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Injuries among weightlifters and powerlifters: a systematic review

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ABSTRACT

Background Olympic weightlifting and powerlifting are two sports that expose the body to great forces. Injury characteristics have not been systematically reviewed for these two growing sports.

Objective The purpose of this study was to systematically review the literature regarding various definitions of injuries used, injury localisation, the prevalence and incidence of injuries and the associated risk factors for injuries in weightlifting and powerlifting.

Design Systematic review.

Data sources Five databases, PubMed, MEDLINE, SPORTDiscus, Scopus and Web of Science, were searched between 9 March and 6 April 2015.

Eligibility criteria for selecting studies Studies assessing injury incidence and prevalence in Olympic weightlifting and powerlifting were included. The Quality assessment tool for observational cohort and cross-sectional studies was used to assess methodological quality.

Results 9 studies were included in the review. Injury was defined fairly consistently across studies. Most studies were of low methodological quality. The spine, shoulder and the knee were the most common injury localisations in both sports. The injury incidence in weightlifting was 2.4–3.3 injuries/1000 hours of training and 1.0–4.4 injuries/1000 hours of training in powerlifting. Only one retrospective study had analysed possible risk factors.

Summary/conclusions The risk of injury in both sports were similar to other non-contact sports also requiring strength/power, but low compared to contact sports. The severity of injuries differed in the included studies. Since little has been studied regarding possible risk factors to injuries, further research is therefore warranted to explain why athletes get injured and how to prevent injuries.

Trial registration number PROSPERO CRD42015014805.

INTRODUCTION

Olympic weightlifting (hereafter named weightlifting) and powerlifting are the most commonly practiced strength sports where maximal strength in one repetition is the primary focus. In weightlifting there are two events: the snatch and the clean and jerk.[1] Powerlifting consists of three events: the squat, bench press and deadlift.[2] The goal of both sports is to lift the maximum weight in each event.

The risk of injury during heavy lifting at work or during leisure time is a well-recognised problem.[3] In order to secure a balance between total training load and recovery, recommendations about training frequency, intensity and volume for resistance training practitioners have been published.[4] Other factors that have been suggested as risk factors for injuries are heavy loads in extreme joint positions. For example, Gross *et al*[5] described an increasing risk of shoulder injury when the shoulder joint is abducted and externally rotated which is a position weightlifters achieve during a snatch. It has also been suggested by Kujala *et al*[6] that squat movement could increase the risk of osteoarthritis. The reason for this could be the fact that the knee joint is exposed to high forces when performing squats.[7] In powerlifting and weightlifting deep squats are included in daily training and during competition. Regarding the deadlift exercise, there is a high load on the spine during the lifts. It has been shown that the compression forces average >17 000 N in elite powerlifters,[8] and the distribution of forces have a large variation depending on the lifting technique. This might mirror the findings in a book on the injury epidemiology of Olympic sports, where it was suggested that competitive level might also be associated with injury rate in weightlifters.[9]

The definition of a sports injury varies between studies. Sometimes the definition can be restricted to the consequences of sudden, damaging events such as strains and lacerations.[10] However, signs and symptoms of overuse syndromes (eg, pain and functional limitations) appear gradually and the athlete often continues training.[11] The different definitions used in earlier studies about weightlifters and powerlifters make it hard to get an overview of the prevalence and incidence of injuries, and the causes of the injuries. According to Van Mechelen's model,[12] this is crucial information in injury prevention. Therefore, the purpose of this study was to systematically review the various definitions of injuries used, the localisation of injuries, the prevalence and incidence of injuries and associated risk factors for injuries in weightlifting and powerlifting.

METHODS

The methodology was in according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).[13] The review was registered in PROSPERO[14] before starting the search process in 2015 (id CRD42015014805). The study protocol is available at: http://www.crd.york.ac.uk/prospero/DisplayPDF.php?ID=CRD42015014805.

Eligibility criteria

Peer-reviewed observational studies, published in English and available in full text were included. There was no limitation for publishing year or sex. Studies had to meet the following criteria for inclusion: study population consisting of competitive weightlifters or powerlifters and inclusion of injury incidence and/or injury prevalence (regardless of injury definition, ie, injury could be due to training only, non-training and/or competition-related).

The reason why we chose competitive weightlifters and powerlifters as study population was that we wanted to ensure that the participants in the studies performed the events included in weightlifting or powerlifting regularly. Studies including athletes with a disability were excluded (since these athletes do not participate in all events of powerlifting/do not represent the majority of lifters). Further, case studies and/or studies not including all the events of weightlifting or all the events of powerlifting (in figure 1 named case studies, etc) were excluded.

Data collection process and search strategy

The literature search was performed between 9 March and 6 April 2015 by searching the following databases: PubMed, MEDLINE, SPORTDiscus, Scopus and Web of Science. To increase sensitivity a broad search strategy was formed for each database in cooperation with staff at the Medical Library in Umeå, Sweden (table 1). Titles, abstracts and full texts were screened individually by two of the four authors (IS and FA). Studies with obviously irrelevant titles were excluded. Titles were screened twice to minimise the risk of missing relevant studies. Two of the authors (IS and FA) independently reviewed the abstracts and those that did not meet the eligibility criteria were excluded. Thereafter, full text articles were reviewed for a final exclusion. Also their reference lists were screened for relevant articles. During the review of full text articles, a majority decision was taken in consultation with the coauthors (LB and UA), when disagreements regarding inclusion/exclusion occurred. Possible publication bias was not assessed since the aim for this review was to systematically review and summarise certain data regarding injuries in weightlifting and powerlifting.

Quality Assessment Tool for Observational Cohort and Cross-sectional Studies[15] was used to assess the quality of the included studies. All authors assessed the studies individually and thereafter compared their results. Any disagreements were discussed until consensus was reached. Every article received a total score according to the assessment tool (poor, fair or good).

RESULTS

The search strategy resulted in 4439 potentially relevant articles. A total of 140 abstracts and 56 full text articles were selected for review and, of these, 9 studies met the inclusion criteria[10 16–22] (figure 1).

Study characteristics

Characteristics of the included studies are also presented in table 2.

In total, 472 powerlifters[16 20–22] (422 men and 50 women) and 663 weightlifters[10 18 19 21 23] were analysed in the included studies. The study by Calhoon and Fry[17] did not present data of the number of individuals included in the study. The mean competitive experience of all the lifters varied from 17 months[16] up to 12–16 years[21] of competitive lifting. The age of the lifters included in this review varied from adolescent competitors[16] up to competitors in the masters' class.[20] Only one study had a control group with inactive persons.[19] The study by Raske and Norlin[21] compared the top-ranked athletes in Sweden in powerlifting and weightlifting with a control group of non-competing lifters.

The classification of injuries differed somewhat between the included studies. The study by Raske and Norlin[21] classified an injury as severe when symptoms last for more than a month. The study by Keogh *et al*[20] classified an injury as severe when the athlete was forced to rest for more than a week. Calhoon and Fry[17] and Kulund *et al*[23] did not report a classification of injury severity but rather how long the athlete would be, or had been, absent from training. In the study by Brown and Kimball[16] the athletes self-reported their pain as somewhat severe, moderate, mild or none. Athletes had to answer if they experienced pain: most of the time, always, sometimes, almost never and never. Two studies reported only the number of injuries[10 22] and one study assessed the self-reported pain in body regions during the previous week.[19] Three studies[18 20 22] defined injuries as acute or chronic. Brown and Kimball[16] only reported injuries with a pathoanatomic diagnosis; for example, muscle pull or tendonitis. Injury type was not reported in four of the included studies.[10 19 22 23]

Weightlifting

Six of the included studies reported injuries in weightlifting.[10 17–19 21 23] Two of the studies reported an injury incidence between 2.4 and 3.3 injuries/1000 hours of training.[17 21] Two of the studies presented their data as injury proportion (ie, per cent of competitors with injury).[10 18] Jonasson *et al*[19] presented the prevalence of pain during the previous year. Kulund *et al*[23] reported injuries from an undefined period of time. No study identified risk factors for injuries in weightlifting.

Localisations of injuries

Raske and Norlin[21] reported that the low back, knee and shoulder areas were the most frequently injured localisation. Calhoon and Fry[17] reported the same results as Raske and Norlin.[21] Kulund *et al*[23] also reported the shoulder and knees, in addition to the wrist, as the most commonly injured areas. Jonasson *et al*[19] assessed the prevalence of pain during the previous year and found that pain in the low back was the most common area. They also found that half of the participants had experienced pain in the neck and shoulder. The studies by Junge[10] and Engebretsen[18] did not examine the localisations of injuries when they investigated injuries during the Olympic Games.

Types of injuries

Injuries to muscles and tendons dominated the injury profiles in weightlifting.[10 21] The study by Calhoon and Fry[17] reported that acute injuries represented 59.6%, chronic 30.4% and 10% were of other types. According to Raske and Norlin,[21] 20% of all injuries were acute muscle injuries and 25% were due to overuse injuries of tendons. At the Olympic Games 2008[10] five of the injured athletes had a rupture in a ligament or a tendon. The study by Engebretsen *et al*[18] did not specify the type of injuries which the weightlifters sustained during the 2012 Olympic Games. Calhoon and Fry[17] reported that 90.5% of all injuries forced the athlete to rest for less than a day. They also reported that only 0.5% of the injuries lasted for more than 3 weeks. The study by Raske and Norlin[21] reported that 93% of the shoulder injuries, 85% of injuries to the low back and 80% of knee injuries had symptoms that lasted for more than 4 weeks. Kulund *et al*[23] reported that 33% of injuries did not result in any impairment, 30% lasted 1 day to 2 weeks, 34% between 2 months and 2 years and 5% lasted for more than 2 years.

Powerlifting

Four of the included studies investigated injuries among powerlifters.[16 20–22] Raske and Norlin[21] reported injuries from both powerlifting and weightlifting. Three of the studies[20–22] reported an injury incidence of 1.0–4.4±4.8 injuries/1000 hours of training. Brown and Kimball[16] did not explicitly

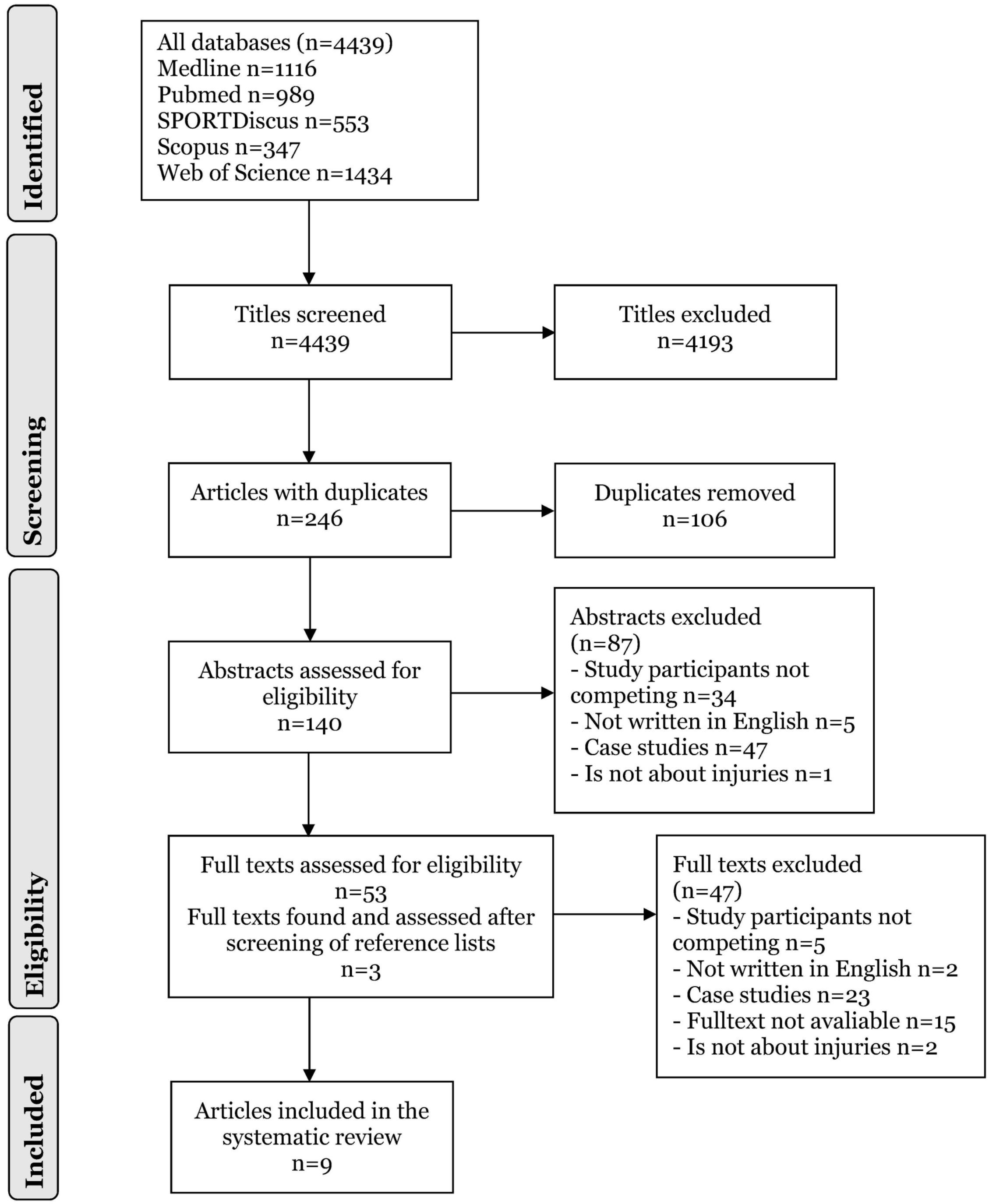

Figure 1 PRISMA flow chart of the literature screening. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

report the injury incidence, but from our calculations there was an injury incidence of 2.9 injuries per 1000 hours training among the 71 men included in his study. No study identified the risk factors for injuries in powerlifting.

Localisations of injuries

Keogh *et al*[20] found that the most common localisation of injury was the shoulder followed by the low back and the elbow. The study by Brown and Kimball[16] reported that half of all the injuries were localised in the lower back followed by the knee and the chest. The study by Siewe *et al*[22] assessed injuries among German elite powerlifters during their entire career. Half of all the athletes in the study by Siewe *et al*[22] had experienced problems in the shoulder and over 40% had been injured in the low back and in the knee. The study by Raske and Norlin[21] reported that injuries to the shoulder, the low back and the knee were most common.

Types of injuries

Keogh *et al*[20] reported that of all the injuries, 60% were acute and the rest were of chronic character. Only 20% of injuries were classified as severe (the lifter had to rest more than a week). In the study by Raske and Norlin,[21] the athletes self-reported that 25% of their injuries were chronic, 20% were acute muscle injuries and the rest were not defined. The authors did not report any difference between weightlifters and

Table 1 Databases used with search words

Database	Search words
MEDLINE	*
PubMed	*
SPORTDiscus	*
Scopus	**
Web of science	***

* (weight lifting OR weightlift* OR weight lift* OR power lift* OR powerlift*) AND ((injur* OR risk factors OR pain OR overuse syndrome OR athletic injuries) AND (Head OR Ankle OR Knee OR Hip OR Pelvic OR Lumbar OR Low back OR Thoracic OR Spine OR cervical OR Neck OR shoulder OR scapula OR Elbow OR wrist OR Hand OR foot))

** TITLE-ABS-KEY (weight lifting OR weightlift* OR weight lift* OR power lift* OR powerlift*) AND (injur* OR risk factors OR pain OR overuse syndrome OR athletic injuries) AND (head OR ankle OR knee OR hip OR pelvic OR lumbar OR low back OR thoracic OR spine OR cervical OR neck OR shoulder OR scapula OR elbow OR wrist OR hand OR foot)

*** TS=(powerlift* OR weightlift* OR weight lifting OR power lift*) AND TS=(injur* OR risk factor* OR pain OR overuse syndrome OR athletic injuries) AND TS=(Head OR Ankle OR Knee OR Hip OR Pelvic OR Lumbar OR Low back OR Thoracic OR Spine OR cervical OR Neck OR shoulder OR scapula OR Elbow OR wrist OR Hand OR foot)

powerlifters. Raske and Norlin[21] also reported that 93% of the shoulder injuries, 85% of injuries to the low back and 80% of the knee injuries resulted in symptoms that lasted for more than 4 weeks. The study by Brown and Kimball[16] reported that muscle pulls were the most common injury types followed by tendonitis and cramps. The injuries forced the athletes to rest from training and competition for a mean time of 11.5 days. Siewe *et al*[22] found that 22.5% of the shoulder injuries were from unspecified pain and 19.6% were inflammatory.

Quality assessment

The results of the quality assessment are presented in table 3. One study was considered to be of 'good' quality.[20] This was the only study that could answer question nine of the assessment tool 'Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?'. Four studies were considered to be of 'fair'[10 18 19 21] and four were of 'poor' quality.[16 17 22 23]

DISCUSSION

This systematic review consisting of nine articles is the first to investigate definitions of injury, injury localisation, the injury incidence and prevalence and risk factors across studies in weightlifting and powerlifting.

Methodological consideration

Five databases were used during the literature search. MEDLINE, PubMed and SPORTDiscus were chosen because they collect studies about sports and they were relevant to this study. Web of Science and Scopus were used in an additional search to make sure that studies published in social science journals were not missed. These five databases were considered adequate to fulfil the aim of the study. We used the same search words in each database but the search strategy varied somewhat to match each database (table 1). Many of the records screened assessed schoolchildren and occupational illnesses. These studies could have been avoided if the search strategy had included 'NOT school NOT work'. For example, this would have erased one-third of the records on MEDLINE. However, this strategy was not executed due to the risk of missing relevant articles. Three studies[24–26] fulfilled all eligibility criteria except the language hence they were excluded. The populations in these studies were large; Ren *et al*[26] published an article in Chinese where they included 265 weightlifters which would have been relevant to this systematic review.

The quality of the included studies was assessed with an assessment tool from the US Department of Health.[15] The tool is constructed to assess observational studies hence it was considered adequate to this study. It has been used in a meta-analysis by Shuang *et al*[27] which also contributed to the choice of assessment tool. Questions 1 and 2 were considered easy to fulfil and therefore the authors (IS and FA) considered these questions less valuable. Questions 8, 9 and 11 were considered harder to fulfil, hence they were considered more valuable (table 3). Owing to this, two articles, which fulfilled the same criteria, received different quality ratings. Since there are no guidelines on how to deal with issues regarding weighting of different criteria, this could affect the inter-rater reliability of the assessment tool.

Two articles which were reviewed but finally excluded were Bethapudi *et al*[28] and Aggrawal *et al*[29] Bethapudi *et al*[28] was excluded since they focused on only one type of injury and therefore their results would not give a broad image of the prevalence or incidence of injuries. Aggrawal *et al*[29] was excluded since it did not meet the eligibility criteria to assess injury prevalence or incidence among athletes. These exclusions were made after discussions between all four authors.

There are also some limitations of this manuscript. Apart from the fact that there is much heterogeneity in the data and that most studies are of poor or fair quality, we want to stress that this review did not report about specific exercise-related injuries (such as bench press-related or squat-related injuries). Instead we used the inclusion criteria of competition-related and training-related injuries and did not focus on specific exercises. Further, we included articles that were written in English although there are other articles written in Chinese and German. Since there are relatively few injury epidemiology studies published on weight training sports, the addition of a few other studies would have added important information. The reason why we did not translate the key data from these non-English articles was that we could not translate the articles accurately enough to receive the information that was crucial for quality assessment.

RESULTS

The injury definition in the included articles was partially consistent; three articles had used almost identical descriptions where an injury was defined as a condition that forces the athlete to refrain or modify training or competition.[20–22] Junge *et al*[10] and Engebretsen *et al*[18] defined an injury as a musculoskeletal condition that had occurred during the Olympic Games and that had required medical attention.

In weightlifting and powerlifting the body is exposed to great forces since the athlete's aim is to lift the maximum weight possible. Since heavy lifting is a well-known injury risk in the general population[3] coupled with the complex demands on balance and coordination, one can assume that the risk of injury is high. However, the results of the studies included in the present systematic review showed that the incidence of injuries were similar compared to other sports with comparable characteristics to weightlifting and powerlifting, that is, non-contact sports which require strength/power. In weightlifting there were 2.4–3.3 injuries/1000 hours of training[17 21] and in

Table 2 Study characteristics and results of assessed articles

Study	Aim	Study type	Population (quantity, sex, experience)	Severity of injury	Injury type	Injury incidence/ prevalence	Localisation of injury	Exposure
Olympic weightlifting Kulund *et al*[23]	Describe overuse problems and injuries in weightlifting.	Retrospective study.	80 weightlifters, 405 cumulative years of experience	*Duration of impairment* No impairment 33% 1 day–2 weeks 30% 2 months–2 years 34% >2 years 2% Chronic, recurrent 3%	NA	111 injuries reported	Shoulder 26% Knee 26% Wrist 20% Elbow 11% Back 8% Thigh 5% Hand 5% Neck 3% Haemorrhoids 3% Hip region 3% Calf 2% Ankle 2% Hernias 1% Foot 0%	NA
Olympic weightlifting Calhoon and Fry[17]	To determine injury types, natures, anatomical locations, recommended amount of time missed, and injury rates during weightlifting training.	Retrospective study. Data retrieved from injury report forms.	853 reported injuries from male weightlifting athletes at US Olympic Training Center	*Absence* <1 day 90.5% <1 week 8.6% <3 weeks 0.4% <3 weeks 0.5%	Acute injuries 59.6% Chronic 30.4% Other types 10%	*Incidence* 3.3/1000 hours training	Low back 23.1% Knee 19.1% Shoulder 17.7% Hand 10% Neck 5.4%	NA
Olympic weightlifting Junge *et al*[10]	To analyse the frequency, characteristics, and causes of injuries incurred during the Summer Olympic Games 2008.	Prospective study. Data retrieved from injury report forms.	255 weightlifters	NA	NA	*Incidence* 43 injuries (16.9% of the competitors)	NA	NA
Olympic weightlifting Jonasson *et al*[19]	To investigate the prevalence of pain in the spine and joints in athletes at national top level who were active in five different sports involving different degrees of load.	Retrospective study. Data collected through a questionnaire.	21 male weightlifters	NA	NA	*Prevalence (pain during the year)* Low back 59% Neck 52% Shoulder 50% Thoracic spine 44% Elbow 35% Hip 31% Ankle 27% Knee 25% Wrist 25%	Low back 35–59%* Neck 41–52%* Shoulder 50%* Thoracic spine 25–44%* Elbow 35–35%* Hip 18–31%* Ankle 18–27%* Knee 18–25%* Wrist 19–25%*	NA
Olympic weightlifting Engebretsen *et al*[18]	The aim of the present paper is to analyse the injuries and illnesses that occurred in London, with the long-term aim to enable the National Olympic Committees (NOCs) and International Federations (IF) to improve their work on protection of their athletes' health.	Prospective study. Data retrieved from injury report forms.	252 weightlifters (149 men, 103 women)	*Absence* ≥1 day 19 injuries (7.5% of the competitors) ≥7 days 11 injuries (4.4% of the competitors)	Overuse injuries 34%	*Incidence* 44 injuries (17.5% of the competitors)	NA	NA

Continued

Table 2 Continued

Study	Aim	Study type	Population (quantity, sex, experience)	Severity of injury	Injury type	Injury incidence/ prevalence	Localisation of injury	Exposure
Powerlifting Brown and Kimball[16]	To construct a profile of the medical history of adolescent powerlifters in order to comprehend more fully the potential for injury in this sport.	Retrospective study. Data collected through a questionnaire.	71 men 17.1 months of experience	*Absence* On average 11.5 days missed per injury	Muscle pull 61.2% Tendonitis 12.2% Crams 10.2% Sprains 4.1% Abrasions 4.1% Nerve injury 3.1% Fractures 2% Dislocations 1% Others 2%	*Incidence* 2.9 injuries per 1000 hours training	Low back 50% Knee 8.2% Chest 7.1% Shoulder 6.1% Elbow 6.1% Hand 4.1% Thoracic back 4.1% Groin 4.1% Abdomen 3.1% Leg 3.1% Ankle 2% Arm 1% Forearm 1%	4.1 times/week ≈ 99.2 min/session
Powerlifting Keogh *et al*[20]	To examine how 4 intrinsic factors would influence the rate, body region, onset, and severity of power lifting injury as well as the exercises affected, causative exercises, and injury treatment options.	Retrospective study. Data collected through a questionnaire.	101 powerlifters 82 men 19 women At least 1 years of experience of powerlifting	Mild 39% moderate 39% great 22%	Acute 59,3% Chronic 40,7%	*Incidence* 1.2±1.1 injury/ lifter/year 4.4±4.8/ 1000 hours of training	Shoulder 36,1% Low back 23,7% Elbow 11% Knee 9,3% Thigh 5,9% Chest 3,4% Arm 2,5% Thoracic back 1,7% Hip/buttocks 1,7% Others 4,2%	6.1±2.4 hours/week
Powerlifting Siewe *et al*[22]	To identify problem zones during workouts, rates of injury, as well as interacting factors, to offer advice to both athletes and sports medicine practitioners for injury prevention and accelerated rehabilitation in the sport of powerlifting.	Retrospective study. Data collected through a questionnaire.	245 powerlifters 219 men 26 women At national and international level. 11 years of median experience	NA	Most common shoulder injury: Unspecified pain 22.5% Inflammation 19.6%	*Incidence* 0.3 injuries/ lifter/year. 1 injury/ 1000 hours of training.	Shoulder 53.1%** Low back 40.8%** Knee 39.2%** Elbow 29.8%** Cervical back 24.5%** Hand/wrist 22.9%** Thoracic back/chest 18%** Ankle and foot 14.3%** Hip 9%**	3–7 times/week 119.1±39.7 min/ session
Olympic weightlifting and Powerlifting Raske and Norlin[21]	The purpose of this study was to investigate the incidence and prevalence of injuries among elite weight lifters and power lifters, with a special focus on shoulder injuries and possible injury-provoking exercises.	Prospective and retrospective study. Data collected through a questionnaire for current injuries and injuries during the past 2 years.	Weightlifters: 50 men 5 women Powerlifters: 50 men 5 women The highest ranked lifters in Sweden.	93% of shoulder injuries 85% of low back injuries 80% of knee injuries lasted >4 weeks	20% acute muscle injuries 25% overuse tendon injuries	*Incidence* Weightlifters 2.4/1000 hours training Powerlifters 2.7/ 1000 hours training	Weightlifters*** Shoulder 0.31 and 0.34 Low back 0.45 and 0.44 Knee 0.43 and 0.49 Powerlifters*** Shoulder 0.57 and 0.71 Low back 0.43 and 0.41 Knee 0.24 and 0.33	1995: 520 hours/ year2000:410 hours/ year

Table 3 Results for the quality assessment with Quality Assessment Tool or Observational Cohort and Cross-sectional Studies

Criteria/included studies	Kulund *et al*[23]	Calhoon and Fry[17]	Junge *et al*[10]	Jonasson *et al*[19]	Engebretsen *et al*[18]	Brown and Kimball[16]	Keogh *et al*[20]	Siewe *et al*[22]	Raske and Norlin[21]
1. Was the research question or objective in this paper clearly stated?	N	Y	Y	Y	Y	Y	Y	Y	Y
2. Was the study population clearly specified and defined?	N	N	Y	Y	Y	Y	Y	Y	Y
3. Was the participation rate of eligible persons at least 50%?	CD	CD	Y	Y	Y	Y	Y	CD	Y
4. Were all the individuals selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?	CD	Y	N	Y	N	N	N	N	N
5. Was a sample size justification, power description, or variance and effect estimates provided?	N	N	N	N	N	N	N	N	N
6. For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome (s) being measured?	N	N	N	N	N	N	N	N	N
7. Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?	N	N	N	N	N	N	N	N	N
8. For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (eg, categories of exposure, or exposure measured as continuous variable)?	N	N	N	N	N	N	Y	Y	Y
9. Were the exposure measures (independent variables) clearly defined, valid, reliable and implemented consistently across all study participants?	N	N	N	N	N	N	Y	N	N
10. Was the exposure(s) assessed more than once over time?	N	N	N	N	N	N	N	N	Y
11. Were the outcome measures (dependent variables) clearly defined, valid, reliable and implemented consistently across all study participants?	N	Y	Y	N	Y	N	Y	N	N
12. Were the outcome assessors blinded to the exposure status of participants?	NA	NA	N	NA	N	NA	NA	NA	N
13. Was loss to follow-up after baseline 20% or less?	NA	NA	CD	NA	CD	NA	NA	NA	N
14. Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?	N	N	N	N	N	N	N	N	N
Quality rating	Poor	Poor	Fair	Fair	Fair	Poor	Good	Poor	Fair

CD, Cannot determine; N, No; NA, not applicable; Y, Yes.

powerlifting the incidence was 1.0–4.4 injuries/1000 hours of training.[16 20–22] In comparison, a study of injuries in track and field by Jacobsson *et al*[30] showed an incidence of 3.57 injuries/1000 hours of training and a study of injuries in alpine skiing by Westin *et al*[31] showed an incidence of 1.7 injuries/1000 hours of training. When comparing the results to the incidence of injury in popular contact sports which also requires strength/power, for example, American football and wrestling (9.6 injuries/1000 hours of training and 5.7 injuries/1000 hours of training respectively[32]), the incidence of injuries in weightlifting and powerlifting could be considered low. The relatively low injury incidence in weightlifting and powerlifting should be interpreted with the background that most of the included studies were of a retrospective design. In studies of injuries in more popular sports, a prospective design is more common[30–32] and could therefore contribute to reflect a more accurate injury risk by reducing the risk for recall bias. Therefore, a suggestion for further research in this area is to conduct prospective, rather than retrospective, studies regarding injury incidence. A further recommendation for future research might be to ask the athletes to report exposure to particular exercises included in the sports instead of hours of training. By this approach, the relative risk of particular activities to the injury can be examined. An example of this is the study by Winwood *et al*[33] where they were able to compare the absolute and relative injury rates to strongman events and traditional weight training exercises by an estimate of the time the athletes allocated to specific exercises.

Several studies describe injuries in weightlifting and powerlifting. The relationships between specific exercises included in the sports and the injuries are, however, still unclear. Raske and Norlin[21] assessed whether there were any relationships between shoulder injuries and certain exercises; however, they did not find any significant relationships. In the study by Keogh *et al*,[20] 52% of the injuries were caused by the three lifts in powerlifting; however, the authors did not see any indications that a specific exercise would lead to more injuries than the others. The other articles included in the present study did not assess risk factors which resulted in that we could not describe any risk factors for the injuries that occur in weightlifting or powerlifting. However, a study that was excluded due to its study design[34] had collected 60 cases of pectoralis major ruptures and 80% of the ruptures had occurred during the bench press exercise. This suggests that there might in fact be a relationship between the bench press exercise and injuries to the pectoralis muscle, and strengthens the above suggestion that future studies should include reports of exposure to certain exercises rather than hours of training.

An important factor that might have influence on the relationships between exposure to training and injury is the use of anabolic androgenic steroids. So far, only case studies[35 36] have suggested that there might be a relationship between use of anabolic androgenic steroids and injuries: Sollender *et al*[36] described four cases of distal ruptures of the triceps brachii muscle where three of the patients had their injury while performing bench press. In a study by de Castro Pochini *et al*,[34] 96% of the participants who suffered an injury due to bench press, had also used anabolic androgenic steroids. With this in mind, the use of steroids might be an important mediator in the process of developing injuries and future studies should always enquire about steroid use. In the study by Keogh *et al*[20] the authors state that they did not know whether the athletes had used steroids or not, and the other included articles do not mention the issue at all.

The included studies in this systematic review are, according to the assessment tool, generally of 'poor' or 'fair' methodological quality. The assessment tool we used is made both for cohort studies and cross-sectional studies and two questions: number 6 'For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?' and number 7 'Was the time frame sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?' can only be answered for cohort studies. In accordance with the assessment tool these questions have been answered 'no' since the included studies are cross-sectional studies. Two other questions were not possible to answer for most of the included articles: number 12 'Were the outcome assessors blinded to the exposure status of participants?' and number 13 'Was loss to follow-up after baseline 20% or less?' and they have therefore been answered with 'not applicable' for most articles. The questions answered 'no' may contribute to lowering the methodological quality even though they were not relevant. The questions answered 'not applicable' may contribute to risk of bias since blinding and follow-up was not made. However, in cross-sectional studies blinding and follow-up cannot be made since the exposure has already been made and therefore the answers to these questions have been ignored.

The problem with the questions answered 'no' have been corrected by classifying question 1 'Was the research question or objective in this paper clearly stated?' and question 2 'Was the study population clearly specified and defined?' as less valuable. Question 8 'For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (eg, categories of exposure, or exposure measured as continuous variable)?', question 9 'Were the exposure measures (independent variables) clearly defined, valid, reliable and implemented consistently across all study participants?' and question 11 'Were the outcome measures (dependent variables) clearly defined, valid, reliable and implemented consistently across all study participants?' were considered more valuable since they were harder to fulfil. This is the reason why the study by Keogh *et al*[20] has been classified as 'good' even though it has only answered 'yes' to 6 of the 14 questions.

It is not easy to compare the results of the included studies since they used different methods and different ways of presenting their data. For example, regarding time periods, Jonasson *et al*[19] assessed if and where athletes had pain during the previous year whereas the study by Junge *et al*[10] assessed acute injuries during the Olympic Games 2008. These data-collection periods probably differed in terms of exercise intensity and it makes the results from Junge *et al*[10] difficult to compare with the studies assessing injury prevalence/incidence during an ordinary training period.

The fact that the included studies used different methods for data collection also contributed to difficulties in making fair comparisons between studies. Six studies[16 19–23] collected data by self-report from the athletes. The three other included studies[10 17 18] collected their data through medical records. In studies with self-report there is a risk of underestimating the true number of injuries since the athletes may have forgotten injuries that were not of great severity and therefore have not reported them. This can be the reason why the majority of injuries in the study by Raske and Norlin[21] were rated severe. In Calhoon's and Fry's study[17] minor injuries are over-represented which can be explained that the athletes were in living in a training facility with constant access to medical staff that could examine them every time they felt pain. These examinations would then have been recorded as an injury.

In weightlifting and powerlifting injuries to the shoulder, knee and low back were common. Knee injuries were more common in weightlifting and Keogh *et al*[20] states that a reason for this might be that the weightlifters perform squats with the barbell resting on the upper parts of the trapezius muscle with a vertical back position which results in greater torque around the knees joints.

In this review, shoulder injuries were more common among powerlifters than weightlifters. A possible explanation may be the bench press exercise. Green and Comfort[37] describes bench press with a wide grip as risky because the shoulder joint is in an abducted and externally rotated position. Since the aim is to lift the heaviest weight possible, one can postulate that the athlete often use a wide grip allowing them to make the lift as short as possible, thus perhaps increasing injury risk to the shoulder. What contradicts this is that weightlifters also are exposed to this extreme position of the shoulder joint when performing the snatch. However, the weights used in bench press are often much higher than the weights used in snatch, for example, the world record in bench press is 275 kg[2] and the world record in snatch is 216 kg[1] in respective heavyweight divisions. It should, however, also be said that the relevance of these possible explanations in relation to shoulder pain in weightlifting or powerlifting has not, to the best of our knowledge, been investigated.

CONCLUSION

According to the studies included in this systematic review, injury incidence in weightlifting and powerlifting is similar to other non-contact sports and low compared to contact sports. The shoulders, low back and knee regions were the most common injury localisations; however, the reported severity of the injuries differed between studies.

Since no study identified the possible risk factors, most studies were of retrospective design and generally of 'poor' or 'fair' quality; the information received from this systematic review is insufficient to address the potential for prevention. Future studies are needed to describe the specific injury types and risk factors for injuries in weightlifting and powerlifting.

What are the findings?

- Olympic weightlifting and powerlifting are popular sports and recreational activities.
- The risk of injury during heavy lifting and lifting in extreme joint positions is a well-recognised problem in work-related studies.
- Factors associated with injuries in Olympic weightlifting and powerlifting have rarely been studied.

How might it impact on clinical practice in the future?

- The incidence of injuries was low to moderate in Olympic weightlifting and powerlifting and the most common areas for injuries were the spine, knee and shoulder.
- So far, only one study has investigated the possible risk factors.
- Generally, the methodological quality of the included studies was low.
- In order to suggest preventive measures, high-quality studies which also assess possible risk factors are needed.

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