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Background: CrossFit is a type of competitive exercise program that has gained widespread recognition. To date, there have been no studies that have formally examined injury rates among CrossFit participants or factors that may contribute to injury rates.

Purpose: To establish an injury rate among CrossFit participants and to identify trends and associations between injury rates and demographic categories, gym characteristics, and athletic abilities among CrossFit participants.

Study Design: Descriptive epidemiology study.

Methods: A survey was conducted, based on validated epidemiologic injury surveillance methods, to identify patterns of injury among CrossFit participants. It was sent to CrossFit gyms in Rochester, New York; New York City, New York; and Philadelphia, Pennsylvania, and made available via a posting on the main CrossFit website. Participants were encouraged to distribute it further, and as such, there were responses from a wide geographical location. Inclusion criteria included participating in CrossFit training at a CrossFit gym in the United States. Data were collected from October 2012 to February 2013. Data analysis was performed using Fisher exact tests and chi-square tests.

Results: A total of 486 CrossFit participants completed the survey, and 386 met the inclusion criteria. The overall injury rate was determined to be 19.4% (75/386). Males (53/231) were injured more frequently than females (21/150; $P = .03$). Across all exercises, injury rates were significantly different ($P < .001$), with shoulder (21/84), low back (12/84), and knee (11/84) being the most commonly injured overall. The shoulder was most commonly injured in gymnastic movements, and the low back was most commonly injured in power lifting movements. Most participants did not report prior injury (72/89; $P < .001$) or discomfort in the area (58/88; $P < .001$). Last, the injury rate was significantly decreased with trainer involvement ($P = .028$).

Conclusion: The injury rate in CrossFit was approximately 20%. Males were more likely to sustain an injury than females. The involvement of trainers in coaching participants on their form and guiding them through the workout correlates with a decreased injury rate. The shoulder and lower back were the most commonly injured in gymnastic and power lifting movements, respectively. Participants reported primarily acute and fairly mild injuries.

Keywords: competitive exercise; CrossFit; Olympic lifting; power lifting; injury rate; cross-sectional pilot study

CrossFit is a conditioning program that has gained widespread attention for its focus on successive ballistic motions that build strength and endurance. It is characterized by workouts that use a wide variety of exercises, ranging from running and rowing to Olympic lifting (snatch, clean, and jerk), power lifting (squat, deadlift, press/push press, bench press), and gymnastic movements (pull-ups, toes-to-bar, knees-to-elbows, lunges, muscle-ups, burpees, dips, gluteus-hamstring developer sit-ups, push-ups, rope climbs, handstand push-ups, pistols). These exercises are often combined into high-intensity workouts that are performed in rapid, successive repetition, with limited or no recovery time. It has been adopted in both military and civilian populations with widespread anecdotal reports of impressive fitness gains.

These gains are consistent with existing literature that supports the contention that high-intensity, single modal

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exercise is effective with relatively minimal time investment.[2,6,8,12,17,19,20] A recent study found that participation in CrossFit improved metabolic capacity and resulted in improvements in fitness based on maximal oxygen uptake (VO_2 max) and body composition. These improvements were noted among subjects of both sexes and across all levels of fitness.[18] A study conducted by the US Army found that implementation of CrossFit among soldiers led to significant improvements in soldiers' physical fitness.[14] A consensus paper by the Consortium for Health and Military Performance and the American College of Sports Medicine acknowledged the beneficial effects of extreme conditioning programs while addressing concerns over the possible injury rate and rhabdomyolysis.[1]

The primary purpose of this pilot study was to investigate the injury rate among CrossFit participants. A secondary objective was to identify trends and associations between injury rates and demographic categories, gym characteristics, and athletic abilities among CrossFit participants. We aimed to establish a baseline for further research and investigation into CrossFit. With identification of risk factors for injury, we can establish effective means of preventing these injuries. Similar strategies have been applied to handball and soccer to reduce injury rates.[11,13]

MATERIALS AND METHODS

General Design

This study utilized a cross-sectional design. Study data were collected from October 2012 to February 2013 via an electronic survey (see the Appendix, available at http://ojsm.sagepub.com/supplemental). Data were collected and managed using REDCap electronic data capture tools hosted at the University of Rochester.[7] REDCap (Research Electronic Data Capture) is a secure, web-based application designed to support data capture for research studies, providing (1) an intuitive interface for validated data entry, (2) audit trails for tracking data manipulation and export procedures, (3) automated export procedures for seamless data downloads to common statistical packages, and (4) procedures for importing data from external sources. To normalize data, we chose to only use responses from CrossFit participants who train at a CrossFit gym in the United States. Responses from CrossFit athletes from outside the United States or those who trained on their own were excluded. The Institutional Review Board at the University of Rochester approved this study.

Survey Development

The survey was developed from May 2012 to July 2012 via a series of semistructured interviews with physicians and CrossFit gym owners, coaches, and participants. It was based on a survey developed to assess injury in track and field participants.[9,10] Over the course of the interviews, the survey was modified to reflect specific factors that should be measured in CrossFit participants. The survey was then piloted with multiple groups of CrossFit athletes (5 groups of 3) and was adjusted according to feedback. From this we established a 3-fold injury criterion that encompassed a wide variety of injuries that can occur with CrossFit workouts. "Injury" encompassed any new musculoskeletal pain, feeling, or injury that results from a CrossFit workout and leads to 1 or more of the following options:

1. Total removal from CrossFit training and other outside routine physical activities for >1 week
2. Modification of normal training activities in duration, intensity, or mode for >2 weeks
3. Any physical complaint severe enough to warrant a visit to a health professional

The argument for this definition and time requirement is 3-fold. First, because of the constantly varied programming of CrossFit workouts, athletes are often sore and because of a particularly difficult workout may be unable to exercise for several days. This soreness can often be confused with injury. One week was the most commonly reported time loss period among CrossFit athletes and sports medicine physicians as to when suspected muscle soreness was in reality a pathologic issue. Second, practice in CrossFit consists of many different components, ranging from gymnastics to power lifting. Therefore, when athletes are unable to follow the original schedule, they can modify it around their current injuries. This is defined as partial time loss and enables them to continue training. Most athletes reported that if they had to modify workouts for more than 2 weeks they found that the injury was not going to heal without medical attention. Last, any injury that appeared to the athlete to require immediate medical attention from a health care professional should be reported. This captures both acute injuries and transient injuries that require the athlete to seek help from a medical professional but do not affect their training schedule.

We decided to use athlete-level data collection. While CrossFit athletes regularly perform their workouts in gyms under the supervision of coaches, often they do not consistently train with the same coach, nor is the level of supervision similar to sports teams. CrossFit participants visit a variety of health care professionals in the area, making it impossible to use their care providers to gather this information. Therefore, contacting the athletes directly is the only means of assessing injury rate. To minimize recall bias but maximize injury capture, we choose to survey the athletes over a 6-month time period and created very specific and concrete criteria for what constituted an injury.

Data Collection

A survey was electronically distributed to CrossFit gym owners, coaches, and participants primarily in Rochester, New York; New York City, New York; and Philadelphia, Pennsylvania. Recipients of this survey were encouraged to share the survey with members of their gym. Coaches, owners, and participants were further encouraged to send the survey to members of other gyms. In addition, the

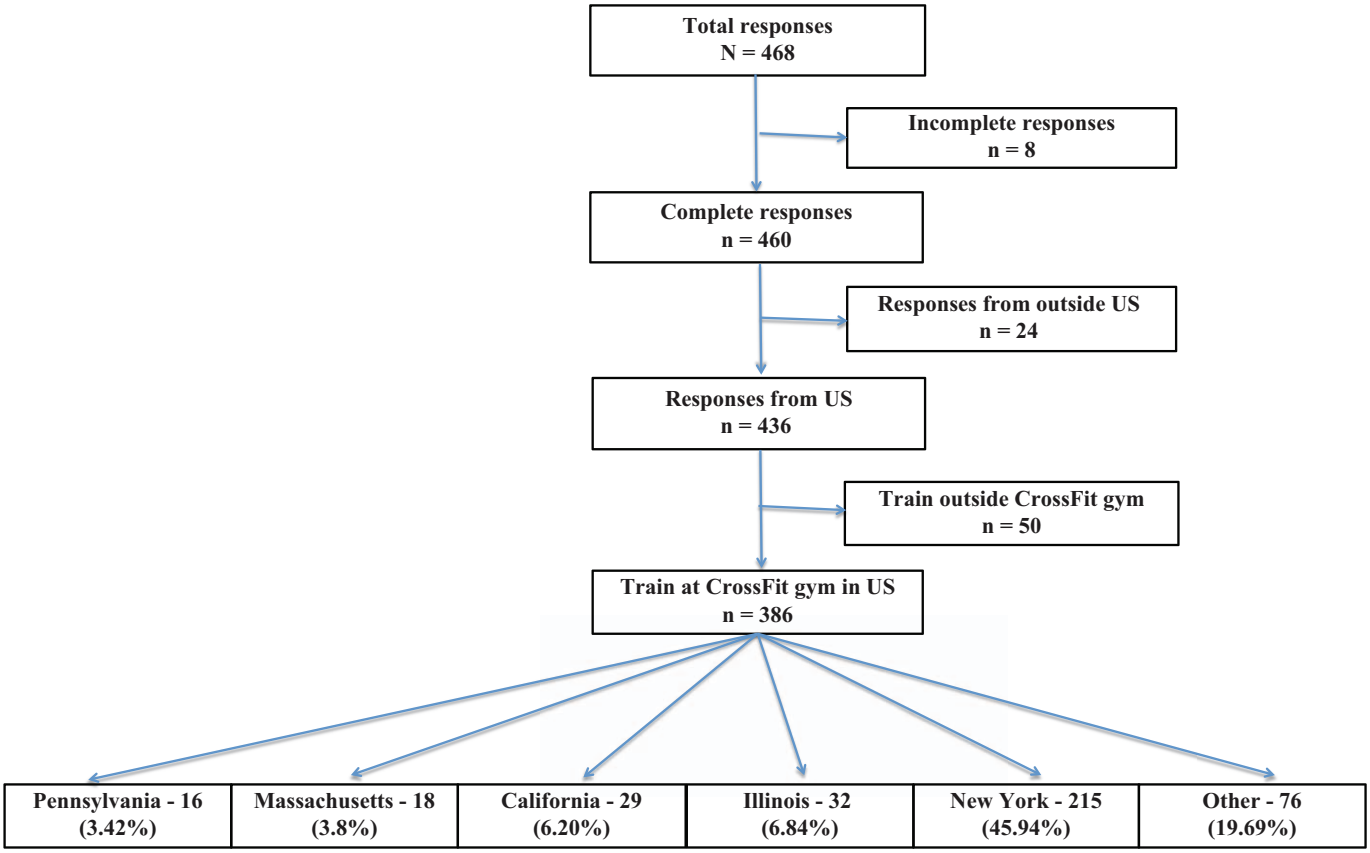

Figure 1. Study flowchart showing the methodology for inclusion criteria, the number of participants included, and where they were from.

survey was made available to CrossFit participants via a posting on the main CrossFit website. As a result, there were a wide variety of responses from many distinct geographical locations, including athletes from outside the United States. Additionally, many athletes responded who did not train at CrossFit gyms but preferred to train on their own. Exclusion criteria included training at a gym outside the United States, training independently outside of a CrossFit gym, and being younger than 18 years. Inclusion criteria included being older than 18 years and training at a CrossFit gym in the United States. This was in an effort to focus our efforts primarily on CrossFit gyms and to limit geographical training bias. This was a single survey that recorded demographic and participant characteristics (ie, sex, age, experience, maximum lifts, and times) and the incidence and characteristics of injuries incurred over the 6 months prior to completing the survey. We specifically looked to determine if there was any association between body part injured and movement type and between injury rate and age, sex, time of participation, training period for beginners, trainer involvement, training time, rest days per week, and length of time involved in CrossFit using chi-square or Fisher exact tests. In addition, we investigated the differences in rates of injury based on prior discomfort in the injured area, prior injury to the injured area, and final diagnosis of injury using the chi-square test for equal proportions. All information, including diagnoses, obtained for the study was from self-reports and was not independently verified by a physician.

Data Analysis

Data analyses were performed using SAS software, version 9.3 (SAS Institute, Cary, North Carolina, USA). The use of chi-square or Fisher exact tests and the chi-square test for equal proportions were outlined in the previous paragraph. All statistical tests were 2-sided, and a P value less than .05 was considered to be statistically significant.

RESULTS

Demographics/Gym Characteristics

There were a total of 468 responses, of which 386 met the inclusion criteria of training at a CrossFit gym in the United States (Figure 1). We focused our demographic data collection on age, sex, and length of participation (Table 1). The majority had been involved with CrossFit for 0 to 6 months (n = 136; 35.2%), trained for 30 to 60 minutes at a time (n = 319; 83.1%), took 2 to 3 rest days per week (n = 279; 72.8%), and exercised 4 to 5 days per week

TABLE 1
Demographic Data by Age and Sex

Age Group, y	Males, n (%) (n = 231)	Females, n (%) (n = 150)
18-29	98 (42)	64 (42)
30-39	84 (36)	49 (32)
40-49	34 (15)	28 (18)
50-59	10 (4)	7 (5)
60-69	5 (2)	2 (1)

(n = 279; 72.8%). Many gyms have a required training period for beginners (n = 325; 84.9%) and have trainers who are present and actively correcting form during workouts (n = 219; 57.0%).

Injury Rate by Demographics/Gym Characteristics

Overall, we found that 75 participants (19.4%) had experienced at least 1 injury resulting from a CrossFit workout in the 6 months prior to filling out the survey that met the defined injury criteria. Of this population, 63 participants experienced 1 injury (84%), 10 experienced 2 injuries (13.3%), and 2 experienced 3 injuries (2.7%).

We found no significant difference in injury rate across age (n = 381; $P = .56$). We separated participants by the amount of time they had been training in CrossFit. We found no significant difference in injury rate based on length of participation in CrossFit (n = 386; $P = .099$), but athletes who had been participating in CrossFit for longer periods of time tended to have longer training sessions (n = 384; $P < .001$) but not an increased number of sessions per week (n = 381; $P = .67$). There was no significant difference in injury rate based on length of training session (n = 384; $P = .17$). Days spent training per week did not show any trends based on injury rate (n = 383; $P = .16$). Participants who attended a gym that required a training period for beginners reported a lower injury rate (18.5%) than training facilities that did not require a training period (25.9%); however, this did not reach significance (n = 383; $P = .2$). Injury rate was separated based on the maximum weight participants could lift in various strength exercises (deadlift, squat, press, clean and jerk), and there was no significant difference between different groups. Five participants failed to report their sex, so there were 381 participants included in the analysis of injury rate based on sex. Males were significantly more likely to injure themselves than females (n = 381; $P = .03$). A significant correlation was noted between injury rate and level of coach supervision when men and women were considered together (Table 2). Females, however, were significantly more prone to seek coach supervision as opposed to males (n = 380; $P = .015$). When men and women were considered separately with regard to injury rate and trainer involvement, the effect of involvement of trainers had a decreasing effect on injury rate for each sex, but neither subgroup reached significance due to a reduced sample size. In subsequent analyses, the effect of the involvement of trainers on injury rate was found to be not significantly different for men versus women, which justified analyzing the 2 groups concurrently.

TABLE 2
Injury Rate Versus Trainer Presence[a]

	No Injury, n (Row %)	Injury, n (Row %)	Total, n (Column %)
Level of trainer involvement			
All of the time	187 (85.4)	32 (14.6)	219 (57)
Most of the time	102 (75.6)	33 (24.4)	135 (35)
Some of the time	20 (69.0)	9 (31.0)	29 (8)
Never	1 (100)	0 (0)	1 (0.2)
Total no. of injuries	310	74	384[b]

[a] $P = .028$ for injury rate versus trainer presence.
[b] Two subjects did not report trainer presence data.

Injury Characteristics

CrossFit workouts often include a wide variety of exercises. Across all exercises, the injury rates were significantly different across body parts ($P < .001$). The most common injured parts were the shoulder (21/84), low back (12/84), and knee (11/84). For gymnastic movements, injury rates were significantly different across body parts ($P = .04$), with shoulder injured most often (7/17). For power lifting movements, injury rates were significantly different across body parts ($P < .001$), with lower back injured most often (9/19) (Table 3). The majority had neither experienced any discomfort in the injured area prior to the injury (n = 88; $P < .001$) nor had an injury to that same body part in the past year (n = 89; $P < .001$). The self-reported final diagnoses were most commonly general inflammation and pain (n = 25; 30.8%; $P < .001$), other (n = 22; 27.2%), sprain/strain (n = 14; 17.2%), while rupture (n = 3; 3.7%) and dislocation (n = 2; 2.5%) were relatively infrequent.

DISCUSSION

CrossFit is a blend of multiple synchronistic exercises, such as gymnastics, power lifting, Olympic lifting, and endurance activities. These movements are often performed at a high intensity with little recovery time between exercises. As such, some reports have predicted a high injury rate among CrossFit participants because of repetitive use of technical exercises at a high intensity.[1] We hypothesized that this would not be true due to the level of supervision at CrossFit gyms and an emphasis on instruction before exercises are performed in a workout. In our study, we found the overall injury rate in CrossFit was approximately 20%. This injury rate was gathered only from athlete-level collection, and we depended on their reporting based on our injury criteria to establish this injury rate. Although the mechanism of injury would not be the same between running and CrossFit, running would be a reasonable logical alternative for exercise in the recreational athlete. As a reference, epidemiological studies on runners have reported injury incidence rates ranging from 19.4% to 79.3%.[21] Elite

TABLE 3
Injury Location Versus Movement Performed

	Movement Type[a]						
	Power Lifting[b]	Olympic Lifting	Gymnastics[c]	Endurance	Other	Not Associated	Total[d]
Body part							
Neck	0	2	0	0	0	0	2
Upper back	1	2	0	0	0	0	3
Middle back	0	0	0	0	1	0	1
Lower back	9	0	0	0	1	2	12
Shoulder	2	4	7	0	1	7	21
Upper arm	0	0	2	0	0	0	2
Elbow	0	2	1	0	0	1	4
Forearm	0	0	0	0	0	1	1
Wrist	1	2	0	0	1	0	4
Hand	0	0	1	0	0	0	1
Hip	1	1	1	1	2	0	6
Groin	0	0	1	0	1	1	3
Knee	4	1	2	2	1	1	11
Upper leg	1	0	0	0	1	1	3
Lower leg	0	0	0	2	1	0	3
Achilles/calf	0	1	1	0	3	0	4
Ankle	0	1	1	0	0	1	2
Foot/toe	0	0	0	0	0	1	1
Total[e]	19	14	17	5	13	16	84[f]

[a]Power lifting = squat, deadlift, press/push press, bench press; Olympic lifting = snatch, clean, jerk, clean and jerk; gymnastics = pull-ups, toes-to-bar, knees-to-elbows, lunges, muscle-ups, burpees, dips, gluteus-hamstring developer sit-ups, push-ups, rope climbs, handstand push-ups, pistols; endurance = rowing, running, sprints; Other = kettlebell swings, thrusters, Turkish get-ups, box jumps, double unders.
[b]$P = .004$ for testing equal injury rates across body parts for power lifting.
[c]$P = .04$ for testing equal injury rates across body parts for gymnastics.
[d]$P < .001$ for testing equal injury rates across body parts overall.
[e]$P < .001$ for testing equal injury rates across movement type.
[f]Five subjects did not report a specific movement.

track and field athletes, while a very different population but with similar high-intensity ballistic mechanisms, demonstrated a 42.8% 1-year retrospective injury prevalence, with gradual onset inflammation and pain being the most common type of injury.

Participants reported injuring their shoulders, knees, and low back most frequently. These were incurred most often during power lifting and gymnastic movements. The shoulder and lower back represented the most frequently injured body areas during these exercises, respectively. This finding is consistent with published injury rates among gymnasts, with athletes experiencing shoulder injuries most commonly.[3] Similar trends have been reported for Olympic and power lifters.[11] Separate studies of elite weight and power lifters have demonstrated a predominance of shoulder, low back, and knee injuries, consistent with the findings of this study, albeit in a different population.[4,15]

Demographically, male athletes tended to injure themselves more frequently than female athletes. Interestingly, females were more likely to seek help from a trainer, and therefore, this may account for their decreased injury rate. There was no significant difference in injury rate across age, which persisted in female- and male-only samples. This indicates that CrossFit is a workout program that can function safely for athletes across all represented age groups if performed in a safe environment.

Most reported injuries in CrossFit appear to be of an acute nature, as participants generally reported no prior history of discomfort or injury to the body area they subsequently injured. The majority of those injuries were fairly mild, with participants reporting some general inflammation/pain or sprain/strain as a result of these injuries as opposed to more severe problems such as dislocation or fracture. This suggests that the majority of injuries in CrossFit are minor and return to participation is likely. However, potential recall bias cannot be excluded from those results, as other studies have demonstrated a 61% accuracy of self-reported diagnosis in participants reporting over 12 months.[5]

Injury prevention programs have become a common adjunct to a variety of athletic activities.[3,10] To design an injury prevention program, it is important to be aware of injury rate and factors associated with injury in a sport.[11,13,16] This is especially important considering the business model of CrossFit. To a certain extent, CrossFit represents a unified organization. However, unlike other large fitness corporations, it does not directly supervise gyms but instead gives them freedom to develop and grow on their own. It does not require them to perform the programming that is produced each day by CrossFit headquarters in Washington, DC. Each gym owner is required to have a CrossFit L1 certification, but aside from that, no

further training is necessary. Therefore, it is possible to be faced with a wide variation in quality between CrossFit gyms based on the experience of the owner and coaches. CrossFit maintains that the market will select out the gyms with poor management and trainers and that the exceptional gyms will succeed.

Findings from this study may be used to guide physicians, CrossFit owners, and coaches as they implement preventive strategies in their gyms and practices. This study identified a specific area of focus that may be used to optimize injury rate reduction strategies based on gym quality. Increased supervision by CrossFit coaches was directly related to injury rate. This could be because of several factors. Coaches guide CrossFit athletes through their workouts, help organize the class, and correct form. In addition, they aid athletes in choosing the correct weight for the workout. Often, workouts are posted with a prescribed weight and repetition scheme, which can prove to be excessive for even more experienced members. An experienced coach can help an athlete choose the right weight and modify the repetition scheme to minimize injury based on the athlete's personal limitations. Our results indicate that athlete experience level and overall involvement of the coaches had the most pronounced effect on the health of the athletes. As such, we recommend that potential participants evaluate the skill and attentiveness of the trainers, as that is crucial to creating a safe environment.

As well, we feel that it is crucial for participants to be personally aware of these risks and strive to maintain form throughout a workout, with specific focus on elements of the movement related to the risk area. For example, when an athlete is performing a power lifting movement, they should be aware that the lower back is most commonly injured in that type of movement and strive to maintain an appropriate lumbar curve to avoid injury. A secondary preventative strategy is to encourage patients with preexisting shoulder or low back pathology to avoid provocative exercises or very gradually build up to performing those exercises in a workout.

This study has limitations. We distributed our survey electronically to current participants who then chose whether to complete it. This introduces sampling bias because participants who have had injuries may be more likely to complete the survey. Alternatively, because we only surveyed active CrossFit members, it is possible that athletes who were injured and subsequently dropped out may have been missed. We defined an acute injury as one in which the athlete did not experience prior pain or discomfort in the injured area. As this concentrates primarily on the pain aspect of the injury, it does not take into account that the mechanism of the injury could have started in a prior workout without the appearance of pain. We had athletes group their injury into general categories in place of listing specific injuries, as there was no independent physician validation of the injury and our goal was to primarily differentiate between mild and severe injuries. Furthermore, the retrospective nature of the study design introduces the possibility of recall bias. A study examined injury rates over a 12-month time period.[5] There was a perfect recall of whether an injury had been sustained during that period, with a decreasing percentage of athletes recalling the exact number of injuries, body region, or diagnosis. Therefore, it stands to reason that the injury rate is accurate, with some decreasing accuracy in the reported number of injuries, location of injury, and diagnosis, as all this information was obtained from self-report. There was a small amount of reported injuries, which limits the conclusions on injury location and type. Despite these limitations, this study also has several advantages. Our injury criteria were concrete, encompassed the wide range of injuries that are seen in CrossFit, and were assembled with input from a number of different sources, including physicians, CrossFit owners, and coaches. Although not validated, it also piloted a means of electronic delivery to athletes, and this could easily be replicated on a much larger scale to reach participants throughout the world. Finally, we sampled athletes from a variety of different gyms throughout the country. We have determined that injury rate differs based on trainer involvement, and therefore it stands to reason that certain gyms with more effective or less effective trainers could skew the injury rate in the study. However, because of our wide distribution, we believe that this injury rate comes closer to representing an average for CrossFit gyms throughout the country as opposed to reporting the values from a single gym.

This was structured as a pilot study, which could provide areas of focus for further studies. A larger, prospective study with a validated survey and examination of injury rate with direct comparison with other recreational sports would be the logical next step. The factors we have identified to be associated with injury patterns may then be explored in more detail to help design effective preventative strategies to reduce injury rates and aid CrossFit in growing as a safe and effective exercise program.

CONCLUSION

CrossFit is emerging as a popular form of competitive exercise. As participation in CrossFit continues to expand, injuries associated with involvement will likely grow commensurately. Sports medicine physicians should have an awareness of the elements of this form of exercise and be prepared to treat the various patterns of injury incurred by its athletes. Injury rates in CrossFit are comparable with established injury rates for other recreational or competitive athletes, with an injury profile resembling that of gymnasts, Olympic weight lifters, and power lifters. The increasing involvement of CrossFit trainers in coaching participants corresponds to a decreasing injury rate. The shoulder and lower back areas were the most commonly injured body regions and most frequently were injured during gymnastic and power lifting movements. Most injuries in CrossFit are of an acute nature, without history of previous injury or symptoms in that same body area. In summary, we identified a preliminary injury rate in CrossFit, characteristics of a gym that correlate with injury rates, the most common location of injuries, and trends among CrossFit participants that correlate with injury rates. This information can be used by physicians treating patients who

participate in CrossFit as well as owners and coaches who work with athletes on a daily basis.

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