prevalence of UI and AI among males and females, with females reporting higher rates. Furthermore, females also reported POPs, that is, 'the downward descent of the female pelvic organs into or through the vagina'.[33] Female lifters reported 80.0% of overall AI, 50.0% overall UI and 23.3% POP, whereas males reported 61.8% overall AI and 9.3% overall UI. Among female lifters, stress UI (SUI) was the most prevalent type of UI, defined as 'the complaint of involuntary loss of urine on effort or physical exertion (eg, sporting activities) or on sneezing or coughing'.[33] Additionally, involuntary loss of gas was the most common form of AI (76.7%) in females. Among males, the prevalence of overall AI (61.8%) was high, whereas overall UI (9.3%) was less common. Similar to females, involuntary loss of gas was the most common form of AI in males (56.4%). For females, increasing body mass index, international level of competition and weightlifting more than 4 days per week were associated with SUI and AI. For males, increasing age and frequently straining to void were associated with the prevalence of AI.

DISCUSSION

This updated systematic review analysed 17 reports (including 16 individual samples), which included 3062 total lifters that investigated the prevalence, incidence, anatomical localisation and risk factors of injuries in weightlifting and powerlifting. Five reports were of 'good' methodological quality, six were 'fair' and six of 'poor' quality. When compared with the previous systematic reviews by Aasa *et al*[4] and Keogh *et al*,[10] the present updated review supports the previous findings, that is, demonstrates an overall low injury prevalence and incidence in both sports compared with other strength sports such as highland games or strongman (5.5–7.5 injuries/1000 hours of training).[10] The only exception was the study by Stromback *et al*,[26] which showed a high prevalence of pain affecting training/competition in powerlifters. Regarding the anatomical localisations of injuries, data in the present review supports the conclusions from the previous review,[4] with the main addition being the high prevalence of PFD, as shown in the report by Skaug *et al*.[25] Also, when comparing the proportions of injury localisations between the sports, it was evident that both sports have fairly high proportions of injuries to the lower back and shoulder region, but weightlifting had a clearly higher proportion of injuries to the knee and hands/fingers. Risk factors for injuries are lacking in both sports, but the present review showed some new results regarding risk factors for [25]PFD as well as an association of the onset of low back and shoulder injuries in deadlift and bench press training, respectively.[26] Both the previous and current study reviews emphasise the need for further high-quality research and prospective studies to provide more robust evidence on injuries and risk factors in weightlifting and powerlifting.

According to this review, injury in weightlifting was predominantly found in the knees, lower back, hands/fingers and shoulders. This could be attributed to the greater range of motion required at the knee joint during weightlifting exercises, such as the squat, which is performed to a greater depth than in powerlifting. Swinton *et al*[34] supported this by demonstrating that traditional weightlifting squats resulted in higher biomechanical forces at the knee and ankle, associated with increased flexion angles at both joints. In contrast, powerlifting squats typically involve a more vertical shin angle, resulting in less anterior displacement of the knee and greater muscular forces generated at the hip and lumbar spine, which might explain the comparatively higher prevalence of hip injuries, as shown in Stromback *et al*[26]

In weightlifting, six reports[8 21 27–30] focused on injury registration during competitions. The results indicated that injury prevalence at these events were comparable to previous weightlifting competitions. The prevalence at the Tokyo 2020 Olympics was found to be 10.7%.[30] This was lower than the prevalence found in studies of similar designs conducted on previous summer Olympic games, including 13.3% at Rio de Janeiro 2016,[28] 17.5% at London 2012,[21] and 16.9% at Beijing 2008.[8] Moreover, results indicate that the injury prevalence was similar to other sports with characteristics comparable to weightlifting, which is a non-contact sport that requires strength/power. For instance, during the London 2012 Olympic Games,[21] the injury prevalence was 7.7% for artistic gymnastics, 8.1% for diving and 17.7% for athletics. When comparing the results to the injury prevalence in popular contact sports that also require strength/power, the rates of weightlifting could be considered low. As evidence, during the Rio de Janeiro 2016 Olympic Games,[28] there were relatively higher injury prevalence of 19.4% for water polo, 23.6% for taekwondo and 30.1% for boxing. Regarding the reporting of injuries, there was interestingly some contradictory evidence from Ashikaga and Soligard regarding finger injuries at the Tokyo 2020 Olympic Games. Ashikaga *et al*[30] reported a significantly higher percentage of lifters who experienced injuries to their fingers than Soligard *et al*.[27] One explanation is that injuries presented by Ashikaga *et al*[30] were only recorded if the athlete used the medical venues provided inside the weightlifting competition venue at the Tokyo 2020 Olympic Games and did not account for those provided outside the venue, such as from their own respective therapists. In contrast, both reports by Soligard *et al*[27 28] included injuries reported by all National Olympic

Committee medical team members, including injuries treated outside of the competition venue.

In powerlifting, the included reports focused on self-reported injuries from lifters at different time points and during training or competition. The findings of the present updated review were consistent with the results from the previous systematic review by Aasa *et al*,[4] they reported an incidence of 1.0–4.4 injuries/1000 hours of training, similar to other non-contact sports requiring strength/power. To demonstrate, a report of injuries in gymnastics by Thomas *et al*[35] showed an incidence of 1.4 injuries/1000 hours and 1.5 injuries/1000 hours of training for males and females, respectively. However, another report by Jacobsson *et al*[36] showed an incidence of 3.57 injuries/1000 hours of training in track and field athletes. When compared with contact sports that require strength/power, the incidence of injuries in powerlifting is relatively low. For example, a report from Lystad *et al*[37] showed an incidence of 7.0 injuries/1000 hours of taekwondo training, while a report on American football by López-Valenciano *et al*[38] showed an incidence of 8.1 injuries/1000 hours of training.

Notably, the present review indicated that powerlifters report shoulder injuries to a similar extent as weightlifters, although the demands on the shoulders are different between sports. In the bench press exercise, one report on powerlifting described a significant positive association of lifters with shoulder injuries, also reporting that the injury started during bench press training.[26] Powerlifters often use a wider grip when performing the bench press, which might pose a high risk due to the shoulder joint's abducted and externally rotated position, as Green *et al* described.[39] It is worth noting that weightlifters use an even wider grip when executing the snatch, which may contradict this explanation. The authors of the previous systematic review on injuries among weightlifters and powerlifters[4] also pointed out that the weights used in the bench press are typically much heavier than those used in the snatch relative to body weight, thus placing higher forces on the shoulders at extreme positions. Interestingly, the biomechanics of the snatch and bench press movements differ significantly but tax the shoulder girdle, although in different ways. In the snatch, the shoulders are primarily used to stabilise the bar during the receiving portion of the lift, while in the bench press, the shoulders are consistently engaged and apply force throughout the entire movement. Therefore, this might imply that the shoulder's loading, acutely and chronically, is associated with shoulder injuries in both sports instead of the specific joint movements or muscle actions performed in the different lifts.

Although PFD is not ordinarily considered a typical musculoskeletal injury within sports, the report by Skaug *et al*[25] showed that lifters reported a negative impact of leakage on their performance in sports, and, for some lifters, led to limitations or cessations of the sport itself.[25] Male lifters seemed to not suffer from PFDs to the same extent as female lifters, as the prevalence of UI among males was within the same range as the general male population.[40] However, the males did not recognise the topic as a problem. This coping mechanism observed was a common trend among male lifters to protect their self-esteem or prevent embarrassment. In contrast, PFDs had more implications for the performance of females, as they exhibited higher rates of UI and AI in all but one category.[25] Notably, the UI rates in female weightlifters and powerlifters in the report by Skaug *et al*.[25] (50%) were considerably higher compared with athletes in a wide range of sports, as presented in a meta-analysis by Teixeira *et al*,[41] showing a weighted average of 36.1%.[41] The report by Skaug *et al*[25] highlights the need for increased awareness and management of PFDs in athletes, particularly female weightlifters and powerlifters, to improve athletic performance and overall quality of life. Health professionals working with these athletes should provide specialised training and interventions to target PFDs in athletes, including strengthening programmes and education.

Methodological limitations

There are some methodological limitations that need to be addressed. First, a potential limitation regarding the search and review process is that the search for the present review began immediately after the previous systematic review[4] concluded its search. Additionally, this review included all records from the review by Aasa *et al*.[4] Relying on previous reviews in this manner may have caused the current review to overlook some records, especially if the search strategy used in the previous review was incomplete. Second, two authors of the present study (ADL and LB) were also coauthors of three[26–28] of the included reports, which highlights a potential for bias in assessing the included reports' methodological quality. However, the quality assessment was completed by all four authors, and the final assessment was a consensus agreement.

A further limitation relating to the strength of evidence relates to the quality assessment. The items that lowered the methodological quality of all included reports were items six and seven, which refer to including a data collection period for a longer timeframe, which none included since most had a cross-sectional design. Further, items four and five also lacked information in most reports, that is, they did not specify eligibility criteria or provide a power analysis or clear rationale regarding the sample size. Therefore, to improve the study quality, a prospective study design, including providing clear eligibility criteria and rationale for the sample size and statistically controlling for training exposure and other relevant variables, is needed to improve existing knowledge.

Finally, several reports on weightlifting have focused on injuries occurring during competitions. Future studies should also examine the incidence of chronic or overuse injuries occurring during training rather than exclusively in competition. As such, future studies can explore using more objective injury assessment methods.

Direct comparisons within and between reports of the two sports were challenging due to differences in study design, study settings and the presentation of data in each report. Therefore, a suggestion for further research on injuries in weightlifting and powerlifting is to follow the International Olympic Committee's consensus statement on 'Methods for Recording and Reporting of Epidemiological Data on Injury and Illness in Sports'.[42] This would improve the comparisons and generalisation of results between studies.

Conclusion

Overall, weightlifting and powerlifting exhibit incidence rates comparable to other non-contact sports and lower when compared with contact sports. However, one report on powerlifting showed a high prevalence of injury when defining injury as a painful condition that impairs training/competition. The most common injury localisations were comparable between sports with the lower back, shoulder and knee, most injured but also, as one report showed, PFD. Professionals working with lifters in these sports should be aware of the seemingly high prevalence of PFD in both sexes, more notably female lifters, which might require special attention or referral. Future prospective, high-quality studies investigating injury incidence and risk factors for injuries are needed in both sports to identify effective treatment and preventative strategies.

Contributors All authors declare that they all have contributed to the inception, data synthesis and drafting of the manuscript. MJ-YT and GAL performed the data search and data collection with the supervision of ADL and after consultation with LB. MJ-YT and GAL made the first evidence grading of studies before ADL and LB was included in the grading process. MJ-YT produced the first draft. LB and ADL managed the revision process. LB formatted and revised the manuscript for submission, is the corresponding author and the guarantor for the overall content in the manuscript.

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