# Injuries and Overuse Syndromes in Powerlifting

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Key words
- powerlifting
- overuse syndrome
- exercise pain
- squat
- bench press
- dead lift

## Abstract

Powerlifting is a discipline of competitive weightlifting. To date, no investigations have focused on pain encountered during routine training. The aim of the study was to identify such pain, assign it to particular exercises and assess the data regarding injuries as well as the influence of intrinsic and extrinsic factors. Data of 245 competitive and elite powerlifters was collected by questionnaire. Information regarding current workout routines and retrospective injury data was collected. Study subjects were selected from 97 incorporated powerlifting clubs. A percentage of 43.3 % of powerlifters complained of problems during routine workouts. Injury rate was calculated as 0.3 injuries per lifter per year (1 000 h of training = 1 injury). There was no evidence that intrinsic or extrinsic factors affected this rate. Most commonly injured body regions were the shoulder, lower back and the knee. The use of weight belts increased the injury rate of the lumbar spine. Rate of injury to the upper extremities was significantly increased based on age > 40 years (shoulder/p = 0.003, elbow/p = 0.003, hand + wrist/p = 0.024) and female gender (hand + wrist/p = 0.045). The daily workout of a large proportion of powerlifters is affected by disorders which do not require an interruption of training. The injury rate is low compared to other sports.

## Introduction

Powerlifting is a discipline of competitive weightlifting that is included in both the Paralympic and World Games. It is increasing in popularity all over the world. European and World Championships have been established. There are about 20 000 active athletes and about 3 000 competitive powerlifters in Germany. Powerlifters perform consecutive squat, bench press, and dead lifts. The sport resembles Olympic-style weightlifting, in that both disciplines involve lifting heavy weights over 3 attempts. The aim is to lift the maximum load. The world's strongest people seem to be recruited from this sport [49].

During the squat, the lifter must remove the barbell from the rack, then bend the knees and lower the body until the top surface of the legs at the hip joint is lower than the top of knees (**Fig. 1**). The dead lift entails lifting the bar from the floor until legs are locked in a straight position and the lifter stands erect (**Fig. 2**). During the bench press, the lifter lies in the supine position with the shoulders and buttocks in contact with the flat bench surface. The athlete must lower and then raise the weight to and from the chest (**Fig. 3**).

Men's world records of the World Powerlifting Federation (superheavyweight > 140 kg, open class) are: squat 455.0 kg, bench press 345.0 kg, deadlift 380.0 kg [56]. The following equipment, manufactured by several specified companies, is approved for use [57,58]: suits and shirts (e. g., bench press or erector suits/shirts), briefs under the suit, lifting belts, elbow, wrist and knee wraps and plaster bandages on thumbs and shins.

Lifting such enormous weights using these defined movements can affect high joint moments, compressive loads and shearing forces in the spine and joints [7,12,13,15–17,24]. In addition, studies have identified increasing intrathoracic and intraabdominal pressures during lifting exercises and bench press [26,27].

Extensors of the spine, hip, knee and ankle are the primary muscle groups opposing muscular torque in the squat and dead lift to prevent the body from collapsing with the load. During bench press, the shoulder girdle supports the motions of lowering and raising the weight to and from the chest. Eccentric and concentric contractions

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**Fig. 1** Squat.

**Fig. 2** Deadlift (Sumo-technique).

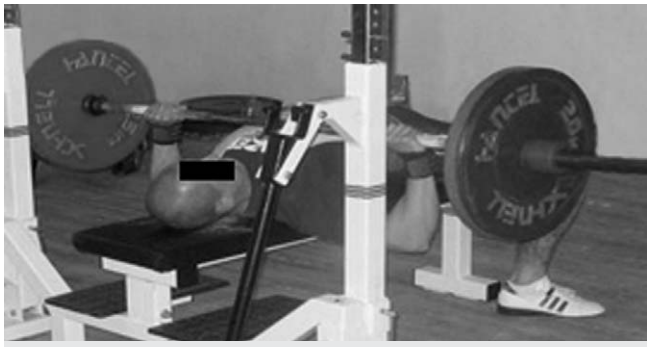

**Fig. 3** Bench press.

occur alternately in the elbow extensors and horizontal flexors of the shoulder [8].

Reeves et al. [42,43] reported on chronic and acute injury patterns of weightlifters and people who perform weight training. Common acute injuries in weight training include sprains, strains, tendon avulsions and compartment syndromes [42]. Common chronic injuries include rotator cuff tendinopathy and stress injuries to the vertebrae, clavicles and upper extremities. In addition, muscle hypertrophy, poor technique or overuse can contribute to nerve injuries such as thoracic outlet syndrome or suprascapular neuropathy. Chronic medical conditions known to occur in weight trainers include vascular stenosis and weightlifter's cephalgia [43]. Risser et al. evaluated the incidence of injury caused by weight training in junior and senior high school football players. The most common injury in this population was a strain and the most common site was the back [44].

Several retrospective studies have investigated powerlifting injuries. Brown and Kimball assessed data of junior athletes by questionnaire. More than 50% of respondents had been powerlifting for less than 1 year [8]. More experienced athletes were assessed by Haykowsky et al., however with a case number of only 11 lifters [29]. There is data with a higher number of study subjects, but in this case, the achievement level is unclear. Subjects were recruited in a commercial sports gym [22]. Thus, epidemiological data regarding adult powerlifters is rare in the literature. With 101 powerlifters in their study, Keogh et al. had the highest case number to date [8,22,29,31,40,41]. The major concerns in this field are the small number of epidemiologic studies for weight-training sports and the predominance of case studies of acute and traumatic injuries [32]. When examining case reports, powerlifting appears to be a high risk sport [21,30,39]. However, closer investigation reveals that in truth, powerlifting might not be very dangerous or risky for participants [31].

Thus, it remains unclear whether powerlifting poses a high risk for injury at all, and which factors might promote risk. Valid data regarding classification of injury as well as the relationships with individual or training-related factors are rare [32]. In particular, information is lacking regarding workout problems encountered by powerlifters on a daily basis as well as the body regions affected.

The current study was designed as a retrospective, epidemiological survey of a large number of competitive and elite powerlifters. In addition to the retrospective component, current training data was collected and assessed. To the authors' knowledge, there are no published studies to date examining this large case number of adult competitive and elite powerlifters. The questionnaire focused on the collection of data implicating individual extrinsic and intrinsic factors, to offer a better understanding of the epidemiology of this sport. Thus, the goal of this survey was 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.

## Materials and Methods

### Study design

This survey was conducted as an epidemiological study. Data was collected by questionnaire. Participation in the study was voluntary and anonymous. This study has been performed in accordance with the ethical standards of the IJSM [28].

### Subjects

In 2008, a questionnaire was distributed and 245 competitive and elite powerlifters (219 male, 26 female) were interviewed. They were recruited from 97 incorporated powerlifting clubs in Germany. Study subjects were selected by the coaches in these societies, who were instructed to choose active members.

The average age of the cohort was 37.8 ± 14.3 years. The average weight (off-season) was 89.1 ± 18.4 kg (male: 91.9 ± 17.1 kg, range 52–140 kg; female: 65.4 ± 10.2 kg, range 47–132). Of the 245 subjects, 225 (92%) were competition winners with 154 titles on the national or international level. The maximum average loads lifted by the participating powerlifters were: squat 205.8 ± 69.12 kg (male 204.3 ± 69.7 kg; female 209.7 ± 64.7 kg), bench press 151.6 ± 52.4 kg (male 152.0 ± 52.9 kg; female 148.2 ± 48.3 kg), and dead lift 214.2 ± 54.8 kg (male 213.4 ± 55.2 kg; female 221.6 ± 52.6 kg). The participating athletes had been powerlifting for 13.6 ± 10.5

years (median 11 years, range 1–53). During the competitive season, 88% of subjects worked out 3–7 times per week. The average workout time was 119.1 ± 39.7 min/day.

### Questionnaire

The questionnaire consisted of 5 parts. The first part assessed general items such as gender, age, weight, number of competitive wins, competitive level of success (regional, national, international) as well as the subjects' maximum load for each of the 3 powerlifting disciplines. The second section collected workout-related data, e.g., regarding warm-up programs, use of supporting devices, routine endurance training, maximum weights during workouts and workout duration. In addition, the athletes were requested to localize pain symptoms during workouts and relate them to particular exercises. These questions referred to the current ongoing training. The athletes were instructed to indicate this pain, if it is an unpleasant sensation which exceeds the usual extent of exercise pain and in particular, if it decreases performance. Data was also collected regarding medical support during workouts and competitions. Medical support was defined as attendance by a physician or physical therapist. In the third part of the questionnaire, the frequency and localization of previous injuries and/or disorders of the musculoskeletal system were assessed. Athletes were instructed to answer based on their entire powerlifting career. The subjects were offered space to specify a diagnosis. Injury was defined as an incident leading to an interruption in training or competition. The fourth part focused on general disorders, and finally the fifth part assessed parameters regarding life style, nutrition, and medical therapy. The questions were validated by 3 orthopaedic surgeons and a statistician.

### Statistical analysis

Values of $p < 0.05$ were considered significant. The chi-square test was used to analyze differences in the examined population regarding the entire powerlifting career. The following parameters formed the basis of this analysis: gender, age (master vs. open class: >40 vs. <40 years), medical support (attendance by a physician or physical therapist), exercise weight (<70%/>70% of the maximum weight), duration of work out (<120/>120 min per day), competition on national/international (vs. regional) level, routine endurance training (yes or no), warm-up (yes or no) and the use of supporting devices (yes or no). Overall injury rates were estimated as number of injuries per lifter per year and the number of injuries per 1 000 h of exercise.

## Results

### Anatomic distribution of current workout pain

The findings regarding pain during workouts are based on the current training of the athletes. 106 powerlifters (43.3%; 14 female, 92 male) complained of pain during workouts (**Fig. 4**). Of these, 40 (16.3%) reported arm/shoulder problems, and 31 (12.7%) hand/wrist pain. Thus, 29% of the athletes complained of upper extremity problems. In addition, 37 (15.1%) subjects specified back pain and 34 (13.9%) reported lower extremity pain.

### Pain distribution during specific exercises

**Fig. 5–8** show the allocation of pain during specific exercises. Back pain ensued from squats and dead lifts. Arm/shoulder and hand/wrist pain was noticed during the bench press. Problems in the cervical spine and the chest were also often aggravated by performing bench press. Pain in the lower extremities occurred mainly during squats. Exercises outside of the 3 main disciplines caused predominantly upper extremity pain.

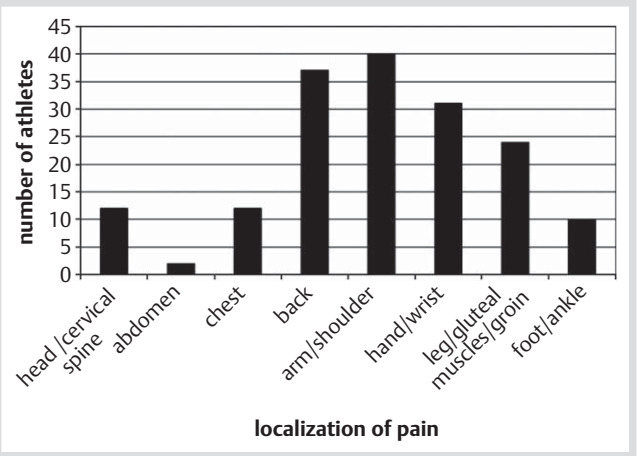


**Fig. 4** Anatomic distribution of workout pain.

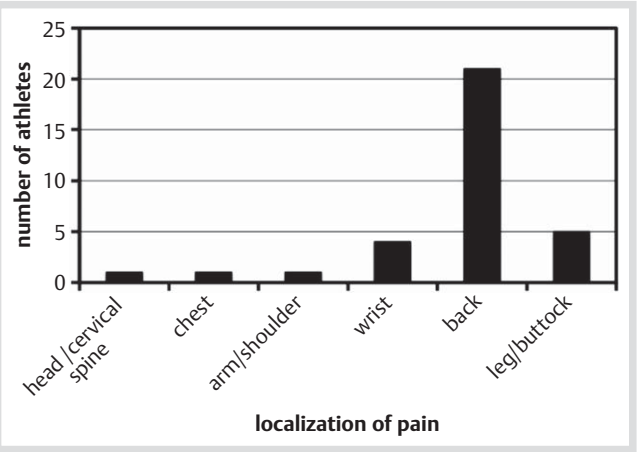


**Fig. 5** Distribution of pain during deadlift workout.

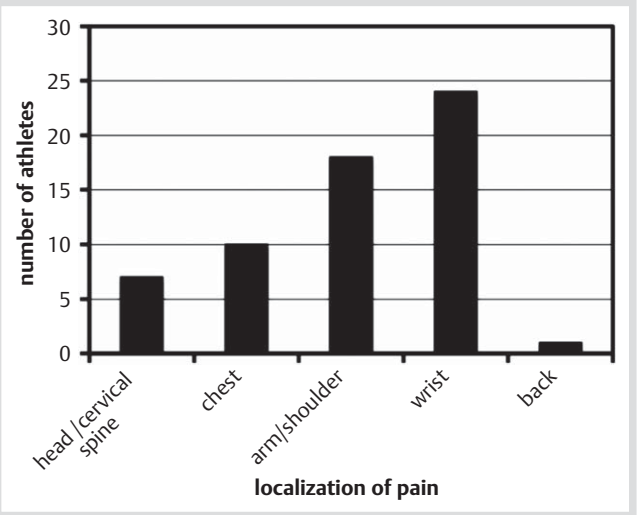


**Fig. 6** Distribution of pain during bench press workout.

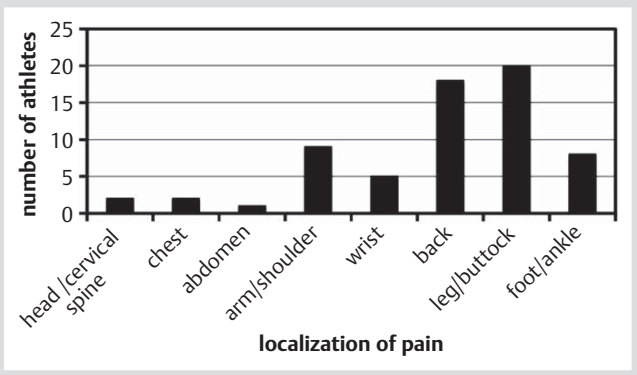


**Fig. 7** Distribution of pain during squat workout.

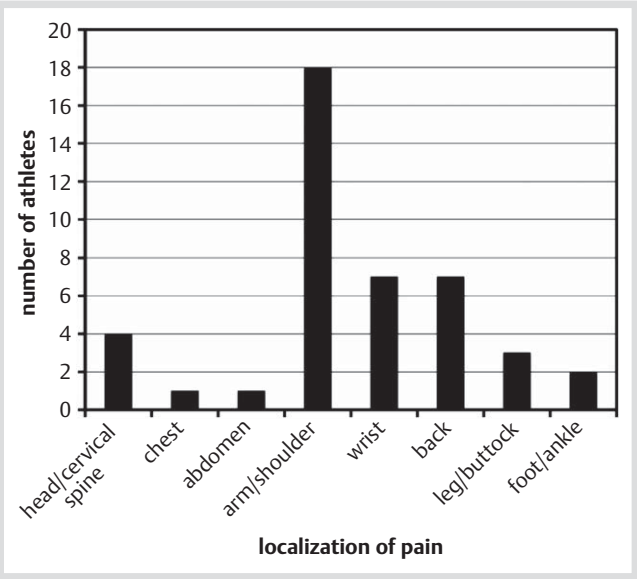


**Fig. 8** Distribution of pain during other workout exercises.

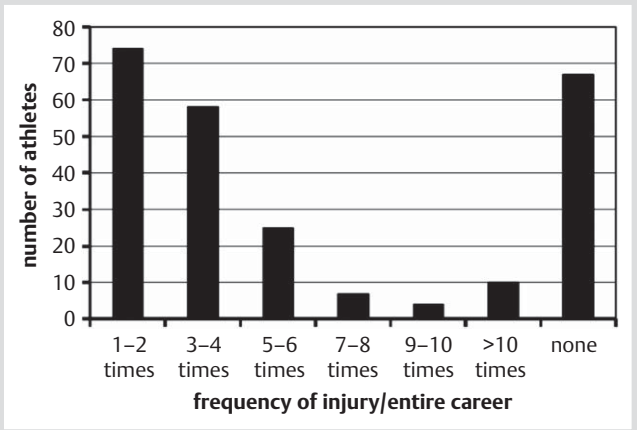


**Fig. 9** Frequency of injury (powerlifting career).

## Frequency of injury (career)

These findings are retrospectively based on the athletes' entire powerlifting career. Overall, only 27% (n=67) of athletes had never suffered a powerlifting injury (**Fig. 9**). The overall injury rate was calculated as 0.3 per lifter per year. In this group of subjects, there was approximately one injury per 1000 h of powerlifting.

**Table 1** Disorders of the cervical spine.

| Disorders of the cervical spine (n=absolute number of athletes/% of 245 athletes) | | |
|---|---|---|
| **Diagnosis/symptom** | **n=60** | **%** |
| pain | 21 | 8.6 |
| myogelosis | 37 | 15.1 |
| arthrosis | 10 | 4.1 |
| herniated vertebral disc/protrusion | 11 | 4.5 |
| sliding vertebra | 6 | 2.5 |
| spinal stenosis | 4 | 1.6 |
| others | 1 | 0.4 |

Frequency of injury did not differ significantly based on gender or age (open and master class athletes, i.e., <40 vs. >40 years). There was also no significant difference between athletes receiving medical support during competitions and/or training and those who did not. Routine endurance training also had no influence. In addition, the following variables did not statistically affect the rate of injury: use of supporting devices, exercise weight (more or less than 70% of the maximum weight), duration of workout (more or less than 120 min), warm-up training or performing the sport on regional vs. national/international level.

## Specification of Injuries

The following data are based on reported diagnoses and descriptions of past injuries/disorders. Multiple answers were possible. Absolute numbers of athletes are given and percentages regarding the entire collective are included in brackets.

## Spine

### Cervical spine

Overall, 60 athletes (24.5%) reported previous injuries to the cervical spine. Description/diagnoses included: pain not otherwise specified (NOS), myogelosis, arthrosis, herniated vertebral discs/protrusion, and sliding vertebrae (**Table 1**). The following parameters showed no significant influence on incidence rate: gender, open/master class, medical support, routine endurance training, use of supporting devices, exercise weight (<70%/>70% max. weight), duration of work out (<120/>120 min), use of warm-up training and performing the sport on regional vs. national/international level.

### Thoracic spine and thorax

44 (18%) athletes reported previous disorders of the thoracic spine. 23 (9.4%) reported myogelosis, and 15 (6.1%) athletes indicated pain NOS. Other diagnoses included arthrosis (2.9%), spinal stenosis (0.8%), herniated disc/protrusion (1.2%), sliding vertebrae (2%), and hyperkyphosis (0.4%). 3 athletes suffered rib/sternum fractures (1.2%).

Analogous to the above results, none of the investigated parameters significantly affected the injury rate.

### Lumbar spine

Injuries of the lumbar spine were mentioned by 108 (40.8%) athletes. The most frequent diagnoses were sciatica and myogelosis (**Table 2**). The following parameters yielded no significant difference in injury rates: gender, open/master class, medical support, exercise weight, duration of work out (<120/>120 min), competition level, routine endurance training, warm-up.

**Table 2** Disorders of the lumbar spine.

| Disorders of the lumbar spine (n = absolute number of athletes/ % of 245 athletes) | | |
|---|---|---|
| **Diagnosis/symptom** | **n = 108** | **%** |
| pain | 29 | 11.8 |
| myogelosis | 32 | 13.1 |
| arthrosis | 8 | 3.3 |
| herniated vertebral disc/protrusion | 15 | 6.1 |
| spondylolisthesis (sliding vertebra) | 5 | 2 |
| spinal stenosis | 2 | 0.8 |
| hyperlordosis | 14 | 5.7 |
| sciatica | 38 | 15.5 |
| sacroiliac joint disorders | 13 | 5.3 |
| others | 1 | 0.4 |

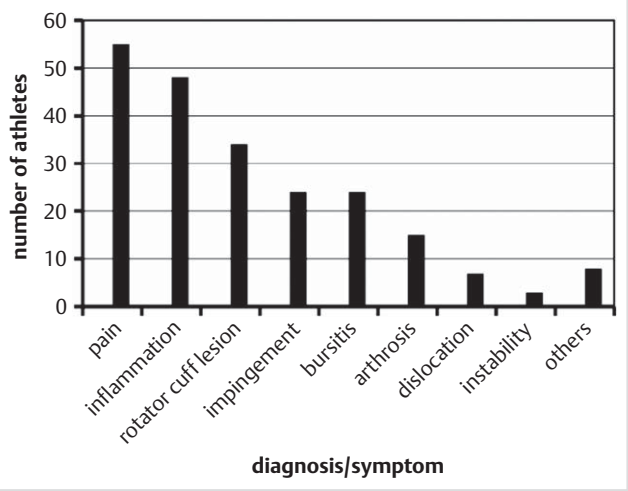


**Fig. 10** Disorders of the shoulder.

However, athletes using supporting devices also reported significantly more lumbar spine problems (p = 0.035) than participants who did not use them. Several different devices were mentioned (e.g., belts, supporting shirts, and suits). In particular the group of athletes using lifting belts showed a higher injury rate than athletes who did without these devices (squat: p < 0.001; dead lift p = 0.01).
24 (9.8 %) athletes reported pain in the entire spine.

## Upper extremity

### Shoulder

130 (53.1 %) of the powerlifters reported previous episodes of shoulder pain. Pain NOS was named by 55 (22.5 %) athletes, and inflammation by 48 (19.6 %) (**Fig. 10**).
There were significantly more shoulder problems in master class athletes (p = 0.003) than in open lifters. Other investigated parameters did not generate a statistical difference.

### Elbow

73 (29.8 %) powerlifters reported injuries in the elbow region. Pain NOS was itemized by 33 athletes (13.5 %). Inflammation was specified by 35 athletes (14.3 %). Other diagnoses included arthrosis, dislocation, instability, bursitis, and muscle, tendon or nerve disorders.
Master class athletes indicated significantly more injuries to the elbow region (p = 0.003) than open lifters. In addition, athletes using supporting devices also reported significantly more problems in this region (p = 0.029) than participants who did not use them. The analysis of other variables did not show any significant differences.

**Table 3** Disorders of the knee.

| Disorders of the knee (n = absolute number of athletes/ % of 245 athletes) | | |
|---|---|---|
| **Diagnosis/symptom** | **n = 96** | **%** |
| pain | 37 | 15.1 |
| arthrosis | 14 | 5.7 |
| inflammation | 11 | 4.5 |
| fracture (femur) | 1 | 0.4 |
| instability of ligament | 8 | 3.3 |
| meniscus injury | 22 | 9 |
| rupture of cruciate ligament | 1 | 0.4 |
| disorder of patella | 8 | 3.3 |
| others | 9 | 3.7 |

### Hand/wrist

56 (22.9 %) athletes reported problems in this region. Pain (n = 27/11 %), tendovaginitis (n = 14/5.7 %), and ganglion cysts (n = 10/4.1 %) were most frequently mentioned. Significantly more problems were reported by females (p = 0.045), master class subjects (p = 0.024), and athletes using supporting devices (p = 0.014) than by males, open lifters and participants who did not use supporting devices. The analysis of other items did not show significant differences.

## Lower extremity

### Hip

22 (9 %) athletes suffered from pain in this region. Besides pain, they specified arthrosis, inflammation, instability, impingement and strain.

### Knee

Disturbances of the knee were reported by 96 subjects (39.2 %). A distribution of the disorders is shown in **Table 3**.
Athletes not receiving medical support complained more often of problems in this region (p = 0.007) than subjects with medical support. The analysis of other investigated variables showed no significant differences.

### Ankle and foot

35 athletes (14.3 %) reported pathology/injury of this anatomical region. The most frequent specifics were flatfoot and splayfoot (21 athletes, 8.6 %). Ligament instability was reported by 16 athletes (6.5 %). 3 powerlifters (1.2 %) had sustained fractures.

## Discussion

Like in Olympic-style weightlifting, in powerlifting, maximal loads must be withstood by the athlete's body. This raises the question whether this sport is connected to a high risk of injury. This seems to be a common preconception. However, research should challenge the epidemiology of powerlifting injuries, and investigate especially the intrinsic and extrinsic factors promoting such injuries [31]. But what are the common problems encountered by powerlifters during their daily workouts? Which body areas are most susceptible to injury or pain during squat, deadlift, or bench press? Other weight training sports like

bodybuilding allow exchange of exercises. The ambitious powerlifter, on the other hand, must address the 3 disciplines during workouts.

In the present study, 43.3% of powerlifters complained of pain during current workout sessions.

Relevant pain rates are described for several sports. Back pain in rowers is described in 32% of the study subjects [47]. Shoulder pain with rates up to 48% is a common problem in swimmers [46]. In contrast to our results, which are a snapshot of the current situation, these data are based on retrospective surveys and a certain time period. However, they suggest that athletes prevalent have to deal with certain pain patterns during their daily exercise. Increased training intensity and consecutive fatigue might be the relevant issue. The knowledge of these sport specific pain patterns and counteractive measures might help to provide a defence against serious injury and provide advice to the athletes [46].

In the current survey 27% of the powerlifters had never suffered previous injury from this sport. Only 18% of the subjects were injured more than 6 times throughout their entire powerlifting career. We found no statistical significance analyzing general injury risk and the individual parameters outlined in the method section of this paper.

At first glance, the relevant percentage of powerlifters reporting pain symptoms during workouts appears to confirm the idea that this sport is dangerous or holds a high risk of injury. However, although such complaints might diminish performance, they did not interrupt training or competitive activities as a result. Thus, serious injuries were most likely not the cause [29,41,48]. Previous studies have suggested that rather moderate, short-term injuries are sustained as a result of powerlifting, with average duration of symptoms from 11.5 to 18.4 days [8,29,40]. One survey of elite powerlifters and weightlifters identified major injuries causing a predominant duration of symptoms longer than 1 month [41]. Our findings regarding the relatively low rate of injury corroborate the results of previous investigators quoting injury rates of 1–2/year and 1–4/1000 workout hours [8,22,29,31,40,41]. Of course, the major limitation of the current results lies in the retrospective assessment of data regarding the powerlifters' entire career [19]. Nevertheless, when examining the literature and comparing, for example, reported injury rates in ice hockey with 54–83 injuries/1000 playing hours, powerlifting does not even approach contact sports regarding risk [38]. Injury rates in other contact sports have been quoted as 20.7/1000 training hours or 6.9/1000 h during preseason (professional rugby), 16/1000 h of practice and competition (American football), 13.5/1000 playing hours (handball), and 17.1/1000 match hours (football/soccer) [4,6,20,33,45]. In fact, powerlifting appears to be more comparable to dancing (1.5–4 injuries per 1000 training hours), rowing (3.67/1000 h), or individual contact sports like boxing (2/1000 h) [14,51,55]. Considering the injury rates of the sports mentioned above, the relative safety of powerlifting might have several reasons. In spite of the extremely heavy loads, relative slow and controlled movements and defined exercises counterpart abrupt and fast courses of motions. Furthermore, the contact with an opponent athlete is reflected in the higher injury rates.

On the other hand, our results suggest that a relevant rate of powerlifters do suffer from musculoskeletal complaints during daily workouts. However, the rate of actual injuries is low when compared to other sports. In a previous study about professional beach volleyball players, a similar discrepancy already has been described. A low injury rate (0.8/1000 training hours) was estimated. A counterpart of 36% of athletes, who did not report pain in the previous 7 days, disposed the author to work on a new approach to quantify the problem of overuse injuries among athletes. He stated the "traditional" cohort study approach with a time-loss injury definition might lead to an underestimation of overuse syndromes [2,3]. This research underlines the importance of our results. Our data suggest that the real world problem for the powerlifter might not only be the acute injury. Collaterally, it is the daily pain during exercise which may cause or lead to a chronical problem. Nevertheless, a rate of persistent symptoms as a result of a past injury is conceivable as it is described in the literature (e.g., for soccer) [9].

The current study highlights the effects of particular exercises on specific body regions during training. Overall, athletes mainly complained about pain of the upper extremities. Deadlift aggravates back pain, as does the squat. However, squats activate more problems in the upper and lower extremities. The bench press is attended by pain predominantly in the upper body.

Compressive loads on the lumbar spine in powerlifters can measure more than 17192 N, while the average L4/5 and hip moments can be 988 and 1047 Nm during deadlift. The sumo deadlift seems to reduce these forces when compared to the conventional style [13,24,37]. Such immense forces certainly explain the pain pattern presented in the current results. The importance of proper technique must be emphasized and athletes suffering from problems in the lumbar spine should consider using the sumo style.

Previous studies have examined joint movements during the squat [16,36,53]. These studies focussed on the trunk, spine and lower extremities and corroborate the results presented here. In addition, the problems encountered by several athletes with the upper extremities during squat must be mentioned. The problem appears to arise during lifting of the barbell off and onto the rack as well as the holding. It remains unclear whether these movements generate pain or whether there were pre-existing problems. However, there are 2 possible exercise modifications for athletes suffering from injury or pain syndromes of the upper extremities described. Instead of regular "back squatting", a special bar is recommended, which modifies the centre of mass and prevents the sliding off the back. Second, athletes can perform front squat which minimizes the stress of the middle and inferior glenohumeral ligaments and the wrist joint [18].

A number of severe chest, shoulder, and wrist ailments have been reported as a result of the bench press [23,30,39]. These studies offer no explanations for the pain suffered by the athletes in the current survey. Chronic soft tissue overload from excessive, repetitive training and hyperextension of the wrist must be suspected as the origin of these problems. Epicondylitis, ulnar neuropathy, tendinitis, exercise-induced compartment syndromes, or intersection syndromes of the forearm and wrist are considerations [52,54]. Bhatia et al. characterized "benchpresser's shoulder" as an overuse insertional tendinopathy of the pectoralis minor muscle [5]. These or comparable pathologies do not obligate an interruption of training, but do decrease performance. In the current study, the subjects were asked to report previous injuries, and if possible to indicate a diagnosis. Retrospective study designs comprise a number of problems regarding the reliability of the data. Underestimated injury rates as well as reliable reports of precise diagnoses are major concerns. Acute symptoms may be based on chronic degeneration. Not least, it is difficult even for medical practitioners to correlate

injuries or overuse syndromes with particular activities [10,19,35]. Nevertheless, the current data yielded some interesting results regarding intrinsic and extrinsic variables.

In the current study, the most commonly cited regions of injury were the lumbar spine, shoulder and knees. This corroborates findings within the existing literature [8,22,29,31,40,41]. Goertzen et al. reported an injury rate of 40% to the upper extremities (shoulder and elbow). The lumbar spine and knee regions were also common sites of injury. Muscle lesions (muscle tears, tendinitis, sprains) were responsible for 83.6% of injuries overall. In total, the injury rate in powerlifters was twice that found in a collective of bodybuilders. The authors suggested differing training schedules as an explanation [22]. Keogh et al. reported injuries in a similar body distribution, which seem to occur also in competitive Olympic-style weightlifters [11,31]. Brown and Kimball assessed 71 adolescent powerlifters and found 13 different sites of serious injury. The lumbar spine was the most commonly affected region [8]. A review of the literature summarized that lower back injury might be determinated by excessive spinal flexion, an imbalance in the coactivation of the spinal and abdominal musculature or a lack of intraabdominal pressure [13,25,32,50]. The inciting mechanisms for injuries of the shoulder and knee are not clearly understood. The review suggests that the injury of these sites are based on a lack of stability at the more proximal joints at end range and muscular endurance/strength and control imbalance. However, underlining our results, the most affected anatomical sites in weightlifting and powerlifting are shoulder, lower back and knee [32]. The access to medical support seems to be relevant for preventing injuries of the knee compared to athletes who do not have this support ($p=0.007$). In fact, the pattern of disorders (e.g., pain, inflammation, arthrosis, **Table 3**) suggest that physical therapy and medical attendance might prevent an exacerbation of initial symptoms.

An in vivo study on weightlifters concluded that wearing a tight, stiff back belt while inhaling before lifting reduces spine loading. The belt reduced compression forces by about 10%, but only when inhaling before lifting [34]. Belts are supposed to support the trunk by increasing the intraabdominal pressure and providing relief to the spine and spinal muscles [37]. In contrast, we identified a statistical difference regarding lumbar spine injuries between athletes using lifting belts and subjects who do not use them (squat $p<0.001$, deadlift $p<0.01$). We suggest that the use of belts or other devices might lead to individual nonphysiological loading. In addition, it appears that both the abdominal and back muscles do not work as much when the lifter is using a weight-belt [37]. Working out without the supporting device should be considered to restore these muscles. A similar effect regarding the use of supporting devices was evident with the upper extremities (elbow $p=0.029$, hand/wrist $p=0.014$). Of course, it is possible that athletes use the devices to reduce symptoms of previously existing disorders or injuries to continue training. In such a case, the basic pathology could be aggravated.

In the current study, older athletes in particular had suffered more previous injuries in their career of the upper extremities (shoulder $p=0.003$, elbow $p=0.003$, hand/wrist $p=0.024$) than open lifters. Remarkably, we could not detect a significantly greater number of injuries to other body regions in master class athletes in comparison to younger subjects. Due to these findings, we propose that the upper extremity is a flaw of master athletes. In contrast to this data, a previous study could not show a different injury rate to certain body regions depending on age. Greater training experience and higher willingness to receive medical treatment as a confounding variable is suggested [31]. The data of the mentioned study is based on a one year retrospective survey, whereas our data refers to the entire powerlifting career. This might be an explanation for the difference in data. Nevertheless, taking into account that our study is based on a high number of study subjects and the absence of statistical effects in other body regions, the compiled higher rate of injury of this body region seems to be relevant in our collective. A retrospective analysis of weightlifters and powerlifters has shown that peak anaerobic muscular power, as assessed by peak lifting performance, decreases progressively even from a younger age [1]. This decreased muscle power, in combination with the natural course of aging and the previous ability to lift increased loads, could be an explanation for an increased risk of injury at this body site.

The collective of females in our survey reported significantly more wrist injuries than the male athletes ($p=0.045$). Raske and Norlin did not find a significant difference between male and female lifters in their survey regarding the overall injury rate. But their data provide a higher injury rate of the wrist in elite power and weightlifting women compared to a male collective of elite powerlifters [41]. We assume that this anatomical site is a weak point in female lifters.

Fees et al. developed weight-training modifications for several exercises (e.g., squat, bench press), which might help to bring these athletes back to the weight room after shoulder injury. They recommended modifications of hand spacing, grip selection and start and finish positions used in bench press to decrease microtrauma to the joints of the shoulder and reduce the strain on passive and active shoulder stabilizers [18]. A proper bench press technique, bench press training program variables (e.g., warming up, training volume and intensity) and addressing upper body muscular and range of motion imbalances and deficits are recommended in athletes suffering from injuries of the upper extremities [31]. Generally, lifters should perform the most demanding, challenging exercises early in their training sessions and avoid tiredness, fatigue, technical errors and excessive overload [32].

Considering a high rate of soft tissue generated problems in this sport many of these injuries are not visible radiographically. Early MRI evaluation, especially in high-caliber athletes, is recommended to accelerate rehabilitation [54].

## Conclusion

Powerlifting is a weightlifting discipline in which a large number of athletes complain about pain or problems during routine workouts. The isolated exercises (squat, dead lift and bench press) provoke specific pain patterns, and understanding of these patterns may be beneficial for therapy. The health care practitioner must be aware that such problems do not necessarily require an interruption of training. In contrast, the overall injury rate compared to many sports is low. Individual intrinsic and extrinsic factors do not affect the rate of general injury. However, the use of supportive weight belts enhances the rate of lumbar spine injury. The abandonment of these devices during routine training should be considered, especially after previous injury in this area. Master and female athletes and their medical practitioners should be aware of a higher risk of upper extremity

injuries. Temporary established exercise modifications should be discussed with these patients.

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