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Research article

Retrospective Injury Epidemiology and Risk Factors for Injury in CrossFit

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Abstract
The objective of the study is to examine injury epidemiology and risk factors for injury in CrossFit athletes. A survey was administered to athletes at four owner-operated facilities in South Florida. Respondents reported number, location of injury, and training exposure from the preceding six months and answered questions regarding potential risk factors for injury. Fifty out of 191 athletes sustained 62 injuries during CrossFit participation in the preceding six months. The most frequently injured locations were the shoulder, knee, and lower back. Injury incidence was 2.3/1000 athlete training hours. Competitors were more likely to be injured (40% v 19%, $p = 0.002$) and had greater weekly athlete training hours (7.3 ± 7.0 v 4.9 ± 2.9, $p < 0.001$) than non-competitors. Athletes who reported injury also reported significantly higher values for the following risk factors: years of participation (2.7 ± 1.8 v 1.8 ± 1.5, $p = 0.001$), weekly athlete training hours (7.3 ± 3.8 v 4.9 ± 2.1, $p = 0.020$), weekly athlete-exposures (6.4 ± 3.8 v 4.7 ± 2.1, $p = 0.003$), height (1.72 ± 0.09 m v 1.68 ± 0.01 m, $p = 0.011$), and body mass (78.24 ± 16.86 kg v 72.91 ± 14.77 kg, $p = 0.037$). Injury rates during CrossFit and location of injuries were similar to those previously reported. Injury incidence was similar to related sports, including gymnastics and powerlifting. While being a competitor was related to injury, increased exposure and length of participation in CrossFit likely underlied this association. Specifically, increased exposure to training in the form of greater weekly athlete training hours and weekly participations may contribute to injury. Increased height and body mass were also related to injury which is likely reflective of increased load utilized during training. Further research is warranted to determine if biomechanical factors associated with greater height and ability to lift greater loads are modifiable factors that can be adapted to reduce the increase risk of injury during CrossFit.

Key words: Incidence, prevalence, exercise, weight training.

Introduction

CrossFit is a strength and conditioning program that emphasizes functional and constantly varied exercise performed at a relatively high intensity. A key characterizing feature of CrossFit exercise is scalability. Scalability refers not only to progressions in load, but to modifications to movements that involve greater skill and/or flexibility. Through the use of these modifications, individuals of varying fitness levels ranging from beginner to advanced can participate in a similar training regimen, or the "workout of the day" (WOD). The issue of scalability is particularly important in group settings because of the types of WODs that are typically programmed. WODs are usually completed for time, sometimes with a time cap, or as many rounds of the exercise are completed as possible within a given period of time. Scaling of high skill movements, such as muscle-ups and toes-to-bar, allows less skilled athletes to both participate in the WOD in a manner similar to how it was prescribed and to build towards achieving the strength and skill necessary to execute the prescribed movement. Scalability enables another feature of CrossFit: community. Athletes of varying skill levels can share the experience of a WOD together.

While some CrossFit athletes complete WODs individually or informally, many CrossFit athletes belong to CrossFit affiliates, or independently operated facilities, where they may participate in individual or group-based CrossFit. Many affiliates promote another key feature of CrossFit which is the purported reason for CrossFit's effectiveness – a sense of community. CrossFit affiliate members reported experiencing significantly greater bonding (friendship development) and community belongingness compared to traditional gym members (Whiteman-Sandland et al., 2016). Research indicates that cohesion contributes to exercise adherence, which may explain this belief related to CrossFit's effectiveness (Burke et al., 2008).

CrossFit's popularity has increased substantially since 2005. With the rapid increase in participation and limited associated literature on injury epidemiology, CrossFit has been questioned for its safety. CrossFit WODs combine traditional cardiovascular exercises, such as running, biking, and rowing, with elements from Olympic weightlifting, powerlifting, strongman, and gymnastics. The elements from other sports include, but are not limited to, the clean, jerk, and snatch from Olympic weightlifting, the squat and deadlift from powerlifting, the farmer walk, tire flip, and yoke from strongman, and the handstand walk and muscle-up from gymnastics. While it borrows elements from these sports, CrossFit is different from them in distinct ways. Olympic weightlifting and powerlifting have events that occur in a specific order. For example, in Olympic weightlifting the snatch always precedes the clean and jerk. The goals of these sports is to lift the greatest loads. CrossFit is more similar to strongman in the sense that events within a competition vary. Strongman, as the name implies, has a greater emphasis on feats of strength whereas CrossFit utilizes WODs that test cardiovascular and muscular power, strength, and endurance. WODs typically mix aerobic and anaerobic exercises with high skill movements, including

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jerks, snatches and muscle-ups, which are performed under cardiovascular and muscular fatigue conditions. This is in contrast to traditional training principles that promote the execution of multi-joint power movements first in order to maximize load and preserve technique (Baechle and Earle, 2008). Furthermore, traditional training principles emphasize technical competence, especially with multi-joint power movements. Fatigue associated with high intensity anaerobic exercise may result in the deterioration of concentration and skill. This fatigue is believed to put athletes at greater risk of injury. The unorthodox combination and order of exercises and decreased focus on technical competence compared to related sports have contributed to the concerns about CrossFit's safety. As a result, newspapers and media outlets have noted the potential danger of CrossFit participation (Cooperman, 2005; Diamond, 2015; Robertson, 2013).

Despite the safety concerns, little evidence exists to either support or refute safety-related claims for CrossFit athletes. Existing research on CrossFit injury epidemiology utilizes methods that may not result in representative findings as sampling techniques did not address participant self-selection. Hak et al. (2013) utilized online CrossFit forums to collect data on CrossFit injury epidemiology using a retrospective survey, but were unable to determine how many individuals viewed the survey and opted not to take it. Weisenthal et al. (2014) sent their retrospective injury epidemiology survey to specific affiliates and made it available on the main CrossFit website. They also were unable to determine how many individuals viewed the survey and opted not to take it. In addition, there is a dearth of research that uses advanced statistical techniques to identify risk factors that may lead to injury in CrossFit athletes. Therefore, the purpose of this research was to examine injury epidemiology and risk factors for injury in CrossFit. Results of this research may be used to determine relative safety of the sport and to identify potential factors that put athletes at greater risk of injury.

Methods

Subjects

Fourteen CrossFit affiliates in South Florida were asked to participate in the research. Only four affiliates agreed to participate. All participating affiliates were owner-operated facilities, or facilities owned and managed by the same individual. A total of 255 athletes from participating affiliates were asked to participate in the research. Of those athletes who were asked, 191 completed the survey. CrossFit athletes were eligible for participation if they were members at the facilities and were present the day of data collection. There were no exclusion criteria. The research was approved by the university's Institutional Review Board. Consent was implied upon submission of each survey.

Instrumentation

The purpose of this investigation was to examine the location, severity, and number of injuries, and potential risk factors for injury in the preceding six months. The survey was developed and used to collect data on these variables. In addition to original questions, the survey contained questions similar to those posed by Winwood et al. (2014) in a retrospective injury survey for strongman athletes. Content validity was established via review by a Level I certified CrossFit coach, two Division I collegiate athletic trainers, and an exercise science professional. The survey was modified based on suggestions to improve clarity. Next, the survey was piloted at one CrossFit affiliate and changes were made to questions based on feedback from pilot participants.

The survey was composed of three sections. Section one pertained to the athletes' participation. These questions were related to athletes' participation in CrossFit, including length of participation in CrossFit (years), frequency of participation in CrossFit (weekly athlete training days, weekly athlete training hours, and weekly athlete-exposures), and whether or not athletes incorporated warm-ups and cool-downs. Section two pertained to CrossFit injury history within the preceding six months. Injury was defined as any physical damage to a body part that caused them to miss or modify one or more training sessions or hindered activities of daily living. If the athlete had an injury, they were asked to mark with an "X" the exact location of injury on an illustrated representation of an anatomical figure (Figure 1). Because the injury history portion only allowed participants to report one injury at a time additional injuries were reported on separate forms. Questions targeting type of injury were used to determine mechanism (acute versus chronic onset). Questions targeting severity of injury focused on the changes athletes had to make to training because of injury and treatment that athletes received following injury. Section three pertained to the athletes' background. The questions asked about fitness level before beginning CrossFit, motivation for CrossFit participation, physical activity outside of CrossFit, and participation in CrossFit competitions. This section also addressed demographic and biometric information. All measurements were self-reported and injuries were not confirmed via diagnosis from a medical professional.

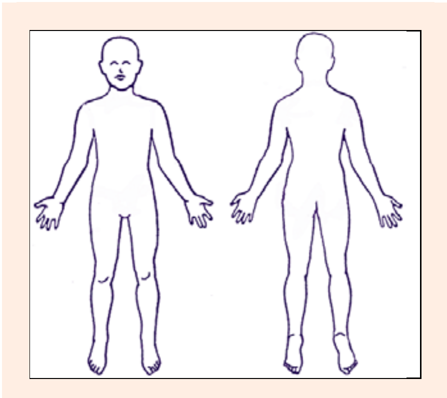

Figure 1. Anatomical diagram used to detail location of injury.

Procedures

Researchers spent one day at each of the four CrossFit facilities administering surveys. Upon entering the facility, CrossFit athletes were asked to participate in the survey and each coach encouraged participation at the end of each WOD. Athletes were given the survey, which included instructions for each section. If the subjects had any questions, researchers were available for answers. Each survey was reviewed for completion upon submission. The number of responses and refusals were tallied in order to calculate a response rate.

Data were coded and entered into a spreadsheet. For location of injury, body parts from the figure were classified using the National Athletic Injury/Illness Reporting System by a licensed and certified athletic trainer (Buckley, 1982; Clarke and Miller Jr, 1974). For open-ended questions where responses were uninterpretable, data were excluded from final analyses.

Injury rates

Injury rates were calculated by estimating the number of athlete training hours in the preceding six months. The question that asked, "In the last week, how much time in hours did you spend doing CrossFit WODs", was used in the estimate. Total weekly athlete training hours reported were multiplied by 26, the number of weeks in six months. Rate was then converted to number of injuries/1000 athlete training hours.

Statistical procedures

Descriptive statistics were calculated for each variable. Chi-Square or Fisher's Exact Tests were used to test the unadjusted association of categorical variables and independent t-tests were used on continuous variables to compare athletes with and without injury in the preceding six months. Multiple logistic regression was used to evaluate adjusted associations. To select the final logistic regression model, forward, backward and stepwise model selection procedures were considered. To avoid multicollinearity, the variation inflation factor was examined before entering the variables into the regression model. For the covariates that were included in the final logistic regression model, adjusted odds ratios (AOR) and 95% confidence intervals (CI) were estimated. A p-value of 0.05 was used to determine statistical significance. All statistical procedures were performed using the SPSS software, version 17.0 (IBM Corporation, NY, USA) and Statistical Analysis System (SAS) 9.4 for Windows (SAS Institute Inc., Cary, NC, USA).

Results

Risk factors for injury

One hundred ninety-one CrossFit athletes were surveyed (94 males, 97 females) from four owner-operated facilities in South Florida. The response rate was 75% (191/255). Participant characteristics are presented in Table 1 (Total). Fifty out of 191 athletes sustained a total of 62 injuries during CrossFit participation in the preceding six months. The reported incidence rate of injury equated to 2.3 injuries/1000 hours of participation. With regard to risk factors, injured athletes differed from uninjured athletes for several characteristics (Table 1). Years of participation in CrossFit, weekly athlete training hours, weekly athlete-exposures, height, and body mass differed between injured and uninjured athletes ($p < 0.05$). Injured athletes did not differ from uninjured athletes with regard to weekly athlete-days, class size, coach number, years completing structured physical activity, or age in unadjusted analyses. In addition, males and females had similar injury prevalence (31.91% v 20.62%, p = 0.076).

In unadjusted models, participation in CrossFit competition was significantly associated with injury (Table 2). Forty percent of competitors were injured in the preceding six months while only 19.05% of non-competitors were injured; however, competitors reported significantly greater athlete training hours than non-competitors (7.1 v 4.7, p = 0.008). In addition, physical activity outside of CrossFit was significantly associated with injury. Over 30% of those who participated in outside physical activity reported injury in the preceding six months while only 15% of those who did not engage in outside physical activity reported injury. Gender, inclusion of warm-ups and cool-downs, and participation in CrossFit for fitness were not related to injury

Greater length of participation in CrossFit increased the odds of being injured (AOR = 1.252, CI: 1.002-1.564; Table 3). Competitors had 93.7% (AOR = 1.937, CI: 0.873-4.298) higher odds of being injured compared to non-competitors; however, participation in CrossFit competitions was not significant in the adjusted model (p = 0.1041). The odds of being injured for those athletes who engaged in physical activity outside of CrossFit were 2.3 (AOR: 2.311, CI: 1.1011, 5.283) times the odds of being injured while not engaging in outside physical activity. Higher weekly athlete-exposures

Table 1. Means and standard deviations and results for independent t-tests comparing uninjured and injured CrossFit participants with regard to potential risk factors (unadjusted).

Variable	Injury status						p-value
	Total (n = 191)		Uninjured (n=141)		Injured (n=50)		
	Mean	SD	Mean	SD	Mean	SD	
Years of participation in CrossFit	2.04	1.65	1.80	1.52	2.71	1.82	0.001
Weekly athlete training hours	5.49	4.48	4.85	2.94	7.30	6.98	0.020
Weekly athlete training days	4.39	1.31	4.29	1.26	4.68	1.42	0.069
Weekly athlete-exposures	5.12	2.78	4.65	2.14	6.41	3.80	0.003
CrossFit class size	9.24	4.76	9.40	4.73	8.79	4.89	0.438
Number of coaches per CrossFit class	1.48	0.64	1.48	0.63	1.48	0.67	0.946
Years of physical activity	17.74	29.64	16.25	28.46	21.94	32.69	0.114
Age	31.69	9.40	31.78	9.78	31.42	8.34	0.817
Height (m)	1.68	0.10	1.68	0.10	1.72	0.09	0.011
Body mass (kg)	74.32	15.49	72.91	14.77	78.24	16.86	0.037

Table 2. **Means and percentages and results for Chi-Square/Fisher's Exact Tests comparing uninjured and injured CrossFit participants with regard to potential risk factors (unadjusted).**

Variable	Injury status						
	Total (n = 191)		Uninjured (n = 141)		Injured (n = 50)		
	n	%	n	%	n	%	sig.
Participation in CrossFit competitions							**
Non-competitor	126	66.0	102	81.0	24	19.1	
Competitor	65	34.0	39	60.0	26	40.0	
Fitness level before CrossFit							
Not fit at all	32	16.8	24	75.0	8	25.0	
Not very fit	33	17.3	26	78.8	7	21.2	
Average fitness	88	46.1	64	72.7	24	27.3	
Very fit	30	15.7	21	70.0	9	30.0	
Extremely fit	8	4.2	6	75.0	2	25.0	
Warm up included in CrossFit workouts							$
Yes	187	97.9	137	73.3	50	26.7	
No	4	2.1	4	100.0	0	0.0	
Cool down included in CrossFit workouts							
Yes	144	75.4	106	73.6	38	26.4	
No	47	24.6	35	74.5	12	25.5	
Physical Activity outside CrossFit							*
Yes	123	64.4	84	68.3	39	31.7	
No	67	35.1	57	85.1	10	15.0	
CrossFit for Fitness							
Yes	180	94.2	134	74.4	46	25.6	$
No	11	5.8	7	63.6	4	36.4	
Gender							
Male	94	49.2	64	68.1	30	31.9	
Female	97	50.8	77	79.4	20	20.6	

* Significant at 0.05 **Significant at 0.01 **Significant at 0.001. $ Fisher's Exact test instead of Chi-Square (expected counts less than 5).

Table 3. **Multivariable logistic regression analysis of risk factors associated with status of injury for CrossFit participants.**

Variable	AOR	95% CI		p-value
Years of participation in CrossFit	1.25	1.00	1.56	0.048
Participation in CrossFit competitions				0.104
Competitor	1.94	0.87	4.30	
Non-Competitor	*Ref*			
Physical activity outside CrossFit				0.047
Yes	2.31	1.01	5.28	
No	*Ref*			
Weekly athlete exposures	1.17	1.00	1.37	0.048
Height	1.12	1.01	1.24	0.029

AOR=adjusted odds ratio, CI=confidence interval, Ref=reference category.

increased the odds of injury (AOR =1.172, CI: 1.002-1.371). Taller CrossFit athletes had increased odds of being injured (AOR = 1.124, CI: 1.013-1.247).

Injury epidemiology

Of the 50 respondents who reported injury in the preceding six months, 12 respondents reported more than one injury over the surveillance period. The most frequent injured locations were the shoulder (14/62), knee (10/62), and lower back (8/62). Table 4 presents the frequency of all injury sites and incidence at each site. Eleven out of 62 injuries were pre-existing or re-injuries and 47/62 were primary injuries that occurred as a direct result of CrossFit participation. Most of the injuries occurred acutely (34/62), whereas a smaller proportion were chronic in onset (22/62). Twenty-four percent of the athletes indicated that their injury did not affect their training while 50% indicated that their reported injury caused them to change their performance of an exercise/training regimen. Nearly 20% of the athletes reported that the injury caused CrossFit cessation and another 20% of the athletes reported that the injury caused cessation of specific exercises. Over half of the athletes reported that their injuries required attention from a medical professional. However, some injuries were resolved using self-administered care. Three injuries did not require treatment or alterations to training program.

Discussion

The overall incidence of injury in CrossFit athletes was 2.3/1000 athlete training hours, with 26% of athletes reporting injury. This rate was similar to those previously reported. Hak et al. (2013) distributed a survey on online CrossFit forums and reported a rate 3.1 injuries/1000 hours of CrossFit participation. Weisenthal et al. (2014)

conducted an internet survey on CrossFit injury epidemiology and found that 19.4% (75/386) of athletes reported injury. Sprey et al. (2016) found that 31% of CrossFit athletes who completed their survey experienced injury during CrossFit participation. Additionally, in a survey investigating only shoulder injuries in CrossFit athletes Summit et al. (2016) found that incidence of new shoulder injuries was 1.18/1000 athlete training hours. This was more than double the incidence we reported. However, Summit et al. (2016) specifically targeted CrossFit athletes with shoulder injury.

Table 4. Frequency, percentage, and incidence rate of injured body parts (n = 62).

Body part	Frequency	Percent	Incidence/1000 athlete training hours
Shoulder	14	22.6	0.51
Knee	10	16.1	0.37
Lower back	8	12.9	0.29
Wrist	7	11.3	0.26
Hand	4	6.5	0.15
Upper arm	3	4.8	0.11
Upper back	3	4.8	0.11
Elbow	2	3.2	0.07
Ankle	2	3.2	0.07
Shin	2	3.2	0.07
Calf	1	1.6	0.04
Cervical spine	1	1.6	0.04
Foot	1	1.6	0.04
Hip	1	1.6	0.04
Rib	1	1.6	0.04
Systemic	1	1.6	0.04
Thigh	1	1.6	0.04

In addition to other CrossFit-specific reports, the rate of injury fell within the range of injury incidence in related sports. The rate of injury in powerlifters has been reported to be between 1.0-5.8 injuries/1000 hours (Brown and Kimball, 1983; Haykowsky et al., 1999; Keogh et al., 2006; Raske and Norlin, 2002; Siewe et al., 2011). The rate of injury in Olympic weightlifters has been reported to be between 2.4-3.3 injuries/1000 hours (Calhoon and Fry, 1999; Raske and Norlin, 2002). Injury incidence in CrossFit was similar to injury incidence in both Olympic weightlifting and powerlifting which suggests that movements from these sports are possibly contributing to a majority of injuries in CrossFit. This finding is supported by Weisenthal et al. (2014) who found that powerlifting and Olympic lifting movements accounted for 40% of injuries. Kolt and Kirkby (1999) reported a rate of 2.63 injuries/1000 hours in elite gymnasts and a rate of 4.63 injuries/1000 hours in subelite gymnasts. The higher incidence of injury in subelite gymnasts indicates that lack of gymnastics skill may be related to injury. The fact that our rate was more similar to that of elite gymnasts suggests that CrossFit athletes performing gymnastics movements are likely skilled and that CrossFit athletes who are less skilled are likely not performing gymnastics movements. Regardless, Weisenthal et al. (2014) reported that gymnastics movements accounted for 20% of all injuries. Finally, the rate of injury in CrossFit was lower than that reported by Winwood et al. (2014) in competitive strongmen (5.5 injuries/1000 hours). This finding is of interest because our results suggested that taller and heavier athletes were more likely to experience injury. In their study, Winwood et al. (2014) reported that the average height and mass of their strongman respondents were 1.83 ± 0.07m and 113 ± 20kg, respectively. Their respondents were considerably larger than our respondents who reported injury (1.72 ± 0.09 m, 78.2 ± 16.9kg). Moreover, Winwood et al (2014) suggest that it is the nature of the movements that may result in the higher rate of injury in strongman athletes. While CrossFit does incorporate elements from strongman, they may not be the elements that put athletes at the greatest risk of injury. These elements include stones, tire flip, and log press, among others (Winwood et al., 2011). Overall, we found that injury incidence in CrossFit athletes was similar to related sports.

With regard to location of injury, our results indicated that the shoulder, knee, and lower back were the most frequently injured locations. This was similar to findings from both Hak et al. (2013) and Weisenthal et al (2014). Hak et al. (2013) identified the shoulder and spine as the most frequently reported locations of injury and Weisenthal et al. (2014) identified the shoulder, lower back, and knee as the most frequently injured locations. In their review, Keogh and Winwood (2016) found that Olympic weightlifters most frequently injured the knee, lower back, and shoulder, powerlifters most frequently injured the shoulder, lower back, and knee, and strongmen most frequently injured the lower back, shoulder, and bicep. CrossFit athletes most closely resembled powerlifters in this sense. This finding was surprising considering the rate of injury in CrossFit athletes most closely resembled that of Olympic weightlifters and because Weisenthal et al. (2014) found that powerlifting movements resulted in more injuries than Olympic weightlifting movements (23% vs 17%). One possible explanation for this finding may be that Olympic weightlifters are more accustomed to lifting weight overhead than powerlifters and CrossFit athletes. As such, they may have increased skill, strength, and flexibility relative to other lifting athletes. Keogh et al. (2006) found that elite Olympic weightlifters had lower injury incidence than non-elite Olympic weightlifters, indicating that greater skill, strength, and flexibility are related to lower injury incidence. All of these findings combined suggest that CrossFit athletes who aim to reduce their risk of shoulder injury should improve skill, strength, and felexibility in overhead gymnastics and Olympic lifting activities.

With regard to potential risk factors for CrossFit participation, injured athletes had significantly greater training exposure than uninjured athletes. Greater exposure equates to more chances in which injury can occur. As such, this finding is expected. As previously mentioned, injured athletes were significantly taller and weighed significantly more than uninjured athletes. Similarly, heavyweight strongmen (>105kg) reported significantly greater incidence than lightweight strongmen (<105kg) (Winwood et al., 2014). Greater height may be associated with greater biomechanical moments. In addition, athletes who are larger are likely training with increased load and placing their musculoskeletal systems at increased risk of injury. We speculate that increased risk of injury may actually be associated with strength and not with anthropometrics. Finally, injured athletes had significantly greater length of participation/experience in CrossFit than uninjured athletes. This finding may be partially explained by skill level and, again, the relative loads utilized, which were not measured in this research. As skill level and strength improve, CrossFit athletes scale to more difficult movements and heavier loads. By scaling to make exercise more challenging, it is possible that athletes are performing movements or lifting loads that may increase their risk of injury. Further research is needed to identify specific movements that resulted in injury to CrossFit athletes and to investigate the effect of load on injury.

With regard to injury severity, most injuries were acute (34/62), caused the athlete to stop performing an exercise or cease activity completely (19/62), and most required medical attention (26/62). Hak et al. (2013) also reported that most injuries in CrossFit athletes were acute. However, they found that most injuries were mild. Conversely, Weisenthal et al. (2014) found that 73.5% of CrossFit athletes reported injury that prevented them from working, training, or competing and that 7% of athletes required surgery for the injury. However, neither Hak et al. (2013) nor Weisenthal et al. (2014) had systematic sampling or reported response rate. Results of this research indicate that injury severity is consistent with what has previously been reported.

Because of the greater skill level assumed to accompany competition, it was hypothesized that competitors would be at greater risk of injury. However, competitors only had a slightly increased risk of injury relative to non-competitors in unadjusted models. This association was not significant in adjusted models. Additionally, while competitors had a significantly greater injury incidence than non-competitors, they also had significantly greater exposure. As previously mentioned, greater exposure allows for more chances for injury to occur. It is likely that time spent participating in CrossFit was a confounding factor for the greater incidence of injury observed in competitors. This association was likely further confounded by length of participation in CrossFit. Rather than competition being a risk factor for injury, it is likely that the increased skill level and strength that accompany greater and longer participation increased injury incidence.

This research was not without its limitations. Only four facilities chose to allow the survey to be administered to patrons and all facilities were owner-operated. These findings may not be generalizable to other types of facilities, such as individual facilities or groups of facilities owned by investors. Specifically the results of the current study may be biased to facilities that follow the safest CrossFit practices. In addition, we were unable to capture information from athletes who were not present for data collection due to injury or who no longer participate in CrossFit due to injury. Finally, exposure was estimated by using the preceding six months. This method may have resulted in an inaccurate estimate of exposure. Furthermore, athletes may have completed the survey under fatigued conditions which could have influenced their ability to recall the preceding six months correctly. However, the injury incidence rate was similar to those of previous research and related sports. This indicates that we likely experienced similar bias to previous research despite efforts to achieve less bias. Future research on injury epidemiology in CrossFit should focus on maximizing external validity and on capturing the true population. Additionally, to overcome recall bias, future investigations into CrossFit injury epidemiology should be prospective as recommended by Keogh and Winwood (2016). To reduce the risk of injury in CrossFit future research should identify which exercises, conditions, or modifiable factors result in injury, especially to the shoulder, lower back, and knee.

Conclusion

Currently, only 20% of American adults meet physical activity guidelines set forth by the US government and 69% of adults are overweight or obese.(Prevention; Prevention) The US government recommends that adults perform 75 minutes of vigorous intensity physical activity and two days of moderate or high intensity muscle strengthening two days per week.(Promotion). CrossFit offers a solution to achieving vigorous physical activity and weight training recommendations with the added benefit of cohesion, which may improve exercise adherence. While the rate of injury in CrossFit is similar to other forms of exercise, some injured respondents reported the need to cease physical activity or seek medical attention. Individuals interested in pursuing CrossFit for fitness, competition, or both should weigh the risks and benefits of participation.

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Key points

- The overall rate of injury in CrossFit athletes was 2.3/1000 athlete training hours.
- The shoulder, knee, and lower back were the most frequently reported locations of injury.
- In adjusted models, length of participation in CrossFit, physical activity outside of CrossFit, weekly athlete-exposures to CrossFit, and height were associated with injury in CrossFit athletes.

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