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Summary

CrossFit is a form of high-intensity interval training and comparable to other high-intensity exercises. CrossFit exercises increase VO_{2max} , strength, endurance, and improves the body composition (e. g. lean body mass).

The injury risk in CrossFit is similar to that of other, comparable sports such as Olympic weightlifting, powerlifting and gymnastics and lower than that of competitive contact sports such as rugby union and rugby league. Shoulder joint, shoulder girdle and spine injuries are predominating in CrossFit and require special attention from physicians and coaches. In particular, this includes expert instruction for CrossFit beginners as well as an initial orthopedic examination before starting CrossFit training. The involvement of well-educated coaches correlates with a decreased injury rate. For this reason, it is recommended that beginners complete a special program with slow load increase and instructions of the fundamental CrossFit techniques. In CrossFit, previous injuries also increase the risk of re-injury, which is consistent with the findings of other sport-related injury studies, and should also be taken into account.

Evidence Level III

Keywords

CrossFit – Injury risk – Prevention – High-intensity interval training – Resistance training

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CrossFit® – Entwicklung, Nutzen und Risiken

Zusammenfassung

CrossFit ist eine Form des hochintensiven Intervalltrainings und mit anderen hochintensiven Trainingsformen vergleichbar. CrossFit-Übungen erhöhen die VO_{2max} , Kraftfähigkeit und Ausdauer und verbessern die Körperkonstitution (u. a. fettfreie Körpermasse).

Die Verletzungshäufigkeit beim CrossFit ähnelt der anderer, vergleichbarer

REVIEW / SPECIAL ISSUE

CrossFit® – Development, Benefits and Risks

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Background

CrossFit is a functional training modality that merges high-intensity exercises with functional multi-joint movements [9]. CrossFit is one of the fastest growing high-intensity functional training modes in the world [3]. Its popularity has grown worldwide over the past decade since its inception by Greg Glassman in 1996 in the USA with more than 15,000 affiliated gyms worldwide (Figure 1).

CrossFit has gained popularity not only among the civilian population but also among military, firefighters and police personnel, since CrossFit originally was developed among others for military strength and conditioning training and gradually spread among the civilian population [29] (Figure 2).

CrossFit was developed as a core strength and conditioning program. The objective of CrossFit is to

[®]CrossFit is a registered trademark. In terms of clarity, the repeated use of the trademark will be omitted in the following but is implicit with every mention of CrossFit.

contribute to an optimization of the general physical competence (including a wide array of adaptations to all three metabolic pathways) without specialization. One of the main features of CrossFit is that the exercises are performed quickly and repetitively while there is limited or no recovery time between the sets [34].

CrossFit – Training

CrossFit training consists of different exercises, and should enable the individual to master various physical tasks (e.g. Olympic lifts, rope climbing, traditional sports, moving large loads over long distances) and prepares for unknown tasks (e.g. surviving fights or fires). The structure of a CrossFit training may vary between different institutions. Usually each training session lasts about one hour and is comprised of a specific warm-up, strength and/or skill training, a programmed strength or conditioning workout for 10–30 minutes and finished with cool-down and/or mobility exercises [1]. In CrossFit, the training program differs depending on the athlete's individual condition, training location, intensity, duration,

Sportarten wie dem Olympischen Gewichtheben, Kraftdreikampf und Turnen und ist niedriger als in kompetitiven Kontaktsportarten wie der Rugby Union und Rugby League. Vorrangig treten beim CrossFit Verletzungen des Schultergelenkes und des Schultergürtels sowie der Wirbelsäule auf, die von Ärzten und Trainern besondere Aufmerksamkeit erfordern. Insbesondere bei CrossFit-Anfängern sind eine fachkundige Anleitung und eine orthopädischen Erstuntersuchung vor Beginn des CrossFit-Trainings dringend angeraten. Die Einbindung gut ausgebildeter Trainer korreliert mit einer verringerten Verletzungsrate. Deshalb wird das Absolvieren eines speziellen Programms für Anfänger mit langsamer Belastungssteigerung und Anleitung der grundlegenden CrossFit-Techniken für empfehlenswert gehalten. Der Tatsache, dass frühere Verletzungen das Risiko einer erneuten Verletzung erhöhen, was auch mit den Ergebnissen anderer Studien zu sportbedingten Verletzungen übereinstimmt, sollte auch im CrossFit Beachtung geschenkt werden.

Evidenzlevel Stufe III

Schlüsselwörter

CrossFit – Verletzungsrisiko – Prävention – Hochintensives Intervalltraining – Krafttraining

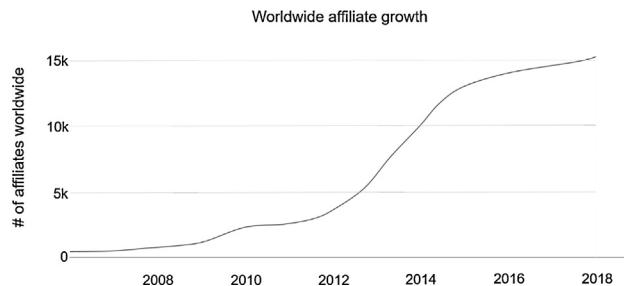


Figure 1
CrossFit – Worldwide affiliate growth until 2018.

organizational form and complexity. CrossFit training contains numerous recurring training elements and a variety of strategies for quantification and competition [24], and is characterized by short and highly intensive exercises (Table 1). The exercises are performed either for time or for maximum repetitions and can be conducted as individual, partner or group training [3]. Another format is to maintain a specific workout pace for a time frame (e.g. complete a specified number of repetitions every minute on the minute (= EMOM) [24].

CrossFit – Associations and competitions

There’s no official association since CrossFit is a branded fitness regimen created by Greg Glassman in 1996. Although there is no official set of rules, there are guidelines depending on the individual competition.

CrossFit – Coaches’ demographics

CrossFit coaches are responsible for the training and therefore also for

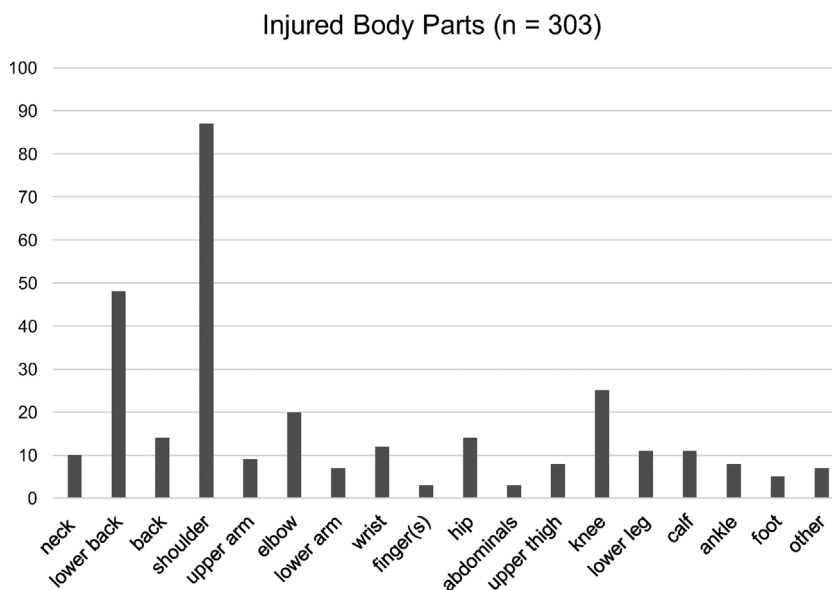


Figure 2
Number of injuries (n = 303) by body part (Mehrab, De Vos, Kraan, & Mathijssen, 2017, p.4).

the health of the participants. In a study by Waryasz, Daniels, Gil, Suric, and Ebersson (2016) a survey questionnaire with 208 participants confirmed, that 77.9% of the CrossFit coaches were male with an average age of 34.5 ± 9.1 years. From all participating CrossFit coaches 80.4% had an exercise-related bachelor's degree, 72.4% an exercise-related master's degree and over 89% a strength and conditioning certification [38].

Within another study by Waryasz, Suric, Daniels, Gil, and Ebersson (2016) asking CrossFit coaches ($n = 193$) 86.6% were certified as instructors and 26.7% had a bachelor's degree in a training-related field. Instructors with a CrossFit certification have significant fewer bachelor's ($p = 0.04$) or master's ($p < 0.001$) degrees than those without a CrossFit certification [39].

CrossFit – Health benefits

Overall, the effectiveness of CrossFit in improving physical fitness as well as health related effects is not well explored [13]. A systematic review revealed 13 studies that examined the safety and health benefits of CrossFit [26].

Some of those recent studies showed, that CrossFit training can be effective for the improvement of several physical fitness parameters as enhanced endurance, increased maximal aerobic capacity VO_{2max} , aerobic and anaerobic capacity and a positive influence on participants' body composition, strength, flexibility, power and balance, BMI, fat mass and waist circumference, not only in adults, also in adolescents ([3,4,14]).

Besides positive physical effects of CrossFit training, also effects on mood state and social aspects were examined and found. Among other

things, it has been shown that CrossFit training has a positive influence on motivational factors and the sense of community ([10,16,22,33,41]).

CrossFit – Incidence and location of CrossFit related injuries

Because of the increasing popularity of CrossFit, questions about the health benefits and risks arise from a medical point of view, especially from an orthopedic perspective ([7,14,18]).

Due to the high intensity of the CrossFit training exercises, sports physicians expect an increased incidence of injuries, especially among beginners.

Previously published studies have reported injury rates ranging from 0.74 to 3.3 per 1000 h CrossFit training ([9,15,21]). On the basis of these studies, the injury incidence in CrossFit is comparable or slightly higher to related sports, including gymnastics, weightlifting and powerlifting with a 2b evidence level [5,15,20]), but lower than in game sports and other traditional sport disciplines [35]. However, injuries to the shoulder appear to be more common in CrossFit [20].

Other researchers found a higher incidence of CrossFit related injuries compared to traditional weightlifting. Elkin, Kammerman, Kunselman, and Gallo (2019) showed that those who were following a CrossFit routine were 1.3 times more likely to be injured and 1.86 times more likely to seek medical attention than those who were following a traditional weightlifting program. In a multivariate logistic regression analysis adjusted for sex and age, an injury was 2.26 times more likely in the CrossFit group. In both groups, shoulder injuries were most common

(46.4%), followed by lower back (38.3%) and hip injuries (9.1%). The authors concluded, that CrossFit athletes are more likely to be injured and to seek medical treatment compared with athletes in traditional weightlifting [5].

Larsen et al. (2020) conducted a prospective cohort study with novice members of a CrossFit Center who began an eight-week, free-of-charge membership period. Among the 168 included participants, a total of 28 injuries (14.9%) were reported. The injury rate per 1000 h of exposure was 9.5 and therefore significantly higher than in previous studies. Therefore, the risk of injuries may be higher among novice participants than among experienced CrossFit athletes. This is consistent with further study showing a higher injury incidence in beginners during the first six months of CrossFit training ([25,27]). Therefore, a care of CrossFit beginners is particularly important, as well as an orthopedic initial examination before starting CrossFit training.

A high injury rate in CrossFit particularly affects the shoulder, spine, hip and knee [40]. In a four-year analysis of a descriptive epidemiology study, 30.5% of the CrossFit athletes experienced an injury over the previous 12 months [9]. Injuries to the shoulders were the most common (39%), followed by back (36%), knees (15%), elbows (12%), and wrists (11%) for both male and female athletes [9]. Elkin et al. (2019) also found that in CrossFit the most injuries concerned the shoulder (46.4%), followed by the lower back (38.4%) and hip (9.1%). Summitt, Cotton, Kays, and Slaven (2016) demonstrated an overall shoulder injury rate of 1.94 per 1000 h training. First-time shoulder injuries occurred at a rate of 1.18 per 1000 h training, and therefore less frequent than recurrent injuries. The

Table 1. Categorization of superordinated CrossFit elements/disciplines with representative exercises. The listed exercises can be combined in many ways. Not shown is the category ‘Mobilization’.

Exercise Categories	Exercise	Übung
Olympic Weightlifting	Clean and Jerk	Umsetzen und Stoßen
	Snatch	Reißen
Powerlifting	Squat	Kniebeuge
	Bench Press	Bankdrücken
	Deadlift	Kreuzheben
Calisthenics (Eigengewichtsübungen, u.a. turnerisch, akrobatisch)	Push-up	Liegestütz
	Pull-up	Klimmzug
	Squat	Kniebeuge
	Dip	Barrenstütz
	Sit-up	Rumpfaufrichten
	New creations e.g.: Human flag	Neuschöpfungen z.B.: Menschliche Flagge (quer an vertikaler Stange fixieren und Körper in die Horizontale bringen)
Plyometrics	Box jump	Kastensprung
	Lateral jump	Lateral Sprung
	Squat jump	Sprung aus der (halben) Kniebeuge
	Jumping lunge	Sprung aus dem Ausfallschritt in den Ausfallschritt
	Standing broad jump	Standweitsprung
Gymnastics	Handstand push-up	Liegestütz im Handstand
	Handstand walk	Handstandlauf
	Muscle up (rings, bar)	Zugstemme (Ringe, Stange)
	Pistol	Einbeinige Kniebeuge
	Pull-up	Klimmzug
	Chest-to-bar	Klimmzug bis zum Brustkorb
	Butterfly/Kipping Pull-up	Klimmzugvarianten (Schwungelemente)
	Dip	Barrenstütz
	L-Sit	Barrensitz
	Rope jump	Seilsprung
Sprint	High intensity running (Ergometer)	Hochintensives Laufen
	High intensity rowing (Ergometer)	Hochintensives Rudern
	High intensity (air) biking (Ergometer)	Hochintensives Radfahren (Fahrradergometer)
	High intensity skiing (Ergometer)	Ski-Ergometer
Metabolic conditioning	Cardio-training–Alternation of aerobic and anaerobic load to avoid (too) specific adaptations to CrossFit (Strength)	Herz-Kreislauftraining – Wechsel von aerober und anaerober Belastung zur Vermeidung (zu) spezifischer Adaptationen an CrossFit (Kraft)
Uncategorized	Rope climbing	Seilklettern
	Burpee	Liegestütze und Sprünge im Wechsel (‘Liegestützsprung’)

most frequent causes for shoulder injuries were improper technique and exacerbation of a previous injury [35] (Table 2).

CrossFit – Rare injuries and diseases

In addition to typical and frequent injuries, the scientific literature also

reports on less frequent injuries and diseases, although these are significant in individual cases (Table 3).

CrossFit – injuries of the spine with neurological symptoms

Injuries of the spine and a ‘Numb-Leg’ in a CrossFit athlete were reported from Esser, Thurston, Nalluri, and

Muzaurieta (2017) [8]. The impact of CrossFit-related injuries was examined by Hopkins et al. (2017). Between June 2010 and June 2016, they evaluated all cases of spine injuries complaining of an injury caused by performing CrossFit. However, it must be noted that in this study the data were collected in only one hospital with neurological specialization (Northwestern University,

Table 2. Injury rate comparison to other sports (Summitt, Cotton, Kays, & Slaven, 2016, p. 542).

Sport/Activity	Study	Injury rate (per 1000 hours)
Elite weightlifting	Raske and Norlin, 2002	0.42-0.53 (shoulders only)
Swimming	Parkkari et al., 2004	1
Walking	Parkkari et al., 2004	1.2
Cycling	Parkkari et al., 2004	2
CrossFit	Giodano and Weisenthal, 2014	2.4
	Hak et al., 2013	3.1
Triathlon (preseason)	Burns et al., 2003	2.5
Running (long distance)	van Gent et al., 2007	2.5
Elite weightlifting	Raske and Norlin, 2002	2.6-3.3
	Calhoon and Fry, 1999	
Gym training	Parkkari et al., 2004	3.1
Gymnastics	Parkkari et al., 2004	3.1
Running (overall)	Parkkari et al., 2004	3.6
Triathlon (competitive season)	Burns et al., 2003	4.6
Tennis	Parkkari et al., 2004	4.7
Women's soccer (practice)	Hootman et al., 2007	5.2
Soccer	Parkkari et al., 2004	7.8
Basketball	Parkkari et al., 2004	9.1
Men's spring football (practice)	Hootman et al., 2007	9.6

Chicago, Illinois) and therefore are not representative for the epidemiology of all CrossFit injuries. Data were collected including age, sex, body mass index (BMI), CrossFit experience level, symptom duration, type of symptoms, type of clinic presentation (emergency department, outpatient), cause of injury, objective neurological examination findings, imaging type, number of clinic visits, and treatments prescribed [18] (Table 4).

The most common injury types were spinal injuries, accounting for 20.9% of all reported injuries. Of these spinal injuries, the lumbar region was the most commonly injured reporting 83.1% of all spine injuries. Although the most commonly prescribed treatment modality was physical therapy (40.4%), surgery was required in six patients (6.7%), and is comparable to other high-intensity

competitive weightlifters as described in previous and actual studies ([2,30,36,37]).

CrossFit – Rhabdomyolysis

Hopkins, Li, Svet, Kesavabhotla, and Dahdaleh (2019) examined 523 patients incurred injuries associated with CrossFit activities [19]. They reported, that 11 patients received a diagnosis of rhabdomyolysis. The average age was 34.9 ± 9.4 years, with 81.9% of the patients being male and 54.5% of the patients being beginners. Routman, Triplet, Kurowicki, and Singh (2018) reported in two cases about isolated rhabdomyolysis of the infraspinatus muscle. As reported, all cases of rhabdomyolysis are attributed to inappropriate training planning and too high intensity [31].

CrossFit – Dissection of the cervical carotid artery

Three cases of dissection of the cervical internal carotid artery were reported that are associated with CrossFit workouts [23]. Patient 1 suffered a distal cervical internal carotid artery (ICA) dissection near

Table 3. Primary causes of injury (Summitt, Cotton, Kays, & Slaven, 2016, p. 545).

Movement	Injury, n ^a
Push-up	3
Handstand push-up	1
Handstand walk	2
Kipping pull-up	5
Butterfly pull-up	2
Toes-to-bar	2
Knees-to-elbow	1
Ring muscle-up	4
Bar muscle-up	2
Ring dips	2
Total, gymnastics	25
Bench press	3
Snatch (any variation: power, squat, dumbbell, push-jerk, split-jerk, etc)	10
Overhead press (any variation: strict press, push-press, push-jerk, split-jerk, etc)	13
Total, weightlifting	26
Unknown origin	14

^aParticipants could choose more than one option for each injury.

Table 4. Distribution of CrossFit-related Injuries (Hopkins et al., 2017, p. 2).

	Count (%)
<i>Overall injury type (n = 523)</i>	
Musculoskeletal	426 (81.5)
Cardiopulmonary complaints	36 (6.9)
Other neurologic complaints*	32 (6.1)
Other injuries/conditions ^a	29 (5.5)
<i>Musculoskeletal injury type (n = 426)</i>	
Spine	89 (20.9)
Shoulder	78 (18.3)
Knee	66 (15.5)
Gluteal region	27 (6.3)
Elbow	24 (5.6)
Leg	24 (5.6)
Wrist	18 (4.2)
Ankle	16 (3.8)
Foot	15 (3.5)
Hand	12 (2.8)
Other musculoskeletal ^b	38 (8.9)

*Headaches, migraines, weakness, paresthesia.

^aRhabdomyolysis, ocular dysfunction, abdominal pain, pulmonary symptoms, scrotal inflammation, proteinuria, dehydration.

^bGroin, fingers, arm, musculoskeletal chest pain.

the skull base and a small infarct in Wernicke's area. Patient 2 suffered a proximal cervical ICA dissection that led to arterial occlusion and recurrent middle cerebral artery territory infarcts and significant neurological sequelae. Patient 3 had a skull base ICA dissection that led to a partial Horner's syndrome but no cerebral infarct. It is discussed that CrossFit's emphasis on speed and high-intensity movements and lack of proper guidance on technique may be one of the main reasons for injuries. Specific exercises, such as those that require rapid twisting movements involving weights, may be particularly dangerous, as they may lead to cervical vascular dissection [23]. reported in a case study a bilateral traumatic internal carotid artery dissection after CrossFit training [11], although committing that these cases are rare (2.5 to 3 per 100.000 athletes) [32].

CrossFit – Females and incontinence

CrossFit training and competitions are performed at high intensity, with high biomechanical impacts on the skeletal system and often with pressurized breathing. Therefore the exercises increase intra-abdominal pressure and cause (involuntary) urinary incontinence (UI), especially in women.

In a population-based internet study of 551 female CrossFit athletes a prevalence of UI of 29.95% was shown. Most women with UI reported loss of urine during at least one exercise (16.70%). Double under, single under and box jumps are the most frequently mentioned exercises that lead to UI [28].

High, Thai, Virani, Kuehl, and Danford (2019) interviewed 314 women through an anonymous questionnaire in CrossFit centers. The

prevalence of UI was 26.1%, which is only slightly above the prevalence in the general female population [17].

Elks, Jaramillo-Huff, Barnes, Petersen, and Komesu (2020) found a much higher incidence of UI among 322 women surveyed. They compared the incidence of UI between participants in CrossFit classes with female participants of other fitness classes. CrossFit athletes more frequently reported UI (84% vs 48%, $p < 0.001$), and higher severity of UI (Urinary Distress Inventory score: 20.8 vs 12.5, $p < 0.001$).

Weightlifting, jumping movements (single and double unders) and box-jumps with high intra-abdominal pressure were the most common exercises and reasons associated with UI in CrossFit athletes; also age and participation in CrossFit are significant and independent predictors of UI as number of vaginal deliveries ([6,12]).

Future directions and implications

According to previously mentioned studies, the sub-disciplines, gymnastics, powerlifting and Olympic weightlifting, were detected as primary cause for the most prevalent injury locations in CrossFit, the shoulder joint, shoulder girdle, spine, hip and knees ([27,35,40]). The shoulder and lower back were the most commonly injured in gymnastic and powerlifting movements, respectively; primarily acute and fairly mild injuries [40]. Due to the frequency of injuries shoulder and spine must be given special attention. This concerns both sports medical preliminary examination/preventive screening by sports physicians familiarized with CrossFit injury profiles and the adaptation

of training exercises to the athlete's health and physical condition by CrossFit coaches. To prevent injuries, the scope and intensity of the exercises in the CrossFit must be increased slowly, scalable and carefully. At this point the injury reducing influence of supervision by qualified coaches becomes apparent [40]; especially among novice participants who seem more prone to injury than experienced participants [21]. Also, this includes the adequate exercise selection for females with urinary incontinence problems which are more likely to occur in CrossFit [6].

Due to the worldwide growth of CrossFit participation since 2008 and a limited amount of empirical research/evidence of injury rates and mechanisms there might be an increased risk of injury for CrossFit participants [20].

Most of the available research on injury rates is based on cumulative retrospective cohort studies [35] or single case-studies on (severe) injuries without proven direct causality to CrossFit [3]. For this reason, we recommend that more prospective studies should be conducted to provide a differentiated survey of CrossFit associated acute and/or chronic injuries and to allow the identification of potential risks.

Checkbox

As a conclusion, athletes who are willing to train CrossFit are advised to

- check their suitability in a preliminary examination by sports physicians based on their current physical condition and medical background.
- participate in an affiliated gym's on-ramp program (= introduction class) before starting CrossFit

- training (getting used to techniques/movements and intensity).
- train in an affiliated gym under supervision of qualified trainers.
- increase the scope and intensity slowly and carefully in accordance with the trainer.

Important note

On June 6, 2020, CrossFit's CEO and founder, Greg Glassman, commented on the murder of African-American George Floyd by police officers with a racist, mocking statement. In connection with the current coronavirus pandemic and the public health situation, he described the issue as "FLOYD-19" [43]. CrossFit's main sponsor, Reebok, announced that it was terminating its collaboration with the CrossFit Company and its representative, Greg Glassman.

Meanwhile, hundreds of fitness studios around the world have distanced themselves from Greg Glassman and his statements [42]. As a result of the fierce criticism, Greg Glassman has resigned as CEO of the CrossFit Company.

In this context, we would like to emphasize that at the time of writing this article, we were not aware of these incidents, and we dissociate ourselves from racist statements of any kind.

Conflict of interest

There is no conflict of interest.

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