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Retrospective Injury Epidemiology of One Hundred One Competitive Oceania Power Lifters: The Effects of Age, Body Mass, Competitive Standard, and Gender

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Abstract. Keogh, J., P.A. Hume, and S. Pearson. Retrospective injury epidemiology of one hundred one competitive Oceania power lifters: The effects of age, body mass, competitive standard, and gender. *J. Strength Cond. Res. 20(3):672–681. 2006.*—The injury epidemiology of competitive power lifters was investigated to provide a basis for injury prevention initiatives in power lifting. Self-reported retrospective injury data for 1 year and selected biographical and training information were obtained via a 4-page injury survey from 82 men and 19 women of varying ages (Open and Masters), body masses (lightweight and heavyweight), and competitive standards (national and international). Injury was defined as any physical damage to the body that caused the lifter to miss or modify one or more training sessions or miss a competition. A total of 118 injuries, which equated to 1.2 ± 1.1 injuries per lifter per year and 4.4 ± 4.8 injuries per 1,000 hours of training, were reported. The most commonly injured body regions were the shoulder (36%), lower back (24%), elbow (11%), and knee (9%). More injuries appeared to be of a sudden (acute) (59%) rather than gradual (chronic) nature (41%). National competitors had a significantly greater rate of injury (5.8 ± 4.9 per 1,000 hours) than international competitors (3.6 ± 3.6 per 1,000 hours). The relative proportion of injuries at some body regions varied significantly as a function of competitive standard and gender. No significant differences in injury profile were seen between Open and Masters or between lightweight and heavyweight lifters. Power lifting appears to have a moderately low risk of injury, regardless of the lifter's age, body mass, competitive standard, or gender, compared with other sports. Future research should utilize a prospective cohort or case-controlled design to examine the effect of a range of other intrinsic and extrinsic factors on injury epidemiology and to assess the effects of various intervention strategies.

Key Words. injuries, risk factors, weight training

Introduction

Power lifting is a sport conducted in a similar fashion to Olympic weightlifting, in which the lifters compete in divisions based on age, body mass, and gender. Although the exercises performed by power lifters in training and competition are similar to those performed by many other weight trainers, power lifting training differs considerably from the training of the vast majority of commercial gym members. Power lifters are continually pushing the envelope in order to exceed their previous personal record 1 repetition maximums in the squat, bench press, and deadlift exercises, with the ultimate aim being to lift greater loads than anyone else in their division. As a result of their never-ending quest to lift heavier loads in these 3 exercises, power lifters can be considered the athletic group closest to the edge of the strength potential of the human race (8, 33). The squat involves placing a loaded barbell on the shoulders, flexing at the hip and knee joints, and descending until the superior surface of the thigh at the hip joint is lower than the knee joint. The lifter then attempts to return to the starting position by extending the knee and hip joints. The bench press requires the lifter to lay supine on a bench, lower a barbell to the chest (where it is held momentarily), and then extend the elbows so the bar finishes above the shoulders. For the deadlift, the lifter starts in a crouched position over the barbell and by knee and hip extension pulls the bar (with straight arms) off the ground to a position across the upper thighs.

Inspection of the current International Powerlifting Federation (IPF) men's world records reveals that the loads lifted in the bench press can exceed 3 times the lifters' body mass, while the loads lifted in the squat and deadlift can be greater than 5 times the lifters' body mass. In order to lift such loads, power lifters must generate exceedingly large internal (musculoskeletal) forces and torques and may therefore be susceptible to a range of musculoskeletal injuries (4, 23).

To the authors' knowledge, only 5 studies (all retrospective in design) have investigated the injury epidemiology of power lifting (4, 16, 17, 26, 27). These studies have focused on Stage I of the van Mechelen injury model (32), as they sought to characterize the injury profile of power lifting by determining the rate, location, severity, or type of injury suffered by power lifters. A summary of these studies is presented in Table 1.

Based on these studies it appears that power lifting results in a relatively low number of injuries (<2 per year), with the majority of these being to the lower back and shoulder. It is also known that power lifters may suffer a range of injury types, with the majority of these being symptomatic for moderately short periods of time (<3 weeks). However, the epidemiology picture for power lifting injury is still incomplete, with a number of gaps still present in this literature. Limited data are available on the nature of the onset of injury, the manner in which the injuries affect training, the mechanisms underlying injury, and the rehabilitation procedures used by power lifters to recover from these injuries. The power lifters used in the previous studies have typically also been young adult (Open) men. As power lifting is a sport that caters to Junior, Open, and Masters lifters of each gender, various body masses, and competitive standards, additional research is required in order to determine the effect that such intrinsic factors could have on the injury epidemiology of power lifting (32). Accordingly, the present authors asked power lifters of varying ages, body masses, competitive standards, and genders to complete a retrospective injury survey that included questions on the nature of the number, location (body region), onset, and cause of injury; the manner in which the injuries affected training; and the rehabilitation procedures used to recover from injuries. This survey was adapted from previously validated retrospective injury surveys (4, 19, 20).

Retrospective surveys have some limitations for injury epidemiology research (14, 20, 31), namely, the accurate recall of injury. For example, Gabbe et al. (14) reported that when Australian rules footballers completed a retrospective injury survey at the conclusion of a 1-year prospective injury study, they were only able to correctly recall 78.6% of the total injuries and injured body regions. The present study sought to mitigate this effect. A retrospective design was used with the power lifters, as they are generally meticulous in recording their daily training sessions in training diaries. We therefore argued that they would be better able to recall information (in a retrospective manner) relevant to a study of injury epidemiology than many other athlete groups (including Australian rules footballers) who don't prospectively record their training sessions. Nevertheless, the validity of determining injury type (e.g., sprain, strain, etc.) in retrospective injury surveys has not been shown to be high, even when assessed by trained medical personnel (14). Further concerns regarding the validity of injury type data in retrospective injury surveys for power lifters have also been expressed (4, 23). As a result of these concerns, no data on injury type was collected in the present study.

TABLE 1. Major findings of previous power lifting injury studies.

Study	Power lifter characteristics	Injury rate	Most frequently injured body regions	Injury severity
Brown and Kimball (3)	71 Junior novice men	1.4 injuries·lifter^{-1}·y^{-1}*	Lower back (50%); knee (8%)	11.5 d·injury^{-1}†
Goertzen et al. (15)	39 Open men	2.1 injuries·lifter^{-1}·y^{-1}	Vertebral column‡ (33%); shoulder (32%)	Not assessed
Goertzen et al. (15)	21 Open women	1.3 injuries·lifter^{-1}·y^{-1}	Knee (28%); vertebral column‡ (24%)	Not assessed
Haykowsky et al. (16)	11 Open elite blind (9 men and 2 women)	1.1 injuries·1,000 h^{-1}	Lower back (25%); shoulder (25%)	12 d·injury^{-1}†
Quinney et al. (25)	31 Open elite§	3.7 injuries·1,000 h^{-1}	Lower back (26%)	18.4 d·injury^{-1}†
Raske and Norlin (26)	100 Open elite men	2.7 injuries·1,000 h^{-1}	Shoulder (24%); lumbar spine (16%)	93% of shoulder, 85% of lower-back, and 80% of knee injuries were major‖

* The duration over which these injuries were surveyed was not stated.
† Average duration of symptoms for each injury.
‡ The authors did not partition the back into upper and lower portions. Therefore, a vertebral column injury includes any injury to any portion of the spine or related structures.
§ Gender unknown.
‖ A major injury was defined as one in which the injury symptoms lasted for longer than 1 month. However, data appears to be combined from an even mixture of power lifters and weightlifters.

METHODS

Experimental Approach to the Problem

The present study used a retrospective injury survey involving categorical and open-ended questions to further examine the injury epidemiology of power lifting. In particular, this study sought to examine how 4 intrinsic factors (i.e., age, body mass, competitive standard, and gender) 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 (32).

Subjects

The majority of the subjects for this study were recruited at 1 regional-, 1 national-, or 1 international-level power lifting competition held in New Zealand during 2002. Of the lifters approached at these competitions, over 50% agreed to participate. Just under 20% of the total subjects were recruited by posting notices on local web-based power lifting forums in late 2002 and early 2003. As a result of these recruitment strategies, 82 men and 19 women gave informed consent to participate in the study (see Table 2). To be eligible to participate in this study, the lifters had to have trained specifically for power lifting for at least 1 year and had to have entered at least 1 power lifting competition in that time period. As a result of these

Table 2. Demographic characteristics of the power lifters.*

		Age		Body weight class		Competitive standard		Gender	
	All lifters ($n = 101$)	Open ($n = 59$)	Masters ($n = 42$)	Lightweight ($n = 59$)	Heavyweight ($n = 42$)	National ($n = 36$)	International ($n = 65$)	Men ($n = 82$)	Women ($n = 19$)
Age (y)	36.6 ± 12.4	28.4 ± 6.6	49.6 ± 6.9†	36.6 ± 13.4	36.5 ± 11.0	32.8 ± 11.5	38.6 ± 12.4†	35.8 ± 12.3	40.2 ± 12.3
Weight training experience (y)	9.9 ± 7.4	7.9 ± 5.7	13.5 ± 8.9†	9.6 ± 7.9	10.3 ± 6.8	8.3 ± 7.2	10.7 ± 7.5	10.8 ± 7.7	5.8 ± 3.8†
Power lifting experience (y)	5.4 ± 4.8	3.8 ± 3.7	8.5 ± 5.1†	4.9 ± 5.0	6.1 ± 4.4	3.7 ± 4.5	6.3 ± 4.7†	5.8 ± 4.9	3.6 ± 3.6
Amount of weight training ($h \cdot wk^{-1}$)	6.1 ± 2.4	6.0 ± 2.4	6.3 ± 2.5	6.0 ± 2.7	6.2 ± 2.1	5.2 ± 1.9	6.6 ± 2.5†	5.6 ± 1.8	8.1 ± 3.5†
Personal record (PR) total (kg)	538 ± 156	551 ± 155	519 ± 159	477 ± 130	619 ± 153†	513 ± 147	548 ± 159	596 ± 122	333 ± 69†
Body mass (kg)	88 ± 24	89 ± 24	87 ± 25	73 ± 12	108 ± 19†	94 ± 21	86 ± 25†	94 ± 22	66 ± 16†

* Results are mean ± standard deviation. The personal record (PR) total is the sum of the best squat, bench press, and deadlift for each lifter in the year of data collection. Body mass is the official body mass recorded during the competition in which the PR was recorded.
† Significantly different ($p < 0.05$) to other level of variable.

inclusion criteria, there was considerable intersubject variability in power lifting experience and ability. At one extreme, some lifters were in their first full year of power lifting competition, and others were seasoned competitors, having competed (and medaled) in IPF Oceania or Worlds Championships. Although it could not be stated categorically that all power lifters were drug free during the course of this study, the lifters were subject to random in- and out-of-competition drug testing. No lifters tested positive to anabolic agents during the course of the study. All procedures used in this study complied with the guidelines of the Auckland University of Technology Ethics Committee.

Procedures

For the purposes of this study, an injury was defined as any physical damage to the body that caused the lifter to miss or modify one or more training sessions or to miss a competition (17, 19, 20, 27, 32). Based on this definition, occurrences such as delayed-onset muscle soreness, blisters, etc., were not considered injuries unless they were of sufficient magnitude to cause the lifter to miss or modify his or her regular training program or to miss a competition. The survey contained questions on the anthropometric, demographic (e.g., age, competitive standard, gender), training (resistance- and power lifting–training experience, hours of training per week), and injury (rate per lifter per year, rate per 1,000 hours training, body region, onset, severity, exercises affected, causative exercise, and treatment type) characteristics of the lifters. It was made clear to the power lifters that they were to complete this survey based on their previous 12 months of training.

Injured body regions were categorized as shoulder, arm, elbow, chest, upper back, lower back, hip and buttock, thigh, knee, or other. A sudden (acute) injury was defined as an injury that occurred at a specific point in time, whereas gradual-onset (chronic) injuries were defined as any mild pain or discomfort that gradually became worse over time. An estimate of the severity of the injury was based on the way in which the training program or competition had to be modified or discontinued and the exercises that were modified or discontinued. No distinction of injury severity was made with regard to whether the injury affected training or competition performance. A mild modification (effect) meant that the lifter had to modify his or her execution of an exercise; a moderate effect meant that the lifter had to stop performing an exercise; and a major effect meant that the lifter had to cancel all training sessions for a period of at least 1 week. A somewhat similar approach has been recently used to assess injury severity in kickboxing classes (30). The activities that were believed to cause the injury and the treatment options used to rehabilitate the injuries were also recorded. Injury-causing activities were divided into weight training, cross-training, and unknown categories. Weight training injuries were further categorized as occurring as a result of each of the 3 individual power lifts or as a result of other weight training exercises. These other weight training exercises will be referred to as assistance exercises in the remainder of the text, as this term is commonly used by power lifters. Cross-training injuries were defined as those resulting from any other recreational (non power lifting) pursuits. Rehabilitation options included no treatment (rest); self-treatment (e.g., ice, strapping, and massage), and medical treatment (e.g., physician, physiotherapist, chiropractor).

Statistical Analyses

Means and standard deviations were calculated for the subject characteristics and injury rates. Injury rates were quantified in 2 ways: the number of injuries per lifter per year and the number of injuries per 1,000 hours of training. In order to calculate the number of injuries per 1,000 hours of training, annual exposure (training) time was estimated by multiplying each lifter's reported average weekly training time by the number of weeks in a year (27). For all other dependent variables (e.g., onset of injury and causative activity), the number and percentage of total occurrences were calculated. Results were calculated for the entire sample, as well as for the various subgroups of age (Open: <40 years and Masters: ≥40 years), body mass (lightweight and heavyweight), competitive standard (National and International), and gender (men or women). International lifters were defined as those who had competed in IPF Oceania or World Championships, with all remaining lifters described as being of National level. As men and women compete in 11 and 10 body mass (bodyweight) classes, respectively, in IPF events, arbitrary body mass cut-offs were selected for the present study in order to categorize lifters as lightweight or heavyweight. Lifters were assigned to these groups based on their normal competition body weight class, with lightweight men and women being defined as <90 kg and <67.5 kg, respectively. All lifters who competed at greater bodyweights were defined as being heavyweights.

A 2-tailed unequal variance *t*-test was used to determine if any significant differences existed in the demographics or injury epidemiology of the power lifters as a function of age, body mass, competitive standard, or gender. Statistical significance was set at $p \leq 0.05$. All analyses were performed using Microsoft Excel (version 9.0; Microsoft, Seattle, WA).

RESULTS

The main finding of the present study was that power lifting resulted in a relatively low rate of injuries and that the severity of the majority of these injuries, as estimated by the effect on training, was not that high. While some significant differences in injury epidemiology existed between national and international level lifters, as well as between men and women, no significant differences were observed as a function of age or body mass.

A summary of these results is presented in Tables 3 and 4. Each table includes data for the entire sample of 101 power lifters as well as for the subgroups representing age, body mass, competitive standard, and gender. A portion of this data has been previously presented in abstract form (18).

Power lifter injury rates, proportion of injuries at various body regions, and onset of injury data are presented in Table 3. Table 3 indicated that on average, each power lifter obtained just over 1 injury per year (4 injuries per 1,000 hours of training), with the most frequently injured body regions being the shoulder (36%) and lower back (24%). National lifters had a significantly greater number of injuries per 1,000 hours of training than international lifters. A number of significant differences were also observed in the relative injury rate at different body regions between national and international lifters, as well as between men and women. National lifters had a significantly greater rate of shoulder and chest injuries, but fewer thigh injuries, than international lifters. Men had a significantly higher rate of chest and thigh injuries than women.

The severity of injuries, as estimated by the effect of the injuries on training, the injury-causing activities, and, to some extent, the injury treatment options, are presented in Table 4. Most injuries had a mild (39%) to moderate (39%) effect (severity) on training, meaning that the lifters only had to make relatively minor modifications to the prescribed training program. No one particular power lifting exercise was found to be affected by injury to a greater extent than the others, with each injury having a 33–41% chance of affecting the training of each of the 3 power lifts. The majority of the injuries were caused by the 3 power lifts (52%) or assistance exercises (20%), although some injuries were attributed to cross-training activities (13%) or were of unknown origin (15%). The power lifters utilized self-treatment (31%) or medical professionals (57%) for the majority of their injuries.

DISCUSSION

Power lifting is a sport in which the stresses applied to the musculoskeletal system of the body when the lifter is performing the squat, bench press, and deadlift exercises can be immense (7, 12, 13). Some members of the public, sporting, medical, and scientific communities may believe that power lifting is an inherently dangerous sport that would result in numerous serious or long-term injuries. The results of this study indicated that power lifters suffer a relatively low number of injuries during the course of a year and that the majority of these injuries were of minor or moderate severity in terms of their effect on subsequent training.

The rate of injury observed in the present study for the Oceania power lifters appeared relatively low, possibly much lower than what many sections of the community would have expected. This relatively low rate of injury appeared consistent with the results described in the power lifting literature, in which 1–2 injuries per year (1–4 injuries per 1,000 hours of training) have been reported for American, Canadian, German, and Swedish power lifters (4, 16, 17, 26, 27). On the basis of these retrospective studies, it would appear that power lifters suffer a substantially lower rate of injuries than the 15–161 injuries per 1,000 hours reported for ice hockey (25), rugby league (15), and rugby union players (1), but power lifters suffer a comparable number of injuries (2–4 injuries per 1,000 hours) to those observed for field hockey (31), gymnastics (19), and track and field athletes (31). However, such comparisons must be made with some degree of caution, as it was somewhat unclear whether or not the previous studies included training as well as competition injuries. Interstudy differences in the injury definition and data collection procedures could also make comparisons between the present study and those of the literature difficult. The latter point is particularly important, as retrospective studies may underestimate the true rate of injury (14, 20, 31).

Although epidemiological research is generally concerned with the average response of a sample of the population, the present study was also interested in the degree of interindividual variability in injury rate. Considerable interlifter variation was observed, with 34 of the

TABLE 3. Rate, body region, and onset of injury in power lifters. Injury rates are presented as mean ± *SD*. The results for body region injured and injury onset are expressed in 2 ways, with the first value being the total number of occurrences and the second number (in parentheses) the percentage of total occurrences.

		Age		Body mass		Competitive standard		Gender	
	All lifters (n = 101)	Open (n = 59)	Masters (n = 42)	Lightweight (n = 59)	Heavyweight (n = 42)	National (n = 36)	International (n = 65)	Men (n = 82)	Women (n = 19)
Injury rate									
Injuries·lifter^{-1}·y^{-1}	1.2 ± 1.1	1.1 ± 1.0	1.3 ± 1.1	1.1 ± 1.0	1.3 ± 1.2	1.4 ± 1.1	1.0 ± 1.1	1.2 ± 1.1	1.1 ± 1.1
Injuries·1,000 h^{-1} training and competition	4.4 ± 4.8	4.0 ± 4.7	4.7 ± 4.7	4.3 ± 5.3	4.4 ± 4.1	5.8 ± 4.9	3.6 ± 3.6*	4.7 ± 5.1	3.1 ± 3.4
Body region									
Shoulder injury	43 (36.1%)	21 (33.9%)	22 (39.3%)	24 (38.7%)	19 (39.0%)	21 (42.0%)	22 (32.4%)*	34 (34.3%)	9 (45.0%)
Arm injury	3 (2.5%)	0 (0.0%)	3 (5.4%)	3 (4.8%)	0 (0.0%)	0 (0.0%)	3 (4.4%)	3 (3.0%)	0 (0.0%)
Elbow injury	13 (11.0%)	8 (12.9%)	5 (8.9%)	6 (9.7%)	7 (12.5%)	5 (10.0%)	8 (11.8%)	9 (9.1%)	4 (20.0%)
Chest injury	4 (3.4%)	3 (4.8%)	1 (1.8%)	3 (4.8%)	1 (1.8%)	4 (8.0%)	0 (0.0%)*	4 (4.1%)	0 (0.0%)*
Upper back injury	2 (1.7%)	2 (3.2%)	0 (0.0%)	1 (1.6%)	1 (1.8%)	2 (4.0%)	0 (0.0%)	2 (2.0%)	0 (0.0%)
Lower back injury	28 (23.7%)	15 (24.2%)	13 (23.2%)	11 (17.7%)	17 (30.4%)	10 (20.0%)	18 (26.5%)	24 (24.2%)	4 (20.0%)
Hip or buttock injury	2 (1.7%)	1 (1.6%)	1 (1.8%)	2 (3.2%)	0 (0.0%)	1 (2.0%)	1 (1.5%)	1 (1.0%)	
Thigh injury	7 (5.9%)	3 (4.8%)	4 (7.1%)	4 (6.5%)	3 (5.4%)	0 (0.0%)	7 (10.3%)*	7 (7.1%)	1 (5.0%)
Knee injury	11 (9.3%)	5 (8.1%)	6 (10.7%)	6 (9.7%)	5 (8.9%)	5 (10.0%)	6 (8.8%)	10 (10.1%)	0 (0.0%)*
Other body region									1 (5.0%)
injury	5 (4.2%)	4 (6.5%)	1 (1.8%)	2 (3.2%)	3 (5.4%)	2 (4.0%)	3 (4.4%)	4 (4.1%)	1 (5.0%)
Injury onset									
Acute onset	70 (59.3%)	35 (56.5%)	35 (62.5%)	37 (59.7%)	33 (58.9%)	36 (72.0%)	34 (50.0%)	60 (61.2%)	10 (50.0%)
Chronic onset	48 (40.7%)	27 (43.5%)	21 (37.5%)	25 (40.3%)	23 (41.1%)	14 (28.0%)	34 (50.0%)	38 (38.8%)	10 (50.0%)

* Significantly different ($p < 0.05$) to other level of variable.

TABLE 4. Effect of injury on training, causative activities, and injury treatment procedures for the power lifters. Results are presented in 2 ways, the first value being the total number of occurrences and the second number (in parentheses) the percentage of total occurrences.

		Age		Body mass		Competitive standard		Gender	
	All lifters (n = 101)	Open (n = 59)	Masters (n = 42)	Lightweight (n = 59)	Heavyweight (n = 42)	National (n = 36)	International (n = 65)	Men (n = 82)	Women (n = 19)
Effect on power lifting training and competition									
Mild	46 (39.0%)	22 (35.5%)	24 (42.9%)	21 (33.9%)	25 (44.6%)	20 (40.0%)	26 (38.2%)	36 (36.4%)	10 (50.0%)
Moderate	46 (39.0%)	26 (41.9%)	20 (35.7%)	28 (45.2%)	18 (32.1%)	21 (42.0%)	25 (36.8%)	38 (38.4%)	8 (40.0%)
Major	26 (22.0%)	14 (22.6%)	12 (21.4%)	13 (21.0%)	13 (23.2%)	9 (18.0%)	17 (25.0%)	24 (24.2%)	2 (10.0%)
Exercise affected									
Squats	39 (33.1%)	25 (40.3%)	14 (25.0%)	24 (38.7%)	15 (26.8%)	16 (32.0%)	23 (33.8%)	36 (36.4%)	3 (15.0%)
Bench press	48 (40.7%)	24 (38.7%)	24 (42.9%)	27 (43.5%)	21 (37.5%)	24 (48.0%)	24 (35.3%)	43 (43.4%)	5 (25.0%)
Deadlift	41 (34.7%)	24 (38.7%)	17 (30.4%)	23 (37.1%)	18 (32.1%)	15 (30.0%)	26 (38.2%)	38 (38.4%)	3 (15.0%)
Assistance exercises	54 (45.8%)	33 (53.2%)	21 (37.5%)	30 (48.4%)	24 (42.9%)	24 (48.0%)	30 (44.1%)	42 (42.4%)	12 (60.0%)
Causative activity									
Squats	21 (17.8%)	7 (11.3%)	14 (25.0%)	10 (16.1%)	11 (19.6%)	5 (10.0%)	16 (23.5%)	18 (18.2%)	3 (15.0%)
Bench press	26 (22.0%)	13 (21.0%)	13 (23.2%)	15 (24.2%)	11 (19.6%)	14 (28.0%)	12 (17.6%)	23 (23.2%)	3 (15.0%)
Deadlift	14 (11.9%)	10 (16.1%)	4 (7.1%)	5 (8.1%)	9 (16.1%)	7 (14.0%)	7 (10.3%)	12 (12.1%)	2 (10.0%)
Assistance exercises	24 (20.3%)	14 (22.6%)	10 (17.9%)	13 (21.0%)	11 (19.6%)	10 (20.0%)	14 (20.6%)	20 (20.2%)	4 (20.0%)
Cross training	15 (12.7%)	8 (12.9%)	7 (12.5%)	10 (16.1%)	5 (8.5%)	10 (20.0%)	5 (7.4%)	12 (12.1%)	3 (15.0%)
Unknown	18 (15.3%)	10 (16.1%)	8 (14.3%)	9 (14.5%)	9 (16.1%)	4 (8.0%)	14 (20.6%)	13 (13.1%)	5 (25.0%)
Injury treatment									
None	15 (12.7%)	11 (17.7%)	4 (7.1%)	8 (12.9%)	7 (12.5%)	5 (10.0%)	10 (14.7%)	13 (13.1%)	2 (10.0%)
Self	36 (30.5%)	20 (32.3%)	16 (28.6%)	19 (30.6%)	17 (30.4%)	22 (44.0%)	14 (20.6%)	31 (31.3%)	5 (25.0%)
Medical	67 (56.8%)	31 (50.0%)	36 (64.3%)	35 (56.5%)	32 (57.1%)	23 (46.0%)	44 (64.7%)	54 (54.5)	13 (65.0%)

101 power lifters reporting no injuries over the course of the year, while 12 lifters received 3 or more injuries during the same time period. This variability in injury rate did not appear to be related to the age, body mass, competitive standard, gender, hours of training per week, or training–power lifting experience of the lifters. Thus, other intrinsic factors, such as the lifter's anthropometric profile, previous injury history, muscle balance, flexibility, and training practices as well as extrinsic factors such as use of safety equipment, time of day in which training is performed, and environmental conditions, may have contributed to these differences (32).

Consistent with the general findings of the literature (4, 16, 17, 26, 27), the shoulder and lower back were the most commonly injured body regions. The proportionally high rate of shoulder injuries may be a result of the large stresses that the bench press applies to the shoulder (9, 34), particularly the rotator cuff, acromioclavicular joint, and shoulder capsule (12, 28). Similarly, the majority of the lower-back injuries appeared to be associated with the performance of the squat and deadlift. This may be a consequence of the exceedingly large hip extensor torques (3, 7, 11) and compressive or shear lumbar forces (7, 13) reported for these exercises.

A greater proportion of injuries were reported to be acute (59.3%) than chronic in nature (40.7%). It is, however, acknowledged that some injuries may appear acutely but may actually reflect chronic degeneration (5). Unfortunately, the retrospective design and the lack of medical confirmation of each injury did not easily allow for determination of this third type of injury onset. The true rate of acute injuries may therefore be somewhat less than that reported. While little research has quantified injury onset in power lifting, Raske and Norlin (27) reported that 25% of injuries were overuse (chronic) tendon injuries and 20% of injuries were acute muscle injuries. In conjunction with the results of the present study, this indicates that power lifters are likely to suffer both acute and chronic injuries.

By definition, each injury reported in the present study forced the lifters to modify or discontinue their training or miss a competition. Only 22% of the injuries were described as having a major effect (i.e., required a complete cessation of training for 1 week or more). This could be interpreted as indicating that the majority of injuries seen in the present study were not that severe (disabling). Previous studies have assessed injury severity and disability by recording the number of days during which the injury was symptomatic (i.e., affected training). The majority of these studies reported that the mean time each injury affected training was 11.5–18.4 days (4, 17, 26). In contrast, Raske and Norlin (27) found that over 80% of all shoulder, lower-back, and knee injuries (3 of the 4 most commonly injured body regions) were symptomatic for at least 1 month. Thus, it appears that while the injuries obtained by power lifters may span the spectrum of severity or disability, most are not overly severe or disabling, requiring only minor or moderate modifications to the regular training program.

As well as quantifying the effect of each injury on the overall training program, it was also thought to be important to determine which exercises were affected by these injuries, as an injury that affects all 3 power lifts would likely result in a greater performance decrement than an injury that only affected one of the lifts. The results showed that all 3 power lifts had a similar likelihood (33–41%) of being affected by any particular injury. Almost half (46%) of all injuries also affected the performance of at least one of the assistance exercises. This indicates that no one particular exercise was affected by injury more than the other lifts and that each injury generally disrupted the performance of at least one of the power lifts and assistance exercises.

The 3 power lifts accounted for 52% of total power lifting injuries, with the remainder attributed to assistance exercises, cross-training activities, or of unknown origin. These results indicate that the injuries suffered by power lifters cannot all be attributed to one particular exercise. This extends the findings of Raske and Norlin (27), who found no significant difference in the incidence of shoulder injuries in power lifters based on the upper-body exercises they routinely performed in training. The true rate of injuries attributed to specific power lifting training may be somewhat lower than that reported in this study because of the relatively high proportion of cross-training injuries. These injuries were typically caused by playing ball sports (e.g., rugby and soccer) or resulted from cardiovascular training. Even though these cross-training injuries were not directly caused by specific power lifting training, they did affect the training of the power lifters. Further, the mechanism of injury associated with cross-training may have actually reflected (at least in part) some chronic degeneration or muscle balance and range-of-motion imbalances attributable to long-term power lifting training (5).

The relatively low rate of squatting-related injuries was an interesting finding, as the effect of heavy full squats on the knee joint has been hotly debated for some time (6, 28, 29). If such fears were warranted, the considerable loads and knee range of motion ($\sim$111°) used by power lifters when they are squatting (35) should result in a high rate of knee injuries. In accordance with the vast majority of the literature (4, 16, 17, 26, 27), the present study found that knee injuries accounted for less than 10% of total power lifting injuries.

Of the 11 knee injuries seen in the present study, only 6 were acute in onset, and only 3 of these occurred during the performance of squats. This low number of knee injuries contrasts with the other 2 weight training sports that routinely require performance of highly loaded squat-type exercises (Olympic weightlifting and bodybuilding). In these 2 sports, knees have generally been reported to be the most frequently injured body region, accounting for between 17% and 31% of all injuries (16, 21, 22). The lower rate of knee injuries in power lifters compared to Olympic weightlifters and bodybuilders may be a consequence of differences in the manner in which the squat (and its derivatives) are performed.

When performing the squat, power lifters tend to position the bar further down the back than do other weight trainers. This technique, referred to as the low-bar squat, results in greater forward inclination of the trunk than the front or high-bar squats more commonly used by Olympic weightlifters and bodybuilders (35). In order to maintain the center of mass over the base of support in the low-bar squat, the lifter will have a greater posterior excursion of the hips and less dorsiflexion than when performing the high-bar squat (see Figure 1).

As a result of these differences in joint angles and positions, the power lifting-style low-bar squat reduces the

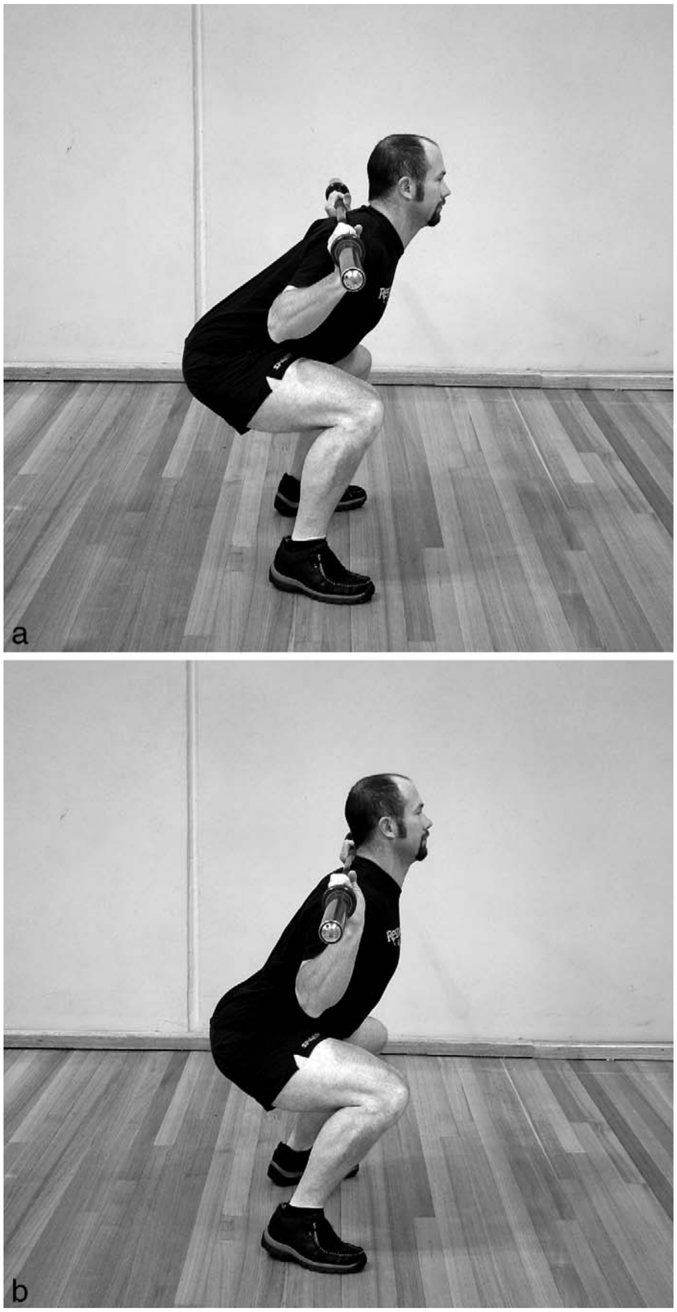

FIGURE 1. Power lifter performing the low-bar squat (a) and high-bar squat (b).

moment arm of the load and the extensor torque about the knee while increasing the moment arm of the load and the extensor torque around the hip, in comparison to the high-bar squat (10, 35). The low-bar squat also produces significantly lower mean compressive patello-femoral forces than do high-bar squats (35). Therefore, the mechanical stress applied to the knee is less in the low-bar than in the high-bar squat. It is proposed that this reduction in stress to the knee in the low-bar squat is one of the main contributing factors leading to the relatively low number of knee injuries in power lifting compared to the other weight training sports.

Once an injury occurs, the athlete will commence a rehabilitation program so that he or she can return to training and competition as soon as possible. The power lifters in the present study appeared to be relatively diligent with their injury management, as they used self-treatment or consulted qualified health professionals for most of their injuries. In the only other study that has assessed injury rehabilitation (management) procedures, Brown and Kimball (4) reported that 73.9% of injuries to novice adolescent power lifters were treated with rest alone and that physicians assessed <25% of all injuries. This interstudy discrepancy in injury management procedures may have been a consequence of the differences in age, training experience, and competitive standard of the power lifters in the present study and those of the Brown and Kimball study (4). It is also possible that interstudy differences in injury severity accounted for this disparity, as it would be more likely that medical professionals would be consulted for severe than for minor injuries. However, both the present study and that of Brown and Kimball (4) drew similar conclusions regarding the severity of injury associated with power lifting.

It was observed that power lifters aged 40 years and older (Masters lifters) received injuries at a similar rate, to the same body regions, and of a comparable severity to Open lifters. While it was conceivable that the greater age of the Masters lifters would have resulted in a higher rate and severity of injury than was seen in the Open lifters, the Masters lifters also had significantly greater weight-training and power lifting experience. The greater experience of the Masters lifters may, therefore, have counteracted the potential effect that their increased age might have had on their rate of injury. This significant difference in training experience between the groups may have been a confounding variable when we tried to determine if a true age-related difference in injury epidemiology would occur.

Substantial differences in injury-management procedures were also seen. Open lifters used rest as a treatment option for a greater percentage of injuries than did Masters lifters, whereas Masters lifters utilized medical treatment for a greater percentage of injuries than did Open lifters. As no age-related difference in injury severity was apparent, these findings further support the proposal that lifters of greater age and training experience are more likely to utilize medical services to diagnose and treat their power lifting injuries (4).

Body mass did not appear to have a significant influence on the injury profile of power lifting. Therefore, people of all body masses may participate in power lifting with the same relative risk of injury. This may be a function of the moderate to high correlation between the load lifted in the 3 power lifts, and, hence, the stress imposed on the system, and the lifter's body mass (r = 0.50–0.68) or fat-free mass (r = 0.86–0.94) (2, 24).

International lifters lifted substantially greater loads in training and competition, were significantly older, and had significantly more power lifting training experience than national lifters. The international competitors also had a significantly lower rate of injury per 1,000 hours of training than their national peers (3.6 ± 3.6 vs. 5.8 ± 4.9). Although no other study has evaluated the effect of competitive standard on injury rate in power lifting, previous studies of elite level power lifters have also reported a relatively low injury rate per year per 1,000 hours of training (17, 27). These results indicate that training experience is an important factor in reducing power lifting injuries.

Regardless of competitive standard, the shoulder and lower back were the 2 most frequently injured body regions. However, the relative proportion of injuries in other body regions differed significantly between these groups, with the national level competitors having significantly more chest and shoulder injuries than the international lifters. This seems consistent with the finding that the bench press was responsible for a greater proportion of injuries and was more frequently affected by injury in the national than in the international lifters. These results indicate that in order to reduce their proportionally higher rates of shoulder and chest injuries, national lifters may need to alter the manner in which they train the upper-body pushing muscles (12). They may need to pay more attention to bench press technique, bench press training program variables (e.g., warm up procedures, training volume, and intensity), and address upper body muscular and range-of-motion imbalances and deficits. Alternately, national lifters suffered a significantly lower number of thigh injuries than did international lifters. The international lifters' higher rate of thigh injuries would appear to be attributable to their greater number of squatting-related injuries.

International lifters had a greater percentage of acute-onset injuries than did national lifters (72% vs. 50%). However, as the international lifters had a significantly lower injury rate than national lifters, the actual number of acute injuries, quantified either per year or per 1,000 hours of training, was actually very similar between the 2 groups of lifters. International lifters also utilized the services of trained health professionals for a greater proportion of all injuries than national lifters (64.7% vs. 46.0%). As little difference in injury severity was observed between the international and national lifters, this offers further support to the view that the utilization of health services increases with age and training experience (4).

The injury epidemiology of men and women appeared relatively similar. The major difference was that, because the women had no chest or thigh injuries, their rate of injuries to these body regions was significantly less than that of the men. As a consequence of the men's higher rate of chest and thigh injuries, a greater percentage of their injuries had a direct effect on the training performance of the 3 power lifts than on that of the women. Only one other study has assessed power lifting injury rates in men and women. Goertzen et al. (16) reported that men had a greater number of injuries over an 18-month period than did women (3.08 vs. 1.90) and that some significant differences in the relative proportion of injury at various body regions also occurred. According to Goertzen et al. (16), although the shoulder, vertebral column, elbow, and knee were the 4 most commonly injured body regions for both genders, the most commonly injured body region for men was the vertebral column, whereas for women it was the knee. In conjunction with the results of Goertzen et al. (16), the present study revealed that some differences may exist between men and women with respect to their injury epidemiology and to the effect of these injuries on their training. However, these results indicate that women are not at increased risk of power lifting injury compared to men.

The results of this study add further to the epidemiology picture of power lifting injury. Future research should involve the use of a prospective cohort or case-controlled design and should examine the effect of a greater range of intrinsic (e.g., anthropometric profile, fatigue, flexibility, muscle balance, previous injury) and extrinsic (e.g., assistance equipment used, environmental conditions, exercises performed, loads used, presence of coach or training partners) factors on injury profile. Such research will assist in the development of specific intervention programs that can then be assessed to determine their efficacy in reducing power lifting injuries. Research should also assess the long-term effect of power lifting training to determine if such training contributes to disability later in life and, if so, how these effects can be minimized.

Practical Applications

Regardless of age, body mass, competitive standard, or gender, power lifting appeared to result in significantly fewer injuries in the short term than are seen in contact sports such as ice hockey, rugby union, and rugby league. On this basis, power lifting should not be considered a high-risk sporting activity. As the majority of power lifting injuries occurred to the shoulder and lower back, lifters should utilize good technique in the 3 power lifting exercises as well as the assistance exercises that most greatly stress these parts of the body. This may be especially important for inexperienced (national) lifters, who were found to have a greater rate of injury than the more-experienced (international) lifters. Lifters may also need to address muscular strength and range-of-motion imbalances around the shoulder and lower back if they wish to minimize the rate and severity of such injuries.

References

1. Babic, Z., M. Misigoj-Durakovic, H. Matasic, and J. Jancic. Croatian rugby project. Part II: Injuries. *J. Sports Med. Phys. Fitness* 41:392–398. 2001.
2. Brechue, W.F., and T. Abe. The role of FFM accumulation and skeletal muscle architecture in powerlifting performance. *Eur. J. Appl. Physiol.* 86:327–336. 2002.
3. Brown, E.W., and K. Abini. Kinematics and kinetics of the dead lift in adolescent power lifters. *Med. Sci. Sports Exerc.* 17: 554–563. 1985.
4. Brown, E.W., and R.G. Kimball. Medical history associated with adolescent powerlifting. *Pediatrics* 72:636–644. 1983.
5. Caine, C.G., D.J. Caine, and K.J. Lindner. The epidemiologic approach to sports injuries. In: *Epidemiology of Sports Injuries.* D.J. Caine, C.G. Caine, and K.J. Lindner, eds. Champaign, IL: Human Kinetics, 1996. pp. 1–13.
6. Chandler, T., G.D. Wilson, and M. Stone. The squat exercise: Attitudes and practices of high school football coaches. *Natl. Strength Cond. Assoc. J.* 11:30–34. 1989.
7. Cholewicki, J., S.M. McGill, and R.W. Norman. Lumbar spine loads during the lifting of extremely heavy weights. *Med. Sci. Sports Exerc.* 23:1179–1186. 1991.
8. Dooman, C.S., and P.M. VanderBurgh. Allometric modeling of the bench press and squat: Who is the strongest regardless of body mass? *J. Strength Cond. Res.* 14:32–36. 2000.
9. Elliott, B.C., G.J. Wilson, and G.K. Kerr. A biomechanical analysis of the sticking region in the bench press. *Med. Sci. Sports Exerc.* 21:450–462. 1989.
10. Escamilla, R.F., G.S. Fleisig, T.M. Lowry, S. Barrentine, and J. Andrews. A three-dimensional biomechanical analysis of the squat during varying stance widths. *Med. Sci. Sports Exerc.* 33:984–998. 2001.

11. Escamilla, R.F., A. Francisco, G.S. Fleisig, S. Barrentine, C. Welch, A. Kayes, and J. Andrews. A three-dimensional biomechanical analysis of sumo and conventional style deadlifts. *Med. Sci. Sports Exerc.* 32:1265–1275. 2000.
12. Fees, M., T. Decker, L. Snyder-Mackler, and M. Axe. Upper extremity weight-training modifications for the injured athlete. *Am. J. Sports Med.* 26:732–742. 1998.
13. Fortin, J.D., and F.J.E. Falco. The biomechanical principles for preventing weightlifting injuries. *Phys. Med. Rehabil.* 11: 697–716. 1997.
14. Gabbe, B.J., C.F. Finch, K.L. Bennell, and H. Wajswelner. How valid is a self reported 12 month sports injury history? *Br. J. Sports Med.* 37:545–547. 2003.
15. Gabbett, T.J. Incidence, site, and nature of injuries in amateur rugby league over three consecutive seasons. *Br. J. Sports Med.* 34:98–103. 2000.
16. Goertzen, V., K. Schoppe, G. Lange, and K.P. Schulz. Medical history associated with body building and power lifting. *Sportverletz. Sportschaden.* 3:32–36. 1989.
17. Haykowsky, M.J., D.E.R. Warburton, and H.A. Quinney. Pain and injury associated with powerlifting training in visually impaired athletes. *J. Visual Impair. Blin.* 93:236–241. 1999.
18. Keogh, J., P. Hume, and S. Pearson. Epidemiology of injury in powerlifting: Retrospective results. *J. Sci. Med. Sport* 6:44. 2003.
19. Kolt, G.S., and R.J. Kirkby. Epidemiology of injury in Australian female gymnasts. *Sports Med. Training Rehab.* 6:223–231. 1995.
20. Kolt, G.S., and R.J. Kirkby. Epidemiology of injury in elite and subelite female gymnasts: Comparison of retrospective and prospective findings. *Br. J. Sports Med.* 33:312–318. 1999.
21. Konig, M., and K. Biener. Sport-specific injuries in weight lifting. *Schweiz. Z. Sportmed.* 38:25–30. 1990.
22. Kulund, D.M. Olympic weight-lifting injuries. *Physician Sportsmed.* 6:111–118. 1978.
23. Lombardi, V.P. Resistance training. In: *Epidemiology of Sports Injuries.* D.J. Caine, C.G. Caine, and K.J. Lindner, eds. Champaign, IL: Human Kinetics, 1996. pp. 312–336.
24. Mayhew, J.L., F.C. Piper, and J.S. Ware. Anthropometric correlates with strength performance among resistance trained athletes. *J. Sports Med. Phys. Fitness* 33:159–165. 1993.
25. Molsa, J., U. Kujala, P. Myllynen, I. Torstila, and O. Airaksinen. Injuries to the upper extremity in ice hockey: Analysis of a series of 760 injuries. *Am. J. Sports Med.* 31:751–757. 2003.
26. Quinney, H.A., D.E.R. Warburton, A. Webster, R. Calvert, and M.J. Haykowsky. Powerlifting injuries associated with elite powerlifting training. *Can. J. Appl. Physiol.* 20:49. 1997.
27. Raske, A., and R. Norlin. Injury incidence and prevalence among elite weight and power lifters. *Am. J. Sports Med.* 30: 248–256. 2002.
28. Reeves, R.K., E.R. Laskowski, and J. Smith. Weight training injuries. Part 1: Diagnosing and managing acute injuries. *Physician Sportsmed.* 26:67–71,74,75,79,80,83,96. 1998.
29. Reeves, R.K., E.R. Laskowski, and J. Smith. Weight training injuries. Part 2: Diagnosing and managing chronic injuries. *Physician Sportsmed.* 26:54–63,73,85,86. 1998.
30. Romaine, L.J., S.E. Davis, K. Casebolt, and K.A. Harrison. Incidence of injury in kickboxing participation. *J. Strength Cond. Res.* 17:580–586. 2003.
31. Twellar, M., F.T.J. Verstappen, and A. Huson. Is prevention of sports injuries a realistic goal? *Am. J. Sports Med.* 24:528–534. 1996.
32. Van Mechelen, W., H. Hlobil, and H.C.G. Kemper. Incidence, severity, aetiology and prevention of sports injuries. *Sports Med.* 14:82–99. 1992.
33. VandenBurgh, P.M., and C. Dooman. Considering body mass differences, who are the world's strongest women? *Med. Sci. Sports Exerc.* 32:197–201. 2000.
34. Wagner, L.L., S.A. Evans, J.P. Weir, T.J. Housh, and G.O. Johnson. The effect of grip width on bench press performance. *Int. J. Sport Biomech.* 8:1–10. 1992.
35. Wretenberg, P., Y. Feng, and U.P. Arborelius. High- and low-bar squatting techniques during weight-training. *Med. Sci. Sports Exerc.* 28:218–224. 1996.

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