

The American Journal of Sports Medicine

<http://ajs.sagepub.com/>

Epidemiology of Weight Training-Related Injuries Presenting to United States Emergency Departments, 1990 to 2007

Zachary Y. Kerr, Christy L. Collins and R. Dawn Comstock
Am J Sports Med 2010 38: 765 originally published online February 5, 2010
DOI: 10.1177/0363546509351560

The online version of this article can be found at:
<http://ajs.sagepub.com/content/38/4/765>

Published by:



<http://www.sagepublications.com>

On behalf of:



[American Orthopaedic Society for Sports Medicine](#)

Additional services and information for *The American Journal of Sports Medicine* can be found at:

Email Alerts: <http://ajs.sagepub.com/cgi/alerts>

Subscriptions: <http://ajs.sagepub.com/subscriptions>

Reprints: <http://www.sagepub.com/journalsReprints.nav>

Permissions: <http://www.sagepub.com/journalsPermissions.nav>

Epidemiology of Weight Training-Related Injuries Presenting to United States Emergency Departments, 1990 to 2007

Zachary Y. Kerr,^{*} MA, Christy L. Collins,^{†‡} MA, and R. Dawn Comstock,^{*‡§} PhD
From the ^{*}College of Public Health, Division of Epidemiology, The Ohio State University,
[‡]The Center for Injury Research and Policy, The Research Institute at Nationwide Children's
Hospital, and the [§]College of Medicine, Department of Pediatrics, The Ohio State University,
Columbus, Ohio

Background: As participation in weight training in the United States increases, the number of persons at injury risk increases.

Purpose: To examine weight training-related injuries in patients presenting to US emergency departments from 1990 to 2007.

Study Design: Descriptive epidemiology study.

Methods: Weight training-related injury data were analyzed from the US Consumer Product Safety Commission's National Electronic Injury Surveillance System. Sample weights provided by this organization calculated national estimates of weight training-related injuries from the 100-hospital sample.

Results: From 1990 to 2007, 25 335 weight training injuries were seen in US emergency departments, correlating to an estimated 970 801 injuries nationwide. Patients' mean age was 27.6 years (range, 6-100 years); 82.3% were male. The upper trunk (25.3%) and lower trunk (19.7%) were the most commonly injured body parts. The most common diagnosis was sprain/strain (46.1%). The most common mechanism of injury was weights dropping on the person (65.5%). A large number of injuries occurred with free weights (90.4%). Males had a larger proportion of upper trunk injuries (26.8%; injury proportion ratio [IPR], 1.45; 95% confidence interval [CI]: 1.36-1.57; $P < .001$) than females (18.4%). Females had a larger proportion of foot injuries (22.9%; IPR, 2.09; 95% CI: 1.93-2.26; $P < .001$) than males (11.0%). Persons 12 years and younger had a larger proportion of hand (37.9%; IPR, 2.08; 95% CI: 1.76-2.46; $P < .001$) injuries than persons 13 years or older (18.2%). Persons 55 years and older were injured more when using machines (18.2%; IPR, 1.96; 95% CI: 1.47-2.61, $P < .001$) than persons 54 years and younger (9.3%). Persons using free weights sustained a greater proportion of fractures/dislocations (23.6%; IPR, 2.44; 95% CI: 1.92-3.09; $P < .001$) than persons using machines (9.7%).

Conclusion: Further research is needed to drive development of targeted, age- and gender-specific, evidence-based injury prevention strategies to decrease injury rates among weight training participants.

Keywords: weight training; injury; epidemiology; National Electronic Injury Surveillance System

The popularity of weight training has grown over the past decade, with approximately 64.5% more persons participating in weight training presently than in 1998.¹⁷ Recent estimates place the number of people working out with free weights and/or weight machines between 2006 and 2008 at 37 to 45 million.^{2,7,16,22} As the number of persons participating in weight training continues to increase, so does the number of persons

at risk for injury. To reduce the burden of weight training-related injuries to the lowest possible level, the epidemiologic factors of such injuries must be understood.

A number of studies have examined weight training-related injuries sustained by specific populations including children and adolescents,^{4,9,24,25} adolescent and college-level athletes,^{3,19,28} and power lifters.^{13,21} The general consensus of the findings was that the majority of weight lifting injuries occurred among males,^{12,20} adolescents,^{3,4,12,24,25} and older persons.¹² Injuries occurred most commonly in the lower back^{3,4,13,21,24,25,28} and shoulder^{18,24} and consisted mostly of strains.^{25,28}

Only a limited number of studies have investigated weight training-related injuries in the general population. One study examined specific groups of athletes, coupled with data from the National Electronic Injury Surveillance System (NEISS).²⁵ Another NEISS study examined weight

[†]Address correspondence to Christy L. Collins, MA, The Research Institute at Nationwide Children's Hospital, Center for Injury Research and Policy, 700 Children's Drive, Columbus, OH 43205 (e-mail: christy.collins@nationwidechildrens.org).

The authors declared that they had no conflicts of interests in their authorship and publication of this contribution.

training-related injuries between 1978 and 1998.¹² However, both studies included cases in which a person sustained an injury not directly related to weight training (eg, a 1-year-old girl who died from strangulation after becoming wedged between a bed and a weight bench and a 4-year-old-boy who fell off a weight training bench and hit his head on the concrete floor). The inclusion of injuries not directly related to weight training will overestimate injury burden and may negatively affect the ability to develop targeted prevention recommendations. Additionally, there is a lack of research on weight training-related injuries among the general population after 2000.

This study aims to build on the findings of prior studies by examining the epidemiology of injuries directly related to weight training across age and gender categories. We examine weight training-related injuries seen at US emergency departments from 1990 to 2007 to identify epidemiologic trends and to develop targeted recommendations to reduce risk of injury.

METHODS

Data were obtained from the US Consumer Product Safety Commission's (CPSC) NEISS.²⁶ The CPSC-trained coders from a nationally representative, stratified probability sample of 100 US hospitals with at least 6 beds and a 24-hour emergency department (ED) service reviewed ED records on a daily basis, inputting demographic, injury, and treatment information into the NEISS database. The CPSC applies statistical weights to the NEISS sample data to calculate national estimates of the number of injuries treated in all EDs across the United States.

Data from weight training-related injuries (product code 3265) captured by NEISS from January 1, 1990, to December 31, 2007, were evaluated (N = 29 368). An additional 575 injury cases were included after a review of exercise (n = 293, product code 3299) and exercise equipment (n = 282, product code 3277) case narratives indicated that weight training was involved. Injury case narratives were reviewed to ensure only injuries specifically related to weight training were included in the sample. Unlike previous studies,^{12,25} injuries not directly associated with weight training were excluded. As a result of this detailed case narrative review, 4599 injuries with product code 3265 were excluded. Nine cases without patient gender were also excluded, resulting in a study sample of 25 335 weight training-related injury cases.

Variables of interest included age, gender, date of injury (by year), body region injured, injury diagnosis, disposition, mechanism of injury, and type of equipment. The 26 CPSC body region codes²⁷ were categorized into 8 body regions consistent with previous NEISS research¹²: head (including eyes, ears, face, mouth, and neck), upper trunk (including shoulders), lower trunk (including pubic region), hand (including wrist and fingers), foot (including ankles and toes), arm (upper and lower), leg (upper and lower), and other (eg, internal injuries, injuries not recorded). The CPSC diagnosis codes were categorized into 7 diagnoses: sprains/strains, soft tissue (including contusions, abrasions,

crushing injuries, and hematomas), lacerations (including punctures and avulsions), fractures/dislocations, concussions, hemorrhages, and other (eg, burns, ingesting foreign objects, diagnoses not recorded). Categories were similar to those of previous NEISS research,¹² but separated sprains/strains from soft tissue injuries. Concussions^{8,15} and hemorrhages^{5,11} were also kept as separate categories because of the relative importance of these diagnoses. Case narratives were reviewed to classify each injury by mechanism: weight dropped on person, body part smashed/crushed between weights, hitting self, overexertion, lost balance/fell, and lifting/pulling. Cases were also categorized by type of equipment: free weights (eg, dumbbells, barbells) and machines (eg, exercise equipment or racks that help stabilize movement of weights).

Data analyses were conducted using SPSS software version 17.0 (SPSS Inc, Chicago, Illinois) while adjusting for sample weights and the stratified survey design, as recommended by the CPSC for NEISS data to produce national injury estimates.²⁷ Chi-square analyses and linear regressions were performed, with $P < .05$ considered statistically significant. Injury proportion ratios (IPRs) with 95% confidence intervals (CIs) were calculated to assess the magnitude and direction of association. As an example, IPRs were calculated as follows:

$$\text{IPR} = \frac{\text{(national estimated no. female head injuries / national estimated no. total female weight training injuries)}}{\text{(national estimated no. male head injuries / national estimated no. total male weight training injuries)}}$$

The institutional review board at Nationwide Children's Hospital approved this study.

RESULTS

Injury Incidence

From 1990 to 2007, 25 335 weight training-related injuries were seen at US EDs, which correlates to an estimated 970 801 injuries nationwide. The mean age of persons who sustained a weight lifting-related injury was 27.6 years (standard deviation, 12.4; range, 6-100 years). Overall, 82.3% of weight training-related injuries occurred in males. The number of weight training-related injuries ranged from a low of 40 585 in 1996 to a high of 66 858 in 2006 (Figure 1), a 48.4% increase in injuries ($P < .001$). Male weight training-related injuries ranged from a low of 33 095 in 1996 to a high of 55 423 in 2006 (Figure 1), a 46.1% increase ($P < .001$). Females sustained a low of 5940 injuries in 1990 and a high of 12 604 in 2002, a 63.0% increase in injuries ($P < .001$).

Persons 13 to 18 years of age had the highest number of injuries (n = 253 019), followed by persons 25 to 34 years of age (n = 252 191) and persons 19 to 24 years of age (n = 200 129). The number of injuries increased significantly over time (Figure 2) among persons 13 to 18, 25 to 34, 35 to 44, 45 to 54, and 55 years and older ($P < .01$ for all age groups). The highest increases occurred among those aged 45 to 54 years (310.6%) and 55 years and older (431.2%). Among those 13 to 18 years old, females had a larger increase in injuries (143.4%, $P < .001$) than males (62.6%,

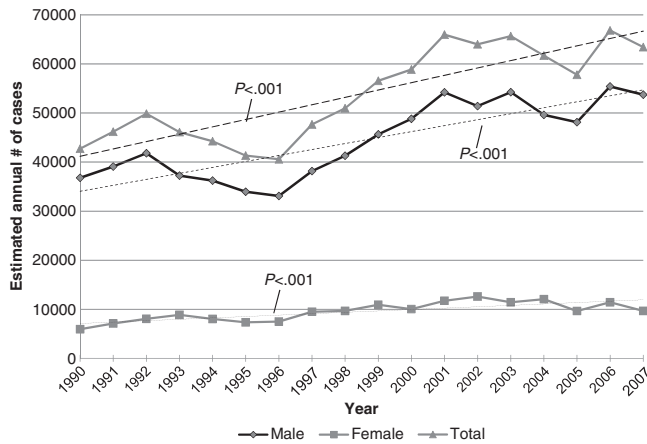


Figure 1. National estimates of annual weight training-related injuries treated in US emergency departments from 1990 to 2007 by gender.

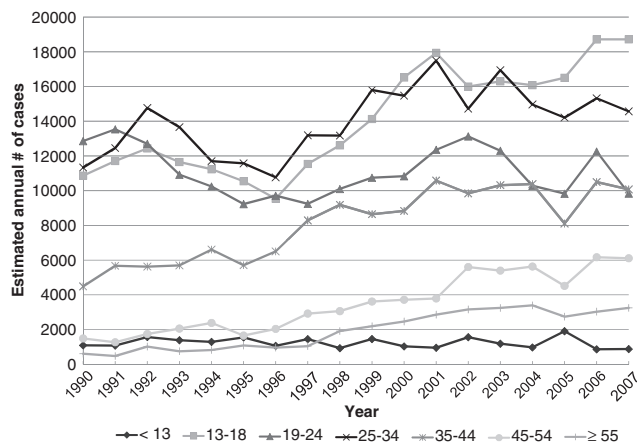


Figure 2. National estimates of annual weight training-related injuries treated in US emergency departments from 1990 to 2007 by age group.

$P < .001$). Although all increases were significant ($P < .001$), males aged 45 to 54 years (390.2%) and 55 years and older (456.3%) had a larger increase in injuries than females in the same age groups (122.2% and 376.7%, respectively). Among those under age 13 years, males had a 31.1% decrease in the number of injuries, whereas females had a 100.0% increase, although these trends were not statistically significant ($P = 0.235$ and $P = 0.593$, respectively).

Injury Characteristics

The most commonly injured body regions were the upper trunk (25.3%), lower trunk (19.7%), and hand (18.6%) (Table 1). Males had a higher proportion of upper trunk injuries (26.8%; IPR, 1.45; 95% CI:1.36-1.57; $P < .001$) and lower trunk injuries (20.8%; IPR, 1.41; 95% CI: 1.24-1.61; $P < .001$) than females (18.4% and 14.7%, respectively). Females had a higher proportion of foot injuries (22.9%; IPR, 2.09; 95% CI: 1.93-2.26; $P < .001$) and leg

TABLE 1
Weight Training-Related Injuries Treated in US Emergency Departments From 1990 to 2007

Variable	Actual Counts		National Estimates ^a	
	n	%	n	%
Body region injured				
Head	3005	11.9	117 342	12.1
Upper trunk	6368	25.1	245 986	25.3
Lower trunk	5323	21.0	191 136	19.7
Hand	4541	17.9	180 964	18.6
Foot	3221	12.7	126 755	13.1
Arm	1524	6.0	58 078	6.0
Leg	1154	4.6	42 793	4.4
Other ^b	199	0.8	7747	0.8
Injury diagnosis				
Sprains/strains	11 964	47.2	447 639	46.1
Soft tissue	4473	17.7	176 780	18.2
Fractures/dislocations	2954	11.7	113 067	11.6
Laceration	2207	8.7	88 858	9.2
Concussions	52	0.2	2288	0.2 ^c
Hemorrhages	32	0.1	1335	0.1
Other ^d	3653	14.4	140 835	14.5
Disposition				
Released	24 888	98.2 ^e	953 499	98.2 ^e
Hospitalized	239	0.9	9197	0.9
Fatality	3	0.0	114	0.0
Other ^e	205	0.8	7991	0.8
Total	25 335	100.0	970 801	100.0

^aNational estimates were calculated by applying statistical weights provided by the US Consumer Product Safety Commission's National Electronic Injury Surveillance System to actual case counts.

^bIncludes internal injuries, injuries not recorded, and so forth.

^cPercentage does not equal 100.0% because of rounding.

^dIncludes burns, ingesting foreign objects, diagnoses not recorded, and so forth.

^eIncludes transferred, left without being seen, not recorded, and so forth.

injuries (6.3%; IPR, 1.57; 95% CI: 1.35-1.81; $P < .001$) than males (11.0% and 4.0%, respectively). The most common diagnoses were sprain/strain (46.1%) and soft tissue (18.2%) (Table 1). Males had a higher proportion of sprains/strains (47.7%; IPR, 1.23; 95% CI: 1.16-1.29; $P < .001$) and lacerations (9.6%; IPR, 1.37; 95% CI: 1.21-1.55; $P < .001$) than females (38.9% and 7.0%, respectively). Females had a higher proportion of soft tissue injuries (26.3%; IPR, 1.60; 95% CI: 1.48-1.72; $P < .001$) and fractures/dislocations (13.6%; IPR, 1.21; 95% CI: 1.09-1.35; $P = .001$) than males (16.5% and 11.2%, respectively).

Overall, mechanism of injury could be coded for 10 034 injuries for a national estimate of 395 587 injuries (40.7%). The most common mechanisms were having weights drop on the person (65.5%), a body part being smashed/crushed between weights (10.4%), and hitting self (9.8%). Other mechanisms included overexertion (7.9%), lost balance/fell (3.3%), and lifting/pulling (3.1%). Males had a higher proportion of overexertion (8.6%; IPR, 1.50; 95% CI: 1.10-2.06; $P = .009$) than females (5.7%).

TABLE 2
National Estimates of Weight Training-Related Injuries Treated in
US Emergency Departments From 1990 to 2007 by Age Group^a

Variable	Age, y						
	<13 (n = 22 213) %	13–18 (n = 253 019) %	19–24 (n = 200 129) %	25–34 (n = 252 191) %	35–44 (n = 145 066) %	45–54 (n = 63 141) %	≥55 (n = 35 043) %
Body region injured							
Head	15.4	13.6	12.2	11.2	11.0	10.8	11.5
Upper trunk	6.9	20.5	25.7	27.6	30.4	26.8	30.4
Lower trunk	5.4	14.1	19.7	24.0	23.2	24.5	14.9
Hand	37.9	26.6	18.2	14.8	12.5	13.4	13.4
Foot	26.5	14.3	12.1	12.6	11.6	11.2	14.0
Arm	4.6	4.9	7.1	5.5	6.3	7.2	7.9
Leg	3.3	5.4	4.1	3.7	4.3	4.6	5.0
Other	0.0	0.6	1.0	0.6	0.7	1.5	2.8
Total ^b	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Injury diagnosis							
Sprains/strains	15.9	36.8	48.8	52.2	53.5	47.8	39.1
Soft tissue	37.5	25.3	16.9	16.1	13.0	11.4	11.5
Fractures/dislocations	22.3	12.4	11.2	10.4	10.6	12.7	13.6
Laceration	17.1	13.5	8.8	6.6	6.6	7.3	7.6
Concussions	0.4	0.4	0.2	0.2	0.1	0.0	0.1
Hemorrhages	0.0	0.0	0.1	0.1	0.1	0.4	0.8
Other	6.8	11.6	14.0	14.4	16.0	20.4	27.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mechanism^c							
Dropped weights	79.8	66.2	65.3	66.0	64.5	58.5	54.2
Smashed between weights	8.1	12.0	12.7	8.9	7.8	7.9	8.4
Hit self	7.6	10.9	9.3	8.1	10.7	11.2	9.4
Overexertion	0.7	5.8	8.1	9.1	9.1	13.5	15.8
Lost balance/fell	3.1	3.9	2.8	3.0	2.6	2.1	5.6
Lifting/pulling	0.8	1.1	1.8	4.9	5.2	6.8	6.6
Total ^b	100.0	100.0	100.0	100.0	100.0	100.0	100.0

^aNational estimates were calculated by applying statistical weights provided by the US Consumer Product Safety Commission's National Electronic Injury Surveillance System to actual case counts.

^bPercentage does not equal 100.0% because of rounding.

^cOnly injuries in which the mechanism was able to be coded (n = 395 587) are included.

The majority of weight training-related injuries were treated and the patient was released (98.2%) (Table 1). An estimated 114 weight training-related deaths occurred, based on 3 fatalities captured during the study period. The first was a 32-year-old man who died from anoxia from a heavy weight landing on his neck. The second and third fatalities were a 49-year-old man and a 56-year-old man, both of whom suffered cardiac arrests while lifting weights.

Age Differences

Body region injured, injury diagnosis, and mechanism of injury differed by age (Table 2). Persons 12 years and younger had a higher proportion of hand (37.9%; IPR, 2.08; 95% CI: 1.76-2.46; $P < .001$) and foot injuries (26.5%; IPR, 2.08; 95% CI: 1.75-2.48; $P < .001$) than those age 13 years and older (18.2%, and 12.7%, respectively). Persons age 13 years and older sustained a greater proportion of upper trunk injuries (25.8%) compared with persons age 12 years and younger (6.9%; IPR, 3.72; 95% CI:

2.10-6.58; $P < .001$). Persons 12 years and younger sustained a higher proportion of lacerations (17.1%; IPR, 1.90; 95% CI: 1.50-2.41; $P < .001$) and fractures/dislocations (22.3%; IPR, 1.96; 95% CI: 1.58-2.42; $P < .001$) than those age 13 years and older (9.0% and 11.4%, respectively). Persons age 13 years and older sustained a greater proportion of sprain/strains (46.8%) than persons 12 years and younger (15.9%; IPR, 2.94; 95% CI: 2.27-3.79; $P < .001$). Persons age 12 years and younger sustained a higher proportion of injuries from having weights fall or drop on them (79.8%; IPR, 1.23; 95% CI: 1.15-1.32; $P < .001$) than persons age 13 years and older (64.9%). The proportion of overexertion injuries increased significantly as age category increased ($P < .001$) (Table 2).

Injury by Type of Equipment

Among injuries in which type of equipment was known (39.4%), the majority of weight lifting-related injuries occurred with free weights (90.4%, n = 345916). Persons

age 55 years and older sustained a higher proportion of injuries with machines (18.2%; IPR, 1.96; 95% CI: 1.47-2.61, $P < .001$) than persons age 54 and younger (9.3%).

Persons using free weights sustained higher proportions of hand injuries (33.6%; IPR, 1.22; 95% CI: 1.06-1.39; $P = .003$) and foot injuries (33.5%; IPR, 4.97; 95% CI: 3.76-6.58; $P < .001$) than persons using machines (27.7% and 6.7%, respectively). Persons using machines sustained higher proportions of injuries to the head (30.0%; IPR, 2.03; 95% CI: 1.78-2.31; $P < .001$), arm (4.3%; IPR, 2.15; 95% CI: 1.42-3.26; $P < .001$), leg (12.2%; IPR, 5.13; 95% CI: 3.78-6.97; $P < .001$), and lower trunk (9.3%; IPR, 2.82; 95% CI: 2.19-3.62; $P < .001$) than persons using free weights (14.8%, 2.0%, 2.4%, and 3.3%, respectively).

Persons using free weights sustained a greater proportion of fractures/dislocations (23.6%; IPR, 2.44; 95% CI: 1.92-3.09; $P < .001$) and soft tissue injuries (41.9%; IPR, 1.98; 95% CI: 1.70-2.30; $P < .001$) than persons using machines (9.7% and 21.1%, respectively). Persons using machines sustained a greater proportion of sprains/strains (21.9%; IPR, 2.50; 95% CI: 2.08-3.01; $P < .001$) and lacerations (35.1%; IPR, 1.93; 95% CI: 1.68-2.20; $P < .001$) than persons using free weights (8.8% and 18.2%, respectively).

Persons using free weights sustained a higher proportion of injuries when weights dropped on them (77.7%; IPR, 5.09; 95% CI: 4.07-6.36; $P < .001$) and while lifting/pulling (3.3%; IPR, 2.40; 95% CI: 1.10-5.24, $P = .022$) than persons using machines (15.3% and 1.4%, respectively). Persons using machines sustained a higher proportion of injuries when a body part was smashed/crushed between weights (26.4%; IPR, 2.69; 95% CI: 2.24-3.24; $P < .001$), from hitting self (45.5%; IPR, 5.94; 95% CI: 5.13-6.87; $P < .001$), from overexertion (2.3%; IPR, 5.44; 95% CI: 1.81-16.10; $P = .001$), and from losing balance/falling (9.2%; IPR, 8.23; 95% CI: 5.60-12.09; $P < .001$) than persons using free weights (9.8%, 7.7%, 0.4%, and 1.1%, respectively).

DISCUSSION

This study is the first epidemiologic analysis of all weight training-related injuries across all age groups of the general population in US EDs over the past 2 decades. Previous weight training-related injury studies were limited to subgroups such as power lifters^{4,21} and adolescents.^{3,25} The 2 previous studies that used NEISS data to evaluate weight training-related injuries^{12,25} included all injuries with the weight lifting product code (3625) whether directly related to weight training or not, which likely resulted in overestimation of incidence. Thus, our study, which used national estimates to analyze all injuries treated in US EDs that were directly related to weight training, contributes important information to drive development of targeted injury prevention efforts for this growing fitness activity.

From 1990 to 2007, the number of weight training-related injuries increased 48.4%, which was larger than the 35.0% increase seen between 1978 and 1998.¹² Compared

with the National Sporting Goods Association 10-year trend data in the prevalence of people participating in weight training,¹⁷ the incidence of injuries may be rising at a similar rate. However, because of the lack of participation data prior to 1998, it is difficult to determine if the increased injury incidence is the result of higher injury rates or increased participation in weight training. To better understand the epidemiology of weight lifting injuries, future research is needed to determine the number of persons engaged in weight training so injury rates can be calculated.

Consistent with previous studies,^{12,20} we found similar gender differences in weight training-related injuries. Males sustained the largest proportion of weight training-related injuries (82.3%), which may imply that weight training is still a male-dominated activity. Although males sustained the majority of weight training injuries, there was a larger increase in the incidence of injury among females than males during this study period. This could be because more women are beginning to weight train as this becomes more accepted as a fitness activity by women.

As in a previous study,¹² the largest proportion of weight training-related injuries occurred in youths (ages 13-24 years). At this age, persons are exposed to a number of weight training-related activities, including gym class, sports programs inside and outside school, and community/school/college gyms. Also, youths may have more free time to weight train and may also weight train to increase body image satisfaction. Persons 12 years and younger were more likely to have hand and foot injuries than persons 13 years of age and older. It is possible that with less knowledge of how to maintain control of the weights while lifting and/or muscular development, the extremities of the body are susceptible to injury. However, because of the limitations of the NEISS data, we were unable to evaluate site of injury and amount of supervision available per site. Nonetheless, youths should take careful consideration of their weight training program with guidance from their parents, coaches, and doctors.^{1,9} In addition, trained supervision is recommended when youths engage in weight training.^{10,12} Because youths are still in biologic developmental stages, additional research is necessary to further understand what mechanisms, specific lifts, and so forth, put them most at risk.²³

Older persons in this study sustained a larger proportion of injuries from overexertion and lifting/pulling than their younger counterparts. Consistent with prior research,¹² we also found older persons had the highest increases in injury incidence. Because interest in weight training seemed to increase during the baby boom era, this age group may have maintained this activity. However with age, their ability to perform their preferred lifts and exercises may have diminished. Overestimating their abilities may lead to injuries. Future research can better determine injury trends in older persons by further investigating duration of participation and specific movements that likely cause injury.

Older persons also had a larger proportion of machine injuries compared with free weight injuries when compared with

their younger counterparts. Possibly, older persons may use machines over free weights because they perceive machines to require less knowledge of technique, and free weights are intimidating because of the perceived learning curve. Alternatively, older weight lifters may have more disposable income to purchase memberships at gyms/fitness centers with nicer equipment, or they may perceive machines as safer. Younger weight lifters, with less disposable income, may have to settle for cheaper free weights. Older populations participating in weight training should understand their lifting capabilities and have a good working knowledge of any machinery they use. Persons should start with lighter weights and work up progressively,¹⁴ and they should work with professionals to build workout plans that acknowledge the natural deterioration from age.¹²

The core of the body (ie, head and trunk) sustained the highest proportion of injuries (58.2%). This proportion was slightly larger than the proportion reported previously¹² (50.7%). This may be because this study limited analysis to injuries that were directly related to weight training. Injuries that originated from accidental contact with weight training equipment may be more likely to harm the arms and legs.

Similar to previous research,^{12,24} the majority of injuries were related to free weights. With more accessibility and affordability, it is not surprising that free weights would be associated with more weight training injuries. It is essential to inspect weights regularly for defects¹⁴ and ensure all components of free weights are secured tightly to ensure that weights do not fall in the middle of a set. Because a majority of free weight injuries were from weights falling or dropping on persons, we support recommendations to select equipment and weight limits that one can effectively handle^{14,19} and to have a spotter present to maintain control.^{2,12,24,25}

The use of machines may be perceived as safer than the use of free weights,⁵ especially when considering that over 90% of the injuries in which the type of equipment used was known were related to free weights. However, the sense of security that comes with machines may lead to exceeding one's capacity. Such overestimation may explain the higher proportion of overexertion injuries seen in injuries of persons who exercise with machines. Persons should receive proper instruction on using machines to avoid injury.¹² Furthermore, most machines are proportioned for average-sized persons, potentially placing those who are bigger/taller or smaller/shorter at increased risk of injury. Research that examines machine-related injuries based on individual body size differences is needed. Despite the differences in weight training-related injuries on the basis of type of equipment, both persons using free weights and persons using machines sustained more injuries from avoidable mishaps (ie, dropping weights, smashed/crushed between weights, hitting self) than overexertion and lifting/pulling. As a result, we recommend more careful adherence to safety protocol by weight training participants to help reduce the overall number of injuries.

The limitations of this study are associated with the NEISS dataset, which provides limited information about

circumstances of injury. Only injuries treated in EDs are captured, excluding less severe injuries that may have not received any medical attention or that may have been treated in other health care settings. In addition, NEISS data contain only the most severe injury for each person and does not include any follow-up information regarding length of injury time or experience level with weight training. The NEISS data also does not include denominator data (ie, the number of persons participating in weight training). Whereas previous studies specifically examined type of lift done (eg, dead lift, bench press),^{4,6,21} the NEISS dataset does not contain this level of detail. Also, NEISS data did not uniformly address other variables that may have had an impact on risk of injury, such as mechanism of injury, type of equipment used, amount of instruction prior to using weights, the site of injury (eg, school fitness center, gym, home), or the presence or absence of spotters and/or supervision. Nevertheless, the large number of cases in this large long-standing national dataset provided the opportunity to investigate the epidemiology of weight training injuries across age and gender groups.

Increasing knowledge of the epidemiology of weight training-related injuries based on gender, age, and type of equipment used should lead to the development of targeted preventive measures aimed at decreasing injury rates among weight training participants. Based on our findings, prior to beginning a weight training program, persons should receive proper instruction in how to use weight lifting equipment, as well as the proper technique for lifts, and should consult health professionals (eg, doctors, athletic trainers) to create a safe training program based on their age and capabilities. Additionally, persons lifting free weights should lift with a spotter, or at least, with other persons present, to assist control of the weights. Persons should adopt such simple, yet practical, habits during the development and implementation of a weight training program to decrease injury incidence and severity.

ACKNOWLEDGMENT

We thank the US Consumer Product Safety Commission for providing the National Electronic Injury Surveillance System data.

REFERENCES

1. American Academy of Pediatrics Council on Sports Medicine and Fitness. Strength training by children and adolescents. *Pediatrics*. 2008;121:835-840.
2. Baechle TR, Groves BR. *Weight Training: Steps to Success*. Champaign, IL: Human Kinetics; 2006.
3. Brady T, Cahill R, Bodnar L. Weight training-related injuries in the high school athlete. *Am J Sports Med*. 1982;10:1-5.
4. Brown E, Kimball R. Medical history associated with adolescent powerlifting. *Pediatrics*. 1983;72:636-644.

5. Casavant MJ, Blake K, Griffith J, Yates A, Copley LM. Consequences of use of anabolic androgenic steroids. *Pediatr Clin North Am*. 2007;54(4):677-690.
6. Fees M, Decker T, Snyder-Mackler L, Axe MJ. Upper extremity weight-training modifications for the injured athlete: a clinical perspective. *Am J Sports Med*. 1998;26(5):732-742.
7. Fleck S, Kraemer W. *Designing Resistance Training Programs*. Champaign, IL: Human Kinetics; 2004.
8. Gessel LM, Fields SK, Collins CL, Dick RW, Comstock RD. Concussions among United States high school and collegiate athletes. *J Athl Train*. 2007;42(4):495-503.
9. Guy J, Micheli L. Strength training for children and adolescents. *J Am Acad Orthop Surg*. 2001;9:29-36.
10. Hamill BP. Relative safety of weightlifting and weight training. *J Strength Cond Res*. 1994;8(1):53-57.
11. Haykowsky MJ, Findlay JM, Ignaszewski AP. Aneurysmal subarachnoid hemorrhage associated with weight training: three case reports. *Clin J Sport Med*. 1996;6(1):52-55.
12. Jones C, Christensen C, Young M. Weight training injury trends: a 20-year study. *Physician Sportsmed*. 2000;28(7):61-66.
13. Kotani PT, Ichikawa N, Wakabayashi W, Yoshii T, Koshimure M. Studies of spondylolysis found among weight lifters. *Br J Sports Med*. 1971;6:4-7.
14. Mazur L, Yetman R, Risser W. Weight-training injuries: common injuries and preventative methods. *Sports Med*. 1993;16(1):57-63.
15. McCrory P, Johnston K, Meeuwisse W, et al. Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004. *Clin J Sport Med*. 2005;15(2):48-55.
16. National Sporting Goods Association. 2008 participation: ranked by total participation. Available at: http://www.nsga.org/files/public/2008RankedByTotal_4Web_080423.pdf. Accessed April 30, 2009.
17. National Sporting Goods Association. Ten-year history of sports participation. Available at: http://www.nsga.org/files/public/10YearHistory_4web_090327.pdf. Accessed April 30, 2009.
18. Neviasser TJ. Weight lifting: risks and injuries to the shoulder. *Clin Sports Med*. 1991;10(3):615-621.
19. Outerbridge A, Micheli L. Overuse injuries in the young athlete. *Clin Sports Med*. 1995;14:503-516.
20. Powell KE, Heath GW, Kresnow MJ, Sacks JJ, Branche CM. Injury rates from walking, gardening, weightlifting, outdoor bicycling, and aerobics. *Med Sci Sports Exerc*. 1998;30(8):1246-1249.
21. Raske A, Norlin R. Injury incidence and prevalence among elite weight and power lifters. *Am J Sports Med*. 2002;30:248-256.
22. Reeves R, Laskowski E, Smith J. Weight training injuries: part 1: diagnosing and managing acute conditions. *Physician Sportsmed*. 1998;26(2):67-83.
23. Rians CB, Weltman A, Cahill BR, Janney CA, Tippet SR, Katch FI. Strength training for prepubescent males: is it safe? *Am J Sports Med*. 1987;15(5):483-489.
24. Risser WL. Weight-training injuries in children and adolescents. *Am Fam Physician*. 1991;44:2104-2108.
25. Risser WL, Risser JM, Preston D. Weight-training injuries in adolescents. *Am J Dis Child*. 1990;144:1015-1017.
26. US Consumer Product Safety Commission. The NEISS sample (design and implementation) 1997 to present. Available at: <http://www.cpsc.gov/neiss/2001d011-6b6.pdf>. Accessed February 20, 2009.
27. US Consumer Product Safety Commission. NEISS Coding Manual. Available at: <http://www.cpsc.gov/neiss/completemanual.pdf>. Accessed January 20, 2009.
28. Zemper E. Four-year study of weightroom injuries in a national sample of college football teams. *Nat Strength Condition Assoc J*. 1990;12(3):32-34.

For reprints and permission queries, please visit SAGE's Web site at <http://www.sagepub.com/journalsPermissions.nav>