Original Research

Prevalence and Consequences of Injuries in Powerlifting

A Cross-sectional Study

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Investigation performed at Umeå University, Umeå, Sweden

Background: Powerlifting consists of the squat, bench press, and dead lift, and extreme loads are lifted during training and competitions. Previous studies, which have defined an injury as an event that causes an interruption in training or competitions, have reported a relatively low frequency of powerlifting injuries (1.0-4.4 injuries/1000 hours of training). No previous study has investigated the prevalence of injuries, defined as a condition of pain or impairment of bodily function that affects powerlifters' training, in a balanced sample of men and women, and no studies have established possible risk factors for an injury.

Purpose: To investigate the prevalence, localization, and characterization of injuries among Swedish subelite classic powerlifters, with an emphasis on differences between men and women, and to investigate whether training and lifestyle factors are associated with an injury.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: A total of 53 female and 51 male Swedish subelite powerlifters answered an online questionnaire including questions about background characteristics, training habits, and lifestyle factors. The main part of the questionnaire included questions about injuries and their consequences. An injury was defined as a condition of pain or impairment of bodily function that affects powerlifters' training.

Results: Seventy percent (73/104) of participants were currently injured, and 87% (83/95) had experienced an injury within the past 12 months. The lumbopelvic region, shoulder, and hip were the most commonly injured areas for both sexes. Women experienced a significantly greater frequency of injuries in the neck and thoracic region than men. Injuries seemed to occur during training, although only 16% (11/70) of those currently injured had to completely refrain from training. Training frequency, greater personal best in the dead lift, injury onset during bench-press and dead-lift training, use of straps, alcohol consumption, and dietary issues were associated with current injuries.

Conclusion: Injuries are very common in subelite powerlifters. Men and women report similar injury frequencies but different anatomic locations. These injuries do not prevent powerlifters from training and competing, but they may change the content of training sessions. Why powerlifters develop injuries is still unclear; however, it is likely that the management of training loads and optimization of the lifting technique during the squat, bench press, and dead lift are of importance.

Keywords: sports injury; risk factors; resistance training; low back pain

Powerlifting consists of 3 disciplines—(1) squat, (2) bench press, and (3) dead lift—and 2 divisions. In the classic division of powerlifting, the only supportive equipment allowed is a lifting belt, neoprene knee sleeves, and wrist wraps. In the equipped division, a squat and dead-lift suit, knee wraps, and a bench-press shirt are allowed.[16] In competitions, the powerlifter has 3 attempts in each discipline, and the best lifts are added together to a total weight. External loads up to 4 times the body weight are lifted in competition settings. During training, submaximal loads are used to increase maximal strength, and in a previous study, powerlifters exercised, on average, 6.1 ± 2.4 h/wk.[18]

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A recent systematic review[1] investigating injuries and possible risk factors for an injury in powerlifters showed that injury rates in powerlifting seem relatively low (1.0-4.4 injuries/1000 hours of training), with an injury being defined as an incident causing an interruption in training or competitions. It was also concluded that the included studies were of fair methodological quality[4] and that no study identified risk factors for the powerlifters' injuries. In addition, no previous study has investigated the prevalence of injuries, defined as a condition of pain or impairment of bodily function that affects powerlifters' training, sometimes referred to as sports illness.[29]

In other sports, some risk factors have been identified as possible causes for injuries.[19,23,31,32] There is evidence that disordered eating behaviors can increase the risk of musculoskeletal injuries.[21] Further, the use of nonsteroidal anti-inflammatory drugs or certain medications[2] as well as a fast progression, poor technique, or excessively high intensity or frequency of training can be associated with athletic injuries.[4,15,17] In team sports, there is also clear evidence of sex-based differences. For example, female soccer players have a higher risk of severe knee injuries.[28] There is, however, little knowledge about sex differences in powerlifting because the studies have included no or very few female participants. A study of powerlifters in Oceania[18] found similar injury patterns for men and women (82 men, 19 women), whereas a study of powerlifters in Germany[25] found an increase of wrist injuries in women (219 men, 26 women).

Because previous studies have not studied a homogenous powerlifting population regarding competition level or sex, further investigations of injury prevalence and the influence of external and individual factors related to training and lifestyle are warranted. Therefore, the purpose of this study was to investigate the prevalence, localization, and characterization of injuries among Swedish subelite classic powerlifters, with an emphasis on differences between men and women, and to investigate whether training and lifestyle factors are associated with an injury.

METHODS

Design

This was a cross-sectional study that used a web-based questionnaire (Google Forms v 0.6; Google) of categorical and open-ended questions to investigate the prevalence, localization, and characterization of injuries among subelite powerlifters in Sweden in 2014. Specifically, questions relevant to the description of how and when injuries started and affected the powerlifter, training habits, competitive experience, and lifestyle factors associated with diet or use of drugs and/or alcohol were included. Because previous studies of injuries in powerlifting[5,18,20,25] have failed to include a balanced sample of male and female powerlifters and also omitted an analysis of potential confounding variables in their statistical analyses, data were analyzed with an emphasis on factors associated with the prevalence of injuries as well as differences between female and male powerlifters regarding injury prevalence and localization.

Participants

The participants were selected from the 2014 open-category ranking list in classic powerlifting of the Swedish Powerlifting Federation,[27] which is based on Wilks points[30] (ie, a mathematical measure of powerlifting performance in relation to body weight) and therefore includes powerlifters from different weight classes. The email addresses were collected from each powerlifting club, and a link to the questionnaire was emailed to the study participants. After the first invitation, 3 reminders were sent to participants who had not accepted or declined participation. To compare sexes, we sought to include an equal sample of men and women with a comparable competitive standard. Hence, 100 male and 100 female powerlifters directly below the top 25% of the rank, that is, subelite, were eligible to participate. The rationale for excluding the top (ie, "elite") powerlifters was to make the results more generalizable to a larger population of powerlifters. In total, there were 576 men and 225 women on the ranking list for 2014, and the range of Wilks points was 89 to 498 (mean, 336) for all men and 82 to 490 (mean, 307) for all women. Powerlifters younger than 18 years of age were excluded (n = 3), leaving 197 participants (96 men, 101 women) who met the inclusion criteria, with a range of Wilks points of 351 to 376 (mean, 363) for men and 278 to 354 (mean, 313) for women.

The study was approved by the Regional Ethical Review Board in Umeå, Sweden. All participants were informed of the benefits and risks of participating before providing their written informed consent for inclusion.

Questionnaire

The questions were modified and adapted to powerlifting from those in a previously used questionnaire.[12] The questionnaire was tested for its comprehension by members of a local powerlifting club, and modifications for grammatical accuracy were made. As well as questions regarding the prevalence of injuries and training and competition experience (see below), information about basic characteristics and lifestyle factors was collected. Standardized questions from the Swedish Association of Clinical Dietitians[9] were included to describe lifestyle factors relating to diet, alcohol consumption, and tobacco usage. The majority of questions required a dichotomous answer (yes/no), while the other questions offered several categorical answers or called for an open-ended response.

Injuries

An injury was defined as a condition of pain or impairment of bodily function that affected powerlifters' training.[12] The powerlifters were asked to mark the location of their current injuries on a body chart, to report whether they had injuries currently and/or during the past 12 months, to report whether there was a gradual or acute

onset of each injury, and to indicate the activity during which each reported injury started to occur (training squat, bench press, or dead lift or competition squat, bench press, or dead lift; other training activities or during daily life activities).

Regarding current injuries, the powerlifters were asked to report how their training habits were affected: altered their training routine (yes/no [if yes, they were asked to describe how]), refrained from training sessions, or completely refrained from squat/bench-press/dead-lift training. They were also asked if they had to refrain from competitions in squat only/bench press only/dead lift only. Regarding injuries during the past 12 months, the powerlifters were asked to report whether they refrained from training sessions/competitions or if, and how, they had altered their training routine during the past 12 months because of their injuries. The powerlifters were also asked to report, in an open-ended question, their thoughts about what caused their injuries. If they reported having either a current injury or an injury during the past 12 months, they were asked to specify whether they had sought out any health care provider, if they were given any diagnosis of their injury, and which profession had diagnosed their injury (physical therapist/doctor/naprapath/chiropractor/massage therapist/trainer). They were further asked if they had received treatment for their injury and, in an open-ended question, what kind of treatment.

Training and Competitions

The participants were asked about training experience (years), training habits (times and hours per week), and engagement in other sports. Questions included competition experience (years), personal best (kg), and support (having a coach, what kind of support they get from the coach [training program, technique guidance, rehabilitation exercises], or whether they create their own training plan). The use of lifting belts and straps during training was rated on a scale ranging from 0 (never) to 10 (always).

Lifestyle Factors

Participants were asked if they had dietary issues, whether they deliberately changed their weight before competitions (I gain weight/I lose weight/no), how often they drink $\geq$5 glasses of alcohol in a week (never/<once a month/every month/every week/every day/almost every day), whether they smoke, and whether they use snuff. There was also a question about the use of illegal supplements (according to the World Anti-Doping Agency prohibited list) (I use/I have used/I have never used).

Statistical Analysis

Frequency and anatomic localization of the current injury were reported as counts and percentages for the entire group and for men and women separately. To describe the basic characteristics of the participants and the other measurements, means and SDs were used for continuous variables and percentages for dichotomous variables. Differences between men and women were analyzed using the chi-square test or Fisher exact test for dichotomized data, the median test for ordinal data, and the independent-samples t test for continuous and normally distributed data. For nonnormally distributed variables, the Mann-Whitney U test was used. The significance level was set at $P < .05$. All tests were 2-sided.

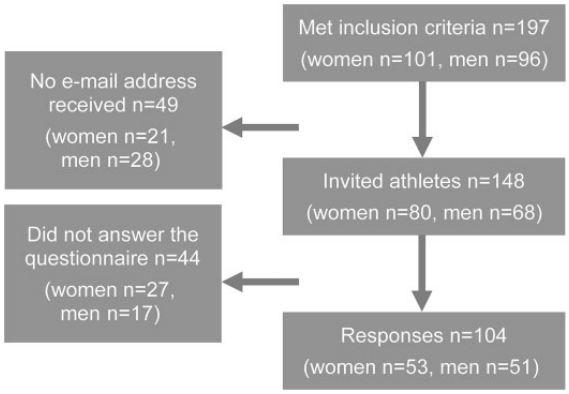

Figure 1. Flowchart of the total number of respondents from the selected population.

Univariate logistic regression analyses were used to analyze associations between the dependent and independent variables. The variables "current injury in any body region" and "current injury in the lumbopelvic region, hip, shoulder, thigh, knee, neck, or thoracic region" were dependent variables (yes coded "1" and no coded "0"). Independent variables were age; weight; training frequency; personal records in squats, bench presses, and dead lifts; the exercise in which the injury started to occur; the use of a lifting belt or straps; having a coach or trainer; eating habits; the use of alcohol and/or tobacco; and the use of illegal supplements. In all analyses, sex was included as an interaction variable and age and sex as covariates. Odds ratios (ORs) and 95% CIs were calculated for each association. Missing data were not replaced by imputations.

RESULTS

Figure 1 shows the flowchart of dropouts and responders. The powerlifters whose email addresses were not received (n = 49) did not differ from those who received the questionnaire (n = 148) in terms of Wilks points ($P = .47$), weight ($P = .30$), or sex ($P = .17$). Further, the powerlifters who did not answer the questionnaire (n = 44) did not differ from those who did (n = 104) in terms of Wilks points ($P = .39$), weight ($P = .47$), or sex ($P = .25$).

Prevalence, Localization, and Characterization of Injuries

Of the 104 study participants, 70% (73/104) reported that they currently have an injury, 87% (83/95) reported that

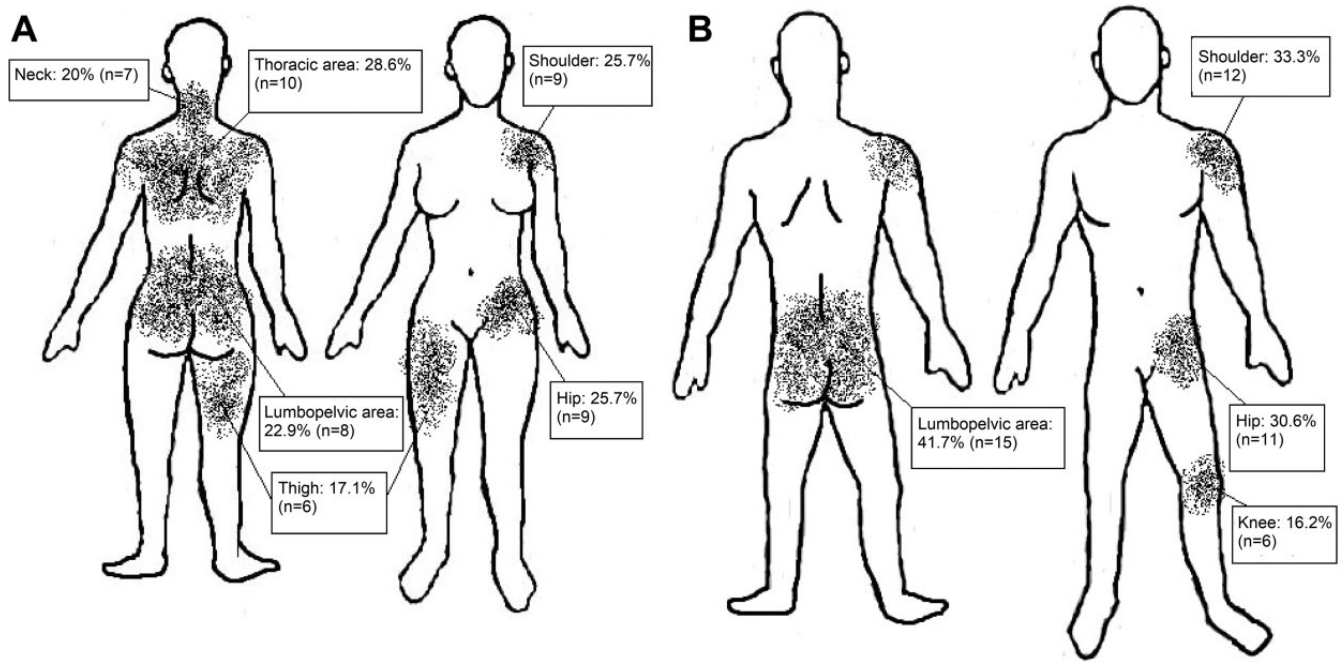

Figure 2. The anatomic localization of current injuries for (A) women and (B) men. Note that each powerlifter may have recorded more than one mark. Results for 35 women and 36 men (missing data: n = 2).

they had experienced an injury during the past 12 months, and 70% (66/95) reported both a current injury and an injury during the past 12 months. Of the powerlifters who reported a current injury, 49% reported 1 injury site, 47% reported 2 to 3 injury sites, and 4% reported ≥4 injury sites. The locations of the injuries (experienced by >15%) are shown in Figures 2 and 3. The most commonly injured body areas were the lumbopelvic region, shoulder, and hip. Women experienced injuries more frequently in the neck and thoracic region than men (current injury: neck, $P = .005$, thoracic region, $P = .01$; injury during the past 12 months: neck, $P = .005$, thoracic region, $P = .012$). No other significant differences between men and women were found for current injuries or injuries during the past 12 months.

Table 1 describes the characteristics of the reported injuries. Most of the injured powerlifters altered their training routine but did not completely refrain from training, although a majority also experienced pain during training-related activities. Reported alterations were reduced training volume/intensity or omission of certain exercises (n = 40), implementation of specific rehabilitative exercises (n = 13), increased emphasis on technique (n = 12), emphasis on warming up (n = 7), and flexibility training (n = 6).

Regarding the activity during which the injury started, 42% (34/81) reported during squat training, 27% (22/81) during training of the bench press, 31% (25/81) during dead-lift training, 3% (2/81) during the squat event in competitions, 4% (3/81) during the bench-press event in competitions, 7% (6/81) during the dead-lift event in competitions, 17% (14/81) during other training activities, and 7% (6/81) during everyday activities. When the powerlifters were asked to report their own thoughts as to the cause of their injuries, 23% (21/90) stated that the injury/injuries were caused by an excessively high training volume and/or intensity, 6% (5/90) stated poor technique, 6% (5/90) stated poor mobility, and 24% (22/90) stated other factors.

A majority, 58% (52/90), reported that they had visited a health care provider; 42% (37/88) stated that they had received a diagnosis of their injury; and 23% (21/90) received the diagnosis from a physical therapist, 21% (19/90) from a medical doctor, 17% (15/90) from a naprapath/chiropractor/massage therapist, and 3% (3/90) from a trainer. Most powerlifters (66%, 57/87) had received treatment for their injury. Different varieties of passive treatment (eg, massage, acupuncture, ultrasound, or laser therapy) were used by 30% (17/57), pharmaceuticals (eg, analgesics, anti-inflammatory drugs, or muscle relaxants) were used by 11% (6/57), different rehabilitative exercises were used by 11% (6/57), stretching was used by 5% (3/57), and 2% (1/57) underwent surgery.

Table 2 shows the basic characteristics, information about training and competitions, and lifestyle factors of the participants. The men had significantly longer powerlifting training and competition experience and trained a significantly greater number of hours per week when compared with the women. Significantly more women than men received help from a coach/trainer and received help with their training program. Four powerlifters (1 man, 3 women) stated that they had used or use supplements (terbutaline: n = 2; ephedrine: n = 1; testosterone: n = 1) that are currently considered illegal to use in sports.

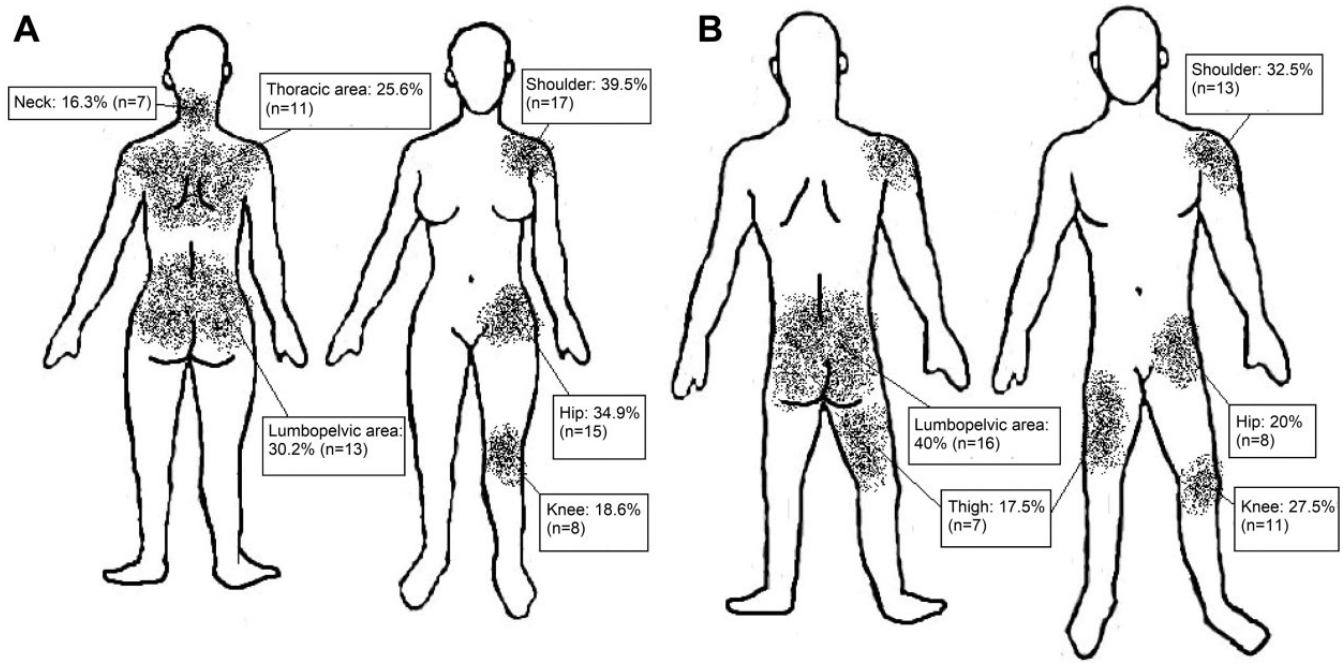

Figure 3. The anatomic localization of injuries during the past 12 months for (A) women and (B) men. Note that each powerlifter may have recorded more than one mark. Results for 43 women and 40 men.

Associations Between Injuries and Training and Lifestyle Factors

For current injuries in any body region, univariate regression analyses showed a significant negative association with squat training (times per week) ($P = .04$; OR, 0.62 [95% CI, 0.39-0.99]). Powerlifters with a current injury trained the squat less frequently (n = 73; mean, 2.10 ± 0.95 times/wk) than those without a current injury (n = 31; mean, 2.55 ± 0.93 times/wk). Personal best in the dead lift (kg) was significantly positively associated with a current injury ($P = .04$; OR, 1.02 [95% CI, 1.00-1.04]). Those with a current injury had a higher personal best in the dead lift (n = 72; mean, 186.93 ± 48.70 kg) compared with those without a current injury (n = 31; mean, 172.10 ± 54.36 kg).

Lumbopelvic Injuries. For current injuries in the lumbopelvic region, there was a significant negative association with powerlifting training (times per week) ($P = .05$; OR, 0.62 [95% CI, 0.38-1.00]). Powerlifters with a current lumbopelvic injury had a lower training frequency (n = 23; mean, 3.30 ± 1.30 times/wk) compared with those without a current injury (n = 48; mean, 3.83 ± 1.30 times/wk). There was a significant positive association with a lumbopelvic injury occurring during dead-lift training ($P = .02$; OR, 4.03 [95% CI, 1.24-13.13]). For those with a current lumbopelvic injury, 52.4% (11/21) stated that the injury started during dead-lift training, compared with 19.0% (8/42) for lumbopelvic injuries that did not start during dead-lift training. There was also a significant negative association with drinking ≤4 standard glasses of alcohol per week ($P = .04$; OR, 0.10 [95% CI, 0.01-0.94]). For those with a current lumbopelvic injury, 28.8% (19/66) stated that they drink ≤4 standard glasses of alcohol per week, whereas for those who drink ≥5 standard glasses of alcohol per week, the proportion was 80.0% (4/5).

Hip Injuries. For current injuries in the hip, there was a significant association with amount of training (hours per week) when sex was included as an interaction variable ($P = .01$). When the analysis was performed for each sex, there was a significant association for men ($P = .03$) but not women ($P = .16$). For men, the OR was 0.70 (95% CI, 0.51-0.97), whereas men with a current hip injury trained for fewer hours per week (n = 11; mean, 6.36 ± 2.91 h/wk) compared with those without a current injury (n = 25; mean, 8.80 ± 2.72 h/wk).

There was a significant association between hip injury and squat training (times per week) when sex was included as an interaction variable ($P = .003$). When the analysis was performed for each sex, there was a significant negative association for men ($P = .02$) and a positive association for women ($P = .04$). For men, the OR was 0.28 (95% CI, 0.09-0.82), whereas men with a current hip injury had a lower squat training frequency (n = 11; mean, 1.36 ± 0.67 times/wk) compared with those without a current injury (n = 25; mean, 2.24 ± 0.97 times/wk). For women, the OR was 2.88 (95% CI, 1.04-8.01), whereas women with a current hip injury had a higher squat training frequency (n = 9; mean, 2.78 ± 1.39 times/wk) compared with those without a current injury (n = 26; mean, 2.08 ± 0.63 times/wk).

Further, there was a significant association with bench-press training (times per week) when sex was included as an interaction variable ($P = .004$). When the analysis was performed for each sex, there was a significant negative association for men ($P = .02$) but not for women ($P = .06$). For men, the OR was 0.22 (95% CI, 0.06-0.80), whereas men with a current

TABLE 1
Characteristics and Consequences of the Injuries as Reported by Powerlifters[a]

	n	All (N = 104)	Men (n = 51)	Women (n = 53)	*P* Value
Onset of injury for athletes with a current injury and/or injury during the past 12 months	90		45	45	
Gradual	90	63 (70.0)	29 (64.4)	34 (75.6)	.25
Acute	90	37 (41.1)	19 (42.2)	18 (40.0)	.83
Powerlifters with a current injury	73		37	36	
Refrains from training sessions	73	21 (28.8)	12 (32.4)	9 (25.0)	.48
Refrains from competitions	73	21 (28.8)	12 (32.4)	9 (25.0)	.48
Can compete in all disciplines	73	56 (76.7)	29 (78.4)	27 (75.0)	.73
Partially refrains from training the SQ/BP/DL	73	33 (45.2)	18 (48.6)	15 (41.7)	.55
Completely refrains from training the SQ/BP/DL	70	11 (15.7)	6 (17.1)[b]	5 (14.3)[b]	.74
Altered their training routine	73	59 (80.8)	32 (86.5)	27 (75.0)	.21
Experiences pain during activities	72	61 (84.7)	28 (75.7)	33 (94.3)	.05[c]
Powerlifters with an injury during the past 12 months	83		40	43	
Refrained from training sessions	83	63 (75.9)	34 (85.0)	29 (67.4)	.06
Refrained from competitions	81	36 (44.4)	21 (53.8)[d]	15 (34.9)	.10
Altered their training routine	83	62 (74.7)	31 (77.5)	31 (72.1)	.57

[a]Data are shown as n (%) unless otherwise specified. All variables were analyzed using the chi-square test unless otherwise indicated. BP, bench press; DL, dead lift; SQ, squat.
[b]n = 35 due to missing data.
[c]Fisher exact test.
[d]n = 39 due to missing data.

hip injury had a lower bench-press training frequency (n = 11; mean, 1.55 ± 0.69 times/wk) compared with those without a current injury (n = 25; mean, 2.48 ± 0.96 times/wk).

There was also a significant positive association with dead-lift training (times per week) when sex was included as an interaction variable ($P = .02$; OR, 6.05 [95% CI, 1.29-28.28]). When the analysis was performed for each sex, there were no significant associations for men ($P = .07$) or women ($P = .15$). There was a significant positive association between hip injury and dietary issues ($P = .03$; OR, 6.17 [95% CI, 1.29-37.02]). For those with a current hip injury, 44.4% (8/18) stated that they had dietary issues, whereas for those who did not have dietary issues, the proportion was 22.6% (12/53).

Shoulder Injuries. For current injuries in the shoulder, there was a significant positive association with the injury's having started during bench-press training ($P = .01$; OR, 4.84 [95% CI, 1.42-16.51]). For those with a current shoulder injury, 56.3% (9/16) stated that the injury started during bench-press training, whereas the proportion was 21.3% (10/47) for shoulder injuries that did not start during bench-press training.

Other Injuries. For current injuries in the thigh, there was a significant negative association with powerlifting training (times per week) ($P = .04$; OR, 0.55 [95% CI, 0.31-0.97]). Powerlifters with a current thigh injury had a lower training frequency (n = 11; mean, 3.00 ± 1.41 times/wk) compared with those without a current injury (n = 60; mean, 3.78 ± 1.24 times/wk). There was also a significant association between thigh injury and squat training (times per week) when sex was included as an interaction variable ($P = .04$). When the analysis was performed for each sex, there was a significant association for men ($P = .03$) but not women ($P = .61$). For men, the OR was 0.18 (95% CI, 0.04-0.83), whereas men with a current thigh injury had a lower squat training frequency (n = 5; mean, 1.00 ± 1.00 times/wk) compared with those without a current injury (n = 31; mean, 2.13 ± 0.88 times/wk). There was also a significant positive association between thigh injury and dead-lift training (times per week) when sex was included as an interaction variable ($P = .02$; OR, 20.07 [95% CI, 1.74-232.07]). When the analysis was performed for each sex, there were no significant associations for men ($P = .06$) or women ($P = .09$).

For current injuries to the knee, there was a significant positive association with wearing lifting straps during training ($P = .01$; OR, 1.46 [95% CI, 1.09-1.96]). Powerlifters with a current knee injury used lifting straps more frequently (n = 9; mean, 4.56 ± 3.94) compared with those without a current injury (n = 62; mean, 1.50 ± 2.12).

For current injuries to the thoracic region, there was a significant positive association with wearing lifting straps during training ($P = .02$; OR, 1.68 [95% CI, 1.10-2.56]). Powerlifters with a current thoracic injury used lifting straps more frequently (n = 12; mean, 2.25 ± 3.11) compared with those without a current injury (n = 59; mean, 1.81 ± 2.50).

For current injuries in the neck, there were no significant associations, and for the remaining background, training, and lifestyle variables, the analyses did not show any significant associations with injuries.

DISCUSSION

Pain or loss of bodily function that affects powerlifters' training is common in Swedish subelite powerlifters. The most commonly injured body areas were the lumbopelvic region, shoulder, and hip. Concerning injuries in the lumbopelvic

TABLE 2
Basic Characteristics, Information About Training and Competitions, and Lifestyle of Powerlifters[a]

	n	All (N = 104)	Men (n = 51)	Women (n = 53)	*P* Value
Age, y	103	28.3 ± 7.6	30.1 ± 8.8	26.7 ± 5.8	.06[b]
Height, cm	104	171.4 ± 9.2	177.5 ± 7.1	165.4 ± 6.8	.00[c]
Weight, kg	104	79.9 ± 17.6	90.9 ± 15.2	69.6 ± 13.0	.00[b]
Powerlifting experience, y	104	3.6 ± 4.7	5.1 ± 6.2	2.2 ± 1.9	.00[b]
Competing in powerlifting, y	104	2.8 ± 4.1	4.0 ± 5.5	1.6 ± 1.5	.00[b]
Powerlifting training, h/wk	104	7.4 ± 3.1	8.1 ± 3.1	6.8 ± 3.0	.04[c]
Powerlifting training, times/wk	104	3.6 ± 1.2	3.8 ± 1.2	3.5 ± 1.2	.17[c]
Squat training, times/wk	104	2.2 ± 1.0	2.1 ± 1.0	2.3 ± 0.9	.23[b]
Bench-press training, times/wk	104	2.3 ± 1.1	2.3 ± 1.1	2.3 ± 0.9	.59[b]
Dead-lift training, times/wk	104	1.6 ± 0.8	1.5 ± 0.8	1.7 ± 0.9	.10[b]
Competitions, times during past year	104	3.0 ± 1.8	2.8 ± 1.7	3.2 ± 1.8	.31[b]
Personal best in squat, kg	103	152.5 ± 48.0	196.5 ± 24.6	111.0 ± 18.1	.00[c]
Personal best in bench press, kg	104	101.2 ± 41.4	140.0 ± 20.7	64.0 ± 10.1	.00[c]
Personal best in dead lift, kg	103	182.5 ± 50.7	229.0 ± 26.7	138.6 ± 18.1	.00[c]
Engage in other forms of physical activity than powerlifting	104	56 (53.8)	20 (39.2)	36 (67.9)	.00[d]
Wear a lifting belt during squat training (0-10; 0 never, 10 always)	104	5.6 ± 2.6	5.3 ± 2.9	5.9 ± 2.4	.98[e]
Wear a lifting belt during dead-lift training (0-10; 0 never, 10 always)	104	5.6 ± 2.8	5.3 ± 2.9	6.0 ± 2.6	.53[e]
Wear lifting straps during training (0-10; 0 never, 10 always)	104	1.6 ± 2.5	2.5 ± 2.9	0.7 ± 1.4	.00[e]
Have a coach/trainer	104	70 (67.3)	27 (52.9)	43 (81.1)	.00[d]
Who helps with technique	70	61 (87.1)	23 (85.2)	38 (88.4)	.70[d]
Who helps with injuries	70	10 (14.3)	4 (14.8)	6 (14.0)	.92[d]
Who helps with training program	70	48 (68.6)	16 (59.3)	32 (74.4)	.18[d]
Have dietary issues	104	26 (25.0)	1 (2.0)	25 (47.2)	.00[f]
Regularly and knowingly lose weight before competitions	104	60 (57.7)	28 (54.9)	32 (60.4)	.57[d]
Use/have used illegal supplements	104	4 (3.8)	1 (2.0)	3 (5.7)	.62[f]
Drink ≤4 standard glasses of alcohol per week	104	94 (90.4)	45 (88.2)	49 (92.5)	.52[f]
Have never smoked cigarettes	104	81 (77.9)	45 (88.2)	36 (67.9)	.01[d]
Have never used snuff	103	68 (65.4)	30 (58.8)	38 (71.7)	.13[d]

[a]Data are shown as mean ± SD or n (%) unless otherwise specified.
[b]Mann-Whitney *U* test between men and women.
[c]Independent-samples *t* test between men and women.
[d]Chi-square test to analyze between sex and variables regarding training planning and coaching, other forms of physical activity, and questions regarding lifestyle factors.
[e]Median test to analyze between sex and variables regarding training planning and coaching, other forms of physical activity, and questions regarding lifestyle factors.
[f]Fisher exact test to analyze between sex and variables regarding training planning and coaching, other forms of physical activity, and questions regarding lifestyle factors.

region, the high prevalence was confirmed by earlier studies.[2,15] It has previously been suggested that the high loads placed on the lumbopelvic region during maximal weights in the dead lift are an important risk factor.[6] It is also known that for most powerlifters, the squat and dead-lift exercises involve a large amount of torque around the lumbopelvic region and hip,[6,10,11] and a nonoptimal technique could negatively affect the distribution of loads and thereby increase the risk of injuries to these regions, as suggested by the localization of injuries in the present study. Regarding the shoulder, earlier studies have found similar injury rates (36%-53%).[18,25] In a previous questionnaire study,[18] it was shown that the prevalence of shoulder injuries varies with the competitive standard, but no such comparison could be made in our study because we included a group of powerlifters within the same competitive standard.

Regarding sex differences and injuries, the present study is the first to include an equal number of male and female powerlifters. The reason for this is that since the publication of previous studies in this area, powerlifting has evolved from being a male-dominated sport to become a sport in which there is an equal number or even more female powerlifters than males. Thus, it has become necessary to reflect this development in research to advance the understanding of injuries in powerlifting and whether there exist differences between the sexes. The results showed that a significantly higher percentage of women reported injuries in the neck and thoracic region compared with men. The reasons for these differences are unclear, but our findings are supported by studies among the general population, which show a higher incidence of pain in the neck and thoracic region among women.[26]

More than half of the powerlifters reported injuries in at least 2 different body regions. The multijoint movements of all the powerlifting disciplines mean that if poor alignment exists in one part of the kinetic chain, then a consequential increased load may be evident in one or several regions of the body.[24] Despite reporting multiple injuries, the

participants continued to train, although 59 of 73 (81%) currently injured powerlifters stated that they altered their training in some way to enable further training. The reason for this might be that their injuries were of an overuse character (gradual rather than acute onset) or because of minor acute-onset injuries such as a muscle strain.[22] These injuries do not always have to lead to reduced time spent training but might result in functional limitations because of pain,[3] thus forcing powerlifters to alter their training plan to avoid aggravating the pain but still enable the training stimulus. Therefore, powerlifters' injuries and injury patterns should be regarded in a similar manner to injuries in other technical sports with repetitive movements, for example, track and field,[17] in which lifting technique/load distribution and training loads could be considered important. Although we were not able to investigate the powerlifters' training loads or technique, we noted that many (23%) of the participants reported excessive training loads as one reason for their injuries. Only 5% reported that lifting technique was the reason for their injuries, which is an interesting finding considering the numerous recommendations regarding the importance of proper lifting technique to avoid injuries.[7,13]

A further finding in relation to the cause and circumstances in which injuries occur was that the majority of reported injuries began during training. More specifically, 43% of injuries started during training of the squat, 27% of injuries during the bench press, and 31% of injuries during the dead lift. For injuries occurring during competitions, the corresponding frequencies were 3% for the squat, 4% for the bench press, and 7% for the dead lift. Generally, powerlifting training entails an accumulation of fatigue at relatively low intensities but through higher frequencies and training volumes to drive adaptations toward increased strength. During competitions, maximal or supramaximal loads are lifted for single repetitions in a state in which the powerlifter ideally is well rested and fresh. This can be compared with a powerlifter's physical and mental fatigue during training, in which he or she is accumulating stress over time and therefore also likely becoming more susceptible to injuries.[8]

As to why so few injuries seem to occur during competitions in which maximal loads are lifted, several reasons are plausible. One explanation could be the general setting in competitions, in which the powerlifter is surrounded by spotters, in combination with the lifts having to be executed in a very controlled manner to adhere to the competition rules. Another explanation could be that the powerlifter's physical and mental status during competitions, that is, well rested and mentally aware/aroused, contributes to a resilience against injuries during competitions.

Associations between certain training-related factors and current injuries were evident in this study. First, a low training frequency in total, and for the squat and bench press in particular, was associated with current injuries as well as injuries in the hip, thigh, and low back. Because the present study was a cross-sectional study, this association could be an effect of 2 opposite reasons. Either a low training frequency is a risk factor for injuries because of "undertraining," or the powerlifters with current injuries have had to lower their training frequency because of their injuries. Interestingly, for current injuries to the hip and training frequency in the squat, there was an opposite significant association for men and women. For men, a lower frequency was associated with injuries, as opposed to a higher frequency for women. This could be explained by differences in either how men and women tend to cope with injuries or differences regarding tissue adaptability.

Second, a higher personal best in the dead lift significantly increased the probability of having a current injury by 2%. This finding may be explained by an increased training load/exposure in powerlifters with a higher personal best.

Third, the results also indicated that certain exercises were associated with injuries in certain regions. Experiencing injury onset during bench-press training was associated with injuries in the shoulder, and onset during dead-lift training was associated with lumbopelvic injuries. This finding further indicates that exercise-specific training loads and/or lifting technique are associated with injuries in powerlifters.

Fourth, the use of lifting straps was significantly associated with current injuries to the knee and thoracic region; a more frequent use of straps increased odds by 46% and 68%, respectively. No previous research has reported similar findings; however, it could be speculated that straps create more difficulty for a powerlifter to achieve a correct starting position and tension throughout the upper body and therefore it could be a possible injury risk factor. Another interpretation is that powerlifters who experience knee or thoracic injuries may use straps to remove load from the injured regions. For example, in the dead lift, it is popular to use a mixed grip, with one hand supinated and one pronated, and on the side of the supinated hand, the arm will have a tendency to push on the thigh and therefore cause knee valgus, possibly related to the origin of the athlete's knee injury. Subsequently, using straps may assist in removing possible valgus movement by allowing both arms to hang straight down.

Fifth, alcohol consumption ($\geq$5 standard glasses per week) and having dietary issues were associated with injuries in the lumbopelvic region and hip, respectively. Although our questionnaire did not include in-depth questions regarding living habits, these findings could indicate that participants with higher alcohol consumption or problems with digestion do not achieve optimal recovery from their training and thus are more likely to get injured.

Because of the high prevalence of injuries in the present study, we suggest that the Swedish, European, and international powerlifting federations prioritize the development of guidelines regarding strategies for preventing injuries. Current data indicate that injuries seem to occur during training of the squat, bench-press, and dead-lift exercises and that training frequency is associated with injuries. Powerlifters also reported that their injuries have occurred because of excessive training loads. Therefore, 2 areas in need of further exploration to develop injury prevention strategies are (1) acute and chronic training loads and (2) relevance of the lifting technique. We therefore suggest that future studies be of a longitudinal design and include factors such as technique and functional tests

(intrinsic factors) in combination with detailed information about training habits (extrinsic factors) to examine if these factors may influence the development of injuries.

Practical Applications

To optimize athletic performance, athletes and strength and conditioning professionals should be aware of the potential risk of developing injuries as part of the practice of powerlifting.[1] The most commonly injured body areas were the lumbopelvic region, shoulder, and hip, which implies that assessments of load distribution in and between these regions should be considered. In previous studies,[1] powerlifters did not report the hip as a commonly injured body region to such an extent as in the present study. Because the impact of squats and dead lifts on the lumbopelvic area has been investigated previously,[6,14] further studies that emphasize the impact of squats and dead lifts on the hip are warranted. Specific consideration should be given to the relevance of hip anatomy, mobility, strength, and movement- and muscle-recruitment patterns during the squat and dead lift in relation to injuries or the risk of injuries in powerlifters. Notably, a majority of the injuries seem to occur specifically during training of the squat, bench press, or dead lift. Training frequency was significantly associated with injuries, and the powerlifters primarily attributed the occurrence of injuries to excessive training loads. Therefore, the management of training loads, preferably by avoiding high spikes without sufficient time for recovery, could be of importance in avoiding injuries in competitive powerlifters.

Methodological Considerations

In contrast to earlier studies on injuries in powerlifting,[1] the definition of an injury used in the present study was a condition of pain or impairment of bodily function that affected powerlifters' training but did not prevent or cause modifications to their training. Previous studies have used a definition that involves an incident or physical damage forcing the powerlifter to modify or refrain from training.[2,15] With the definition used in the present study, the results indicated that injuries are very common in powerlifting as opposed to previous studies that concluded that injury rates are relatively low.[1] However, if we analyze the data from the present study with the more commonly used definition of an injury, we find that only 16% (11/70) of currently injured powerlifters completely refrained from training, which results in an even lower frequency of injuries compared with previous studies.[1] While using a different definition of an injury makes comparisons with previous studies difficult, we believe that it was beneficial to register the injuries and their consequences in a more detailed fashion.

Further, contrary to earlier studies,[1] we included a similar number of male and female participants to avoid problems related to sex differences. However, fewer women compete in powerlifting than men, and thus, the average competitive standard of the women was lower than that of the men in this study. Age and differences in experience of training and competing might have affected the frequency of injuries, as the women in our study were significantly younger and had less powerlifting experience than the men. Earlier studies have shown some differences in injuries between younger powerlifters and those competing in master categories (ie, $\geq$40 years old),[18,25] but it is hard to estimate how this relatively small age difference affected the injury rate.

The powerlifters in the present study trained and competed in the same competitive standard, and the results are therefore only generalizable for powerlifters who compete at a subelite level (ie, below the top 25% of the rank). Previous studies have made comparisons based on level of competition and found that injury rates are higher for national-level powerlifters compared with international-level powerlifters.[18] However, the motive to select powerlifters at a subelite level was that we wanted the results to apply to as large a population of powerlifters as possible and also be applicable to athletes who do not compete in powerlifting but train in a similar way.

Several questions included in the questionnaire dealt with topics that could be considered sensitive in nature, for example, dietary issues and use of illegal substances. Despite participants being ensured of anonymity, it is impossible to know if all the questions were answered truthfully.

Finally, there are some methodological limitations that need to be discussed. First, the possibility of recall bias is always present in a questionnaire study. However, because the majority of questions aimed to document the prevalence of injuries and their consequences (eg, "Do you have a current injury?" or "Do you currently alter your training routine because of an injury?"), we would argue that the results of these questions are accurate. There was certainly a degree of recall bias regarding the questions about previous injuries, thus affecting the validity of findings regarding injury history.

Second, selection bias is also a concern and can directly affect the external validity of the results. One possible bias is that athletes with a current injury could have been more likely to participate in the study and complete the questionnaire than those who were healthy. Further, the present study included male and female subelite powerlifters from Sweden (excluding the top 25% of powerlifters), which makes up the bulk of athletes in the powerlifting community, therefore also making the results generalizable to this population.

Third, the response rate of the questionnaire (53% [104/197] of the total eligible population and 70% [104/148] of the population for which contact information was available answered the questionnaire) could also affect the generalizability of the results. However, when we compared the eligible powerlifters with those who were included in the study (ie, those who answered the questionnaire), they did not differ regarding Wilks points, weight, or sex, meaning that the presented results may be representative for the intended population. Also, by only including currently active powerlifters in the present study, powerlifters who had sustained previous injuries, causing them to retire, were omitted.

Fourth, the detail with which injuries could be described by using a questionnaire is a limitation. Therefore, to account for the inherent limitations of the study design, localization and consequences of injuries were the main focus with regard to injury specifics. To obtain more detailed information regarding injuries in powerlifting, such as specific medical diagnoses, clinical studies will be necessary.

CONCLUSION

Injuries that cause pain or hinder planned training are very common in powerlifters of both sexes at the subelite level: 70% reported a current injury, and 87% reported being injured during the past 12 months. Women more frequently experienced injuries in the neck and thoracic region than men. Injuries did not prevent the majority of either sex from training or competing, but the content and/or focus of training sessions was altered. Training frequency, higher personal best in the dead lift, injury onset during bench-press and dead-lift training, use of straps, alcohol consumption, and dietary issues were associated with having current injuries.

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