

## [ Athletic Training ]

# Injuries in an Extreme Conditioning Program

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**Background:** Extreme conditioning programs (ECPs) are fitness training regimens relying on aerobic, plyometric, and resistance training exercises, often with high levels of intensity for a short duration of time. These programs have grown rapidly in popularity in recent years, but science describing the safety profile of these programs is lacking.

**Hypothesis:** The rate of injury in the extreme conditioning program is greater than the injury rate of weightlifting and the majority of injuries occur to the shoulder and back.

**Study Design:** Cross-sectional study.

**Level of Evidence:** Level 4.

**Methods:** This is a retrospective survey of injuries reported by athletes participating in an ECP. An injury survey was sent to 1100 members of Iron Tribe Fitness, a gym franchise with 5 locations across Birmingham, Alabama, that employs exercises consistent with an ECP in this study. An injury was defined as a physical condition resulting from ECP participation that caused the athlete to either seek medical treatment, take time off from exercising, or make modifications to his or her technique to continue.

**Results:** A total of 247 athletes (22%) completed the survey. The majority (57%) of athletes were male ( $n = 139$ ), and 94% of athletes were white ( $n = 227$ ). The mean age of athletes was 38.9 years ( $\pm 8.9$  years). Athletes reported participation in the ECP for, on average, 3.6 hours per week ( $\pm 1.2$  hours). Eighty-five athletes (34%) reported that they had sustained an injury while participating in the ECP. A total of 132 injuries were recorded, yielding an estimated incidence of 2.71 per 1000 hours. The shoulder or upper arm was the most commonly injured body site, accounting for 38 injuries (15% of athletes). Athletes with a previous shoulder injury were 8.1 times as likely to injure their shoulder in the ECP compared with athletes with healthy shoulders. The trunk, back, head, or neck ( $n = 29$ , 12%) and the leg or knee ( $n = 29$ , 12%) were the second most commonly injured sites. The injury incidence rate among athletes with <6 months of experience in the ECP was 2.5 times greater than that of more experienced athletes ( $\geq 6$  months of experience). Of the 132 injuries, 23 (17%) required surgical intervention. Squat cleans, ring dips, overhead squats, and push presses were more likely to cause injury. Athletes reported that 35% of injuries were due to overexertion and 20% were due to improper technique.

**Conclusion:** The estimated injury rate among athletes participating in this ECP was similar to the rate of injury in weightlifting and most other recreational activities. The shoulder or upper arm was the most commonly injured area, and previous shoulder injury predisposed to new shoulder injury. New athletes are at considerable risk of injury compared with more experienced athletes.

**Clinical Relevance:** Extreme conditioning programs are growing in popularity, and there is disagreement between science and anecdotal reports from athletes, coaches, and physicians about their relative safety. This study estimates the incidence of injury in extreme conditioning programs, which appears to be similar to other weight-training programs.

**Keywords:** CrossFit; extreme conditioning program; injury; epidemiology

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Extreme conditioning programs (ECPs) have gained popularity in recent years. Although participation data are lacking, based on reporting in the lay press, CrossFit is likely the most commonly known program that fits the definition of an ECP. ECPs are “multifaceted, circuit training–like fitness programs using varying forms of resistance training and challenging running intervals and repeated bodyweight exercises, including plyometrics,” further characterized by “high-volume aggressive training workouts that use a variety of high-intensity exercises and often timed maximal number of repetitions with short rest periods between sets.”<sup>1</sup> There are many programs that fit this definition, but there is wide variation in training principles, coaching, and supervision depending on the program in question.

In 2011, the Consortium for Health and Military Performance and the American College of Sports Medicine published a consensus paper on ECPs in military personnel.<sup>1</sup> Health care providers were experiencing an influx of musculoskeletal injuries among ECP participants, particularly novices. Exertional rhabdomyolysis has been reported after participating in a CrossFit program.<sup>5</sup>

The purposes of this study were to (1) retrospectively determine the estimated incidence and prevalence of musculoskeletal injury attributed to participation in an ECP, (2) determine the anatomic distribution of injury, (3) identify any particularly hazardous exercises, and (4) determine the self-reported causes of injury.

## METHODS

The study was approved by the Institutional Review Board of St Vincent’s Health System, then released via email to 1100 ECP participants. This study is a retrospective survey into which athletes participating in a local ECP were recruited. All athletes surveyed were active members of Iron Tribe Fitness, a fitness franchise with 5 locations across greater metropolitan Birmingham, Alabama, with approximately 1100 members. These gyms were selected because of the large number of athletes as well as use of uniform facilities and equipment, uniform training and management of coaching staff, and uniform daily workouts across all locations. Iron Tribe Fitness utilizes circuit training with varying forms of resistance training, bodyweight exercises, plyometrics, and running, and thus can be considered an ECP. The survey was hosted on a secure website (SurveyMonkey.com) and can be found as an appendix (available at <http://sph.sagepub.com/content/by/supplemental-data>). The survey covered demographics, total duration of training in the ECP, outside training or exercise (in addition to the ECP), medical history (including medication and supplement use), and prior injury history, but participants were not required to answer every question. Body mass index was calculated for all athletes. Although body mass index is known to suffer from limitations, especially in an athletic population,<sup>12</sup> it was included as the best estimate of overall adiposity and body composition from the readily available data (height and weight). Athletes

then completed questions pertaining to injuries they attributed to participation in the ECP. Injuries were divided into the following body sites: head, back, neck, or trunk; shoulder or upper arm; elbow or forearm; wrist or hand; hip or groin; knee or leg; ankle or foot; and uncategorized. Athletes reported injuries and were asked if the injury (1) required medical treatment, (2) caused the athlete to miss any time from participation, or (3) caused the athlete to make any modifications to his or her technique to continue. For the purposes of this study, only self-reported injuries that met 1 of these criteria were considered. If an athlete had sustained multiple injuries to a body site, he or she was instructed to describe only the most severe injury.

Specific information was collected on each injury, including the mechanism of injury, treatment, and self-reported cause of injury, among others. The survey remained open for 3 months. Athletes’ responses were then reviewed and, when necessary, injuries were recategorized to accurately reflect true injury patterns and correct body sites (eg, proximal biceps injury incorrectly listed in “elbow or forearm” recategorized to “shoulder or upper arm”). The exercises implicated in injury were then reviewed and categorized by a certified strength and conditioning specialist with additional qualifications from USA Weightlifting.

An individual athlete’s career ECP training hours were calculated by multiplying the weekly ECP training hours by the duration of training in any ECP. These results were calculated for each athlete, and incidence of injury was estimated as the number of injuries per 1000 hours. Furthermore, exercise-specific injury incidence was estimated. Daily training programs from the previous year were examined, and the total percentage of time spent on each of the 13 most commonly reported injury-causing exercises was calculated by a certified strength and conditioning specialist. This percentage was then applied to the total risk pool of hours to determine an estimated risk pool of participation time for each exercise. This number was then used as the denominator to estimate incidence of injury for each specific exercise as injuries per 1000 exercise-hours.

Statistical analysis was performed using JMP 10 (SAS Institute Inc), and the  $\alpha$  level was set at 0.05. In order for results to be representative of all athletes participating in this particular ECP with 95% confidence and given a total athlete population of 1100, 285 respondents would be required for a  $\pm 5\%$  margin of error. Initial counts and frequencies were performed for all variables. Covariate proportions and means were compared between sexes and between injury sites using chi-square methods, 2-tailed Fisher exact tests, and Student *t* tests where appropriate. Specific exercise variables and cause of injury were compared using post hoc Fisher exact tests with a Bonferroni correction ( $P = 0.0018$ ). Estimated incidence rate ratios (IRRs) and their corresponding 95% confidence intervals (CIs) were calculated to compare the estimated incidence of injury due to specific exercises. We calculated IRR as using the total number of injuries reported in the group of interest ( $n_1$ ), the total number of injuries in the reference group ( $n_2$ ), the estimated

Table 1. Athlete demographics

	% (N/Total) or Mean ± SD		
	Women (n = 105)	Men (n = 142)	Overall (N = 247)
Age (y)	38.1 ± 8.8	39.4 ± 8.9	38.9 ± 8.9
Height (cm)	165 ± 6.3	181 ± 6.7	
Mass (kg)	66.2 ± 12.1	89.0 ± 14.9	
BMI	24.3 ± 4.3	27.1 ± 3.9	
BMI category <sup>a</sup>			
Underweight	2 (2/103)	0 (0/141)	
Normal	66 (68/103)	28 (40/141)	
Overweight	22 (23/103)	52 (74/141)	
Obese	10 (10/103)	19 (27/141)	
Race/ethnicity <sup>a</sup>			
White (not Hispanic)	93 (97/103)	95 (135/142)	94 (232/246)
Nonwhite and Hispanic	7 (6/103)	5 (7/142)	6 (14/246)

BMI, body mass index.

<sup>a</sup>Two athletes declined to provide their mass, 1 athlete declined to provide his height, and 1 athlete declined to provide her race/ethnicity.

amount of person-time (athlete-hours) in the group of interest ( $PT_1$ ), and the estimated amount of person-time (athlete-hours) in the reference group ( $PT_2$ ). IRR was calculated as follows:

$$IRR = \frac{n_1 / PT_1}{n_2 / PT_2}$$

IRRs with 95% CIs that did not include 1 were considered statistically significant. For IRRs of specific exercises, the reference group was selected as the total number of injuries sustained due to any exercise other than the exercise being tested.

## RESULTS

Of the approximately 1100 athletes to whom the survey was electronically distributed, 247 completed the survey (22%). The subjects were, on average, middle-aged and the majority were white (Table 1). Information regarding athletes' training histories can be found in Table 2. Of note, men had participated in significantly more training time per week and had completed more lifetime hours of training compared with women. In addition to ECP training, a majority of athletes reported further training, with the most popular activities being running/jogging, weightlifting, and cycling. Athletes spent a mean 3.1 hours training outside the ECP in a typical week, and women spent 0.9 more hours per week in additional training when compared

with men ( $P = 0.022$ ). Of those completing the survey, 72 (29%) reported a preexisting musculoskeletal medical issue, and 107 (43%) reported a previous musculoskeletal injury. Previous injuries were most commonly reported as occurring to the leg or knee (39%); the shoulder or upper arm (36%); or the trunk, back, head, or neck (30%).

Eighty-five athletes reported a total of 132 injuries during their training career, yielding a lifetime prevalence of injury sustained during the ECP of 34% and an estimated incidence rate of 2.71 injuries per 1000 hours (Table 3). The estimated incidence among women was not significantly different from men (IRR, 0.91; 95% CI, 0.6-1.3). Experienced athletes who had participated in the ECP for at least 6 months were 4.4 times more likely ( $P < 0.001$ ) to have sustained an injury (42% vs 14%) than inexperienced athletes (<6 months of ECP training). However, athletes who were newer to the ECP (<6 months of training) sustained injuries 2.5 times more often (95% CI, 1.5-4.2) than more experienced athletes (6.34/1000 vs 2.50/1000 hours). The most commonly injured sites were the shoulder or upper arm; the leg or knee; or the trunk, back, head, or neck. The most commonly implicated exercises were squat cleans, running, and overhead squats. Of all exercises, 13 were classified as aerobic, 42 as power-focused, and 41 as strength-focused. Exercises implicated in injuries were more commonly performed with weighted barbells as opposed to using body weight, rings, pull-up bar, kettlebell, or medicine ball, and

Table 2. Training history compared by sex

	% (N/Total) or Mean $\pm$ SD		P Value	% (N/Total) or Mean $\pm$ SD
	Women	Men		Overall
ECP training history (mo)	11.4 $\pm$ 7.4	13.7 $\pm$ 10.6	0.051	12.7 $\pm$ 9.4
ECP weekly training (h/wk)	3.4 $\pm$ 0.9	3.8 $\pm$ 1.3	0.008	3.6 $\pm$ 1.2
ECP lifetime athlete-hours	167.4 $\pm$ 112.7	225.4 $\pm$ 180.0	0.002	200.6 $\pm$ 157.2
Perform additional training	60 (63/105)	51 (73/142)	0.18	55 (136/247)
Additional running	42 (44/105)	31 (44/142)	0.077	36 (88/247)
Additional weightlifting	6 (6/105)	14 (20/142)	0.034	11 (26/247)
Additional tennis	7 (7/105)	1 (2/142)	0.029	4 (9/247)
Additional biking/spinning	14 (15/105)	8 (11/142)	0.010	11 (26/247)
Additional yoga	10 (10/105)	1 (2/142)	0.003	5 (12/247)
Additional walking/hiking	10 (11/105)	2 (3/142)	0.005	6 (14/247)
Additional training time (h/wk)	3.6 $\pm$ 2.6	2.7 $\pm$ 1.4	0.022	3.1 $\pm$ 2.1

ECP, extreme conditioning program.

Table 3. Injury occurrence

	% (N/Total)		P Value	% (N/Total)
	Women	Men		Overall
Estimated injury incidence (per 1000 h)	2.87	2.62		2.71
Injury prevalence	31 (33/105)	37 (52/142)	0.40	34 (85/247)
Body site				
Shoulder or upper arm	13 (14/105)	17 (24/142)	0.44	15 (38/247)
Trunk, back, head, or neck	10 (10/105)	13 (19/142)	0.35	12 (29/247)
Leg or knee	8 (8/105)	15 (21/142)	0.084	12 (29/247)
Hand or wrist	4 (4/105)	6 (8/142)	0.57	5 (12/247)
Hip or groin	5 (5/105)	4 (5/142)	0.62	4 (10/247)
Forearm or elbow	6 (6/105)	1 (2/142)	0.059	3 (8/247)
Foot or ankle	3 (3/105)	2 (3/142)	0.70	2 (6/247)

slightly more than half were Olympic-style lifts (those incorporating portions of the snatch or the clean and jerk). Furthermore, all injuries to the hand or wrist were attributed to an Olympic-style lift. Estimated IRRs were calculated for the 13 most commonly implicated exercises and revealed that the exercises that were significantly more likely to result in injury

were squat cleans (IRR, 4.7; 95% CI, 2.5-8.7), ring dips (IRR, 3.5; 95% CI, 1.3-9.4), overhead squats (IRR, 3.5; 95% CI, 1.8-6.9), and push presses (IRR, 2.4; 95% CI, 1.1-5.1).

A number of demographic and history factors were significantly associated with a greater likelihood of reporting an injury sustained during participation in the ECP. Athletes who

Table 4. Athlete-reported cause of injury

	% (N/Total)
Overexertion	46 (48/105)
Improper technique	23 (24/105)
Prior injury that predisposed	14 (15/105)
Inadequate warmup	8 (8/105)
Fatigue	5 (5/105)
Lack of supervision	3 (3/105)
Lack of familiarity with exercise	2 (2/105)

self-reported any preexisting medical issues were 2.7 times more likely to have reported sustaining an injury while participating in the ECP (95% CI, 1.6-4.6;  $P < 0.001$ ), while participants reporting a history of any previous musculoskeletal injury were 2.6 times more likely to have suffered an injury during the ECP (95% CI, 1.5-4.5;  $P < 0.001$ ). Athletes reporting a history of injury to their trunk, back, head, or neck were 5.8 times more likely to reinjure the same area (95% CI, 1.7-21.9;  $P = 0.005$ ), as were athletes with a history of shoulder or upper arm injury, who were 8.1 times more likely to reinjure their shoulder or upper arm (95% CI, 2.4-31.2;  $P < 0.001$ ). When asked what factor was most responsible for their injury, respondents most often cited overexertion, improper technique, or predisposition from a previous injury (Table 4).

In terms of treatment, the most utilized was the RICE (rest, ice, compression, and elevation) modality (Table 5). In spite of this commonality among all injury sites, the requirement for medical treatment was significantly different according to the site of injury ( $P = 0.029$ ). Notably, 47% of injuries to the shoulder or upper arm that required medical treatment resulted in surgery, a proportion 15.7 times higher than other injury sites (95% CI, 5.2-47.2;  $P < 0.001$ ). Shoulder and upper arm injuries were also treated with significantly more injections when compared with injuries of other sites.

## DISCUSSION

Little has been reported regarding the incidence and prevalence of injuries sustained secondary to participation in an ECP. Hak et al,<sup>6</sup> in a retrospective survey of athletes participating in a CrossFit program, calculated the incidence of injury to be 3.1 injuries per 1000 hours with a prevalence rate of 74%. Unfortunately, because of the design of this study, these results likely suffer from significant surveillance bias as the survey was distributed only on an online CrossFit forum. Furthermore, what constituted an injury was not clearly defined, and a time period during which these injuries occurred was not specified. The somewhat discordant findings of this study (a relatively low

incidence rate alongside a high prevalence) suggest a cohort of athletes with a lengthy training history who may not be representative of the general population of adults participating in ECPs for general fitness and recreation. In a more recent retrospective study, Weisenthal et al<sup>16</sup> surveyed athletes participating in a CrossFit program and estimated the prevalence of injury in the 6 months prior to the survey to be 19% and the incidence of injury to be 2.4 per 1000 hours. The findings of the current study (estimated incidence, 2.71/1000 hours; lifetime prevalence, 34%) are consistent with these studies.

In comparison with other sports and activities commonly performed recreationally by adults, the estimated rate of injury in this ECP was similar. The incidence of injury in recreational tennis players has been reported to range from 1.6 to 3.0 injuries per 1000 hours.<sup>7,10,15</sup> Triathletes sustain injuries at a rate of 2.5 to 5.4 per 1000 hours.<sup>3,8</sup> Training injuries in cyclists have been reported to occur at a rate of 6.0 per 1000 hours.<sup>14</sup> Injuries in runners and joggers, however, occur at a much higher rate, ranging from 33 to 79 injuries per 1000 hours.<sup>2,9,11,14</sup> It is important to note, however, that the estimated exercise-specific incidence of injury attributed to running in this ECP was much lower than other exercises. In comparison with weightlifting (including free weight lifting, weight machine use, strongman training, and powerlifting), the estimated rate of injury in this ECP was very similar. Injuries in weightlifting have been reported to range from 2.7 to 5.5 per 1000 hours.<sup>4,13,14,17</sup>

A significant finding of the current study is related to the particular susceptibility of the shoulder to injury in this type of training program. Fifteen percent of all athletes (38/246) reported sustaining an injury to the shoulder or upper arm, and these comprised 29% of all injuries sustained (38/132). Not only did shoulder injuries occur more frequently in the present study, they also occurred with a greater severity, with injuries to the shoulder resulting in surgical treatment 15.7 times more likely than other injuries. Second, athletes with a prior history of a shoulder or upper arm injury were 8.1 times more likely to sustain an additional shoulder or upper arm injury during ECP training than athletes without. Finally, of the 4 exercises that were found to be significantly more likely to be implicated in an injury (squat cleans, ring dips, overhead squats, and push presses), all involve a significant load being placed on the shoulder. Because of these findings, athletes, coaches, and trainers should be especially aware of their own and their athletes' functional abilities, especially of those who have suffered previous shoulder injury. It may be appropriate to substitute exercises in athletes with limited shoulder ability and instead focus on corrective exercises until full functionality is restored.

Bergeron et al<sup>1</sup> stated multiple concerns about ECPs. These included failure to adhere to "appropriate and safe training guidelines," specifically when "repeatedly performing maximal timed exercise repetitions without adequate rest intervals." As a broad category of resistance and aerobic training, the training principles, coaching, and supervision in ECPs vary widely depending on the program in question. Additionally, previous

Table 5. Injury treatment differences by body site

	% (N/Total)							P Value	% (N/Total)
	T/B/H/N	S/UA	F/E	H/W	H/G	L/K	F/A		Overall
Medical Treatment	66 (19/29)	66 (25/38)	38 (3/8)	25 (3/12)	60 (6/10)	72 (21/29)	17 (1/6)	0.029	59 (78/132)
Surgery	7 (2/29)	47 (18/38)	0 (0/8)	0 (0/12)	0 (0/10)	10 (3/29)	0 (0/6)	<0.001	17 (23/132)
Brace/cast	3 (1/29)	0 (0/38)	50 (4/8)	42 (5/12)	0 (0/10)	7 (2/29)	17 (1/6)	<0.001	10 (13/132)
Medication	28 (8/29)	53 (20/38)	38 (3/8)	17 (2/12)	20 (2/10)	24 (7/29)	0 (0/6)	0.047	32 (42/132)
Physical therapy	38 (11/29)	47 (18/38)	0 (0/8)	17 (2/12)	40 (4/10)	34 (10/29)	0 (0/6)	0.056	34 (45/132)
Injections	3 (1/29)	45 (17/38)	0 (0/8)	8 (1/12)	10 (1/10)	14 (4/29)	0 (0/6)	<0.001	18 (24/132)
RICE	83 (24/29)	76 (29/38)	75 (6/8)	92 (11/12)	70 (7/10)	69 (20/29)	83 (5/6)	0.34	77 (102/132)
Other	7 (2/29)	3 (1/38)	0 (0/8)	0 (0/12)	30 (3/10)	7 (2/29)	17 (1/6)	0.057	7 (9/132)

F/A, foot or ankle; F/E, forearm or elbow; H/G, hip or groin; H/W, hand or wrist; L/K, leg or knee; RICE, rest, ice, compression, elevation; S/UA, shoulder or upper arm; T/B/H/N, trunk, back, head, or neck.

authors have stated concerns about “insufficient recovery time” resulting in “earlier fatigue, . . . and unsafe movement execution leading to acute injury.”<sup>1</sup> Given the nature and demands of exercises commonly used in ECPs, these concerns may well be valid. Many of the exercises require exact technique to avoid injury. Athletes new to these exercises, as well as those overextending or overexerting themselves, may place themselves at risk.

Although no statistically significant differences were found in athlete-reported cause of injury, overexertion and fatigue were commonly reported. Additionally, improper technique may be a direct result of both of these causes. This is further supported by the fact that relatively more injuries were sustained when performed with weights/barbells as well as during complex Olympic-style lifts. The interrelation between these factors makes determining a single cause of injury difficult—it is unclear whether squat cleans, ring dips, overhead squats, and push presses are inherently more dangerous movements (pointing to improper technique) or that they were performed at dangerously high volumes during a workout (pointing to overexertion or fatigue). Furthermore, the results of this study show that, hour-for-hour, athletes with <6 months of ECP experience sustained more than twice as many injuries as their more experienced counterparts. Bearing all this in mind, it is

clear that athletes and coaches should pay close attention to signs of fatigue and be conscientious with regard to technique, form, and avoiding overexertion, especially as new athletes develop appropriate fitness and proper technique to safely complete the exercises in an ECP.

There are limitations to our study. First, the retrospective nature of the survey is subject to recall bias. Additionally, we relied on athletes' self-reporting of injuries, most of whom presumably do not have a medical background, so the accuracy of some responses may be in question. A major point of this study is estimating the incidence of injury in an ECP. Most importantly, exposure time was not monitored prospectively, and, therefore, incidence could not be calculated directly. As such, the true rate of injury as measured by an adequately powered study conducted prospectively may differ significantly from the current findings. An important consideration in reviewing these data is that only athletes who were currently participating in the ECP were able to complete the survey. Athletes who had been injured and dropped out of the ECP would obviously have been excluded from the study, thus the actual injury rates are likely higher than reported, especially for novice participants. The likelihood of this is quite high since inexperienced athletes sustained injury at a greater rate than their more experienced counterparts. Furthermore, athletes were

only given the opportunity to report 1 injury in each anatomic location category, which may have led to an underreporting of the true incidence of injury. Finally, because of the broad nature of ECP programming, the injury incidence estimates and prevalences presented here may not be representative of all programs that meet the definition of an ECP.

## CONCLUSION

The estimated injury rate among athletes participating in this ECP was similar to the rate of injury in weightlifting and most other recreational activities. The shoulder or upper arm was the most commonly injured area, and previous shoulder injury predisposed to new shoulder injury. New athletes are at considerable risk of injury compared with more experienced athletes.

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