

From Sweat to Strain: An Epidemiological Analysis of Training-Related Injuries in CrossFit®

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Purpose: This study aims to conduct an epidemiological investigation into the types and causes of injuries during CrossFit® training in Germany.

Patients and Methods: Voluntary athletes from various German CrossFit® gyms participated, providing personal information, training habits, and details on injuries through a standardized questionnaire.

Results: The study involved 308 participants, with an equal sex split, a peak age of 20–40, and a BMI of $24.3 \pm 3.3 \text{ kg/m}^2$. Most participants trained for over two years (49.4%), primarily in supervised groups. Motivations for engaging in CrossFit® included health prevention (33.1%), athletic training (32.8%), and work-life balance support (17%). Injuries were reported by 28.6% of participants, with 61.4% experiencing single injuries. The majority of injuries (55.3%) occurred during the middle of workouts. Injury types included wounds (23.3%), contusions, sprains, or strains (cumulative 30.8%), and fractures (2.9%). Almost all injured individuals (96.5%) had a time-loss injury, with a return to sport ranging from a day to over three months. Treatments varied, with 50.6% not requiring medical intervention, 34.1% undergoing physiotherapy, 21.2% receiving medication and 8.2% needing surgery. Barbell exercises, notably Snatch and Clean, were main exercises with association to injuries, accounting for 36.3%. The Box Jump stood out as the exercise with the highest isolated injury prevalence (14.3%). Notable injury causes included falls during Pull-Ups and lumbar disc herniation linked to Deadlifts. Following injuries, 45.8% of participants made training adjustments.

Conclusion: This study provides an epidemiological investigation into the types and causes of injuries during CrossFit® training in Germany. The shoulder and knee joint exhibited the highest injury prevalence. Barbell exercises, box jumps, and bar pull-ups were identified as major exercises with association to injuries. Prevention through technical training and the incorporation of soft boxes could reduce the risk of injuries in CrossFit®.

Plain language summary: This study looks at the types and causes of injuries during CrossFit® training in Germany. A total of 308 CrossFit® athletes took part, with an equal number of men and women, mostly aged 20–40, and an average BMI of $24.3 \pm 3.3 \text{ kg/m}^2$. Most had trained for over two years, often in supervised groups, and were motivated by health, fitness, and balancing work and life.

About 28.6% of participants reported injuries, mostly single injuries happening in the middle of workouts. The types of injuries included cuts, bruises, sprains, strains, and fractures, with the shoulder and knee being the most commonly affected areas. Notably, exercises involving barbells like the Snatch and Clean caused a significant number (36.3%) of injuries, followed by Box Jumps (14.3%) and bar pull-ups. Causes of injuries included falls during pull-ups and back injuries from Deadlifts.

After getting injured, nearly half of the participants changed their training routines. Treatments varied, with some not needing medical help and others undergoing physiotherapy, taking medication, or having surgery.

The findings suggest that focusing on proper technique and using softer equipment, like softer landing surfaces for Box Jumps, could help reduce the risk of injuries in CrossFit® training.

Keywords: fitness, weightlifting, bodyweight, barbell, sport injury, gymnastics

Introduction

CrossFit® is a fitness movement established by former American fitness trainer Greg Glassman in 1980. In his 2002 article titled “What Is Fitness” Glassman defined fitness based on performance in three categories.¹ He asserted that fitness involves proficiency in major physical domains, in the optimal execution of any conceivable athletic task and the optimal functioning of the physiological pathways for energy production. The CrossFit® training program includes exercises for endurance, elements of Olympic weightlifting, and bodyweight exercises.²

To attain the highest level of fitness, the CrossFit® training program incorporates constantly varied functional training exercises performed with high intensity, with the “Workout of The Day” (WOD) serving as the focal point of each session. In the WOD, athletes strive to either complete the maximum number of repetitions of exercises within a specified time limit or achieve a set number of repetitions in the shortest possible time. This methodology facilitates athlete comparisons and underscores CrossFit® as a competitive sport.

Since its establishment, CrossFit® has been experiencing continuous global popularity, including a growing presence in Germany. As of 2018, there were 300 registered CrossFit® training facilities in Germany, commonly referred to as “boxes”.³ Globally, the official CrossFit® website (www.crossfit.com/map) indicates the existence of over 13,000 gyms.

Despite the increasing interest in the CrossFit® fitness movement, there is a scarcity of comprehensive studies on CrossFit® itself and the injuries associated with it, with very few epidemiological studies relating to German CrossFit® athletes available.⁴ While it is acknowledged that CrossFit® exhibits lower injury rates than contact sports such as football or basketball as well as comparable injury rates to other weight-training sports, disciplines with shared elements, such as weightlifting, bodybuilding, or gymnastics, have been more extensively researched.^{5–9}

This study aims to conduct an epidemiological investigation into the types and causes of injuries during CrossFit® training in Germany.

Material and Methods

Study Design

In this retrospective cohort analysis injuries and their circumstances in athletes participating in CrossFit in Germany were investigated. The study period was from December 2018 to December 2019. The participants in this study were voluntary athletes engaged in training across various CrossFit® gyms in Germany. The study included both recreational and competitive athletes. Recruitment of participants was facilitated by distributing flyers in the respective CrossFit® boxes, informing athletes about the study. All athletes could participate without inclusion or exclusion criteria. No participant withdrew from the study. Data collection was performed through a German online standardized questionnaire utilizing the “SoSci Survey” platform (<https://www.soscisurvey.de>). All participants provided informed consent, in accordance with the Declaration of Helsinki.

Data Collection

The questionnaire, written in German, encompassed personal details such as sex, age, height, and weight. It also captured information on participants’ training habits, experience, the use of training aids, and any additional sports they engaged in, along with their prior experience in fitness or strength training. Following this, retrospective inquiries were made concerning injuries sustained during CrossFit® training. An injury was defined as damage resulting from an accident during training that hindered the athlete from participating in training or competitions for at least twenty-four hours.

The questions delved into the type and location of the injury, the respective cause, and the timing of the injury during training. Information regarding injury treatment and any subsequent modifications to training habits was also collected. Athletes who provided their Email addresses in the questionnaire received monthly follow-up emails over the subsequent twelve months, during which new injuries were queried. The data was assessed by the authors.

Statistical Analysis

Sample size estimation was done by modeling the sample size on similar studies, which included approximately >100 participants.⁹ Therefore, the group size of 308 participants that were included was considered sufficient to conduct an

epidemiological study with a focus on descriptive statistics. Responses from both the retrospective and follow-up questionnaires were initially recorded, categorized, and pseudonymized using Microsoft Excel Version 2406 (Microsoft Corporation, Redmond, WA, USA). Subsequently, a descriptive statistical analysis was conducted using SPSS Statistics Version 25 (SPSS Inc., IBM, Chicago, IL, USA). The *t*-test was applied to test for significant changes in injury frequency between male and female athletes or between groups of different duration of CrossFit® training.

Results

Participant Demographics

A total of 308 athletes were included in the study (Table 1). Men and women participated in the study in nearly equal proportions. Hereby, 146 males (47.4%), 160 females (51.9%), and two participants with unspecified sex (0.6%) participated in the study. The age distribution of the participants peaked between 20 and 40 years. With a BMI of $24.3 \pm 3.3 \text{ kg/m}^2$, participants were classified as having a normal weight. Nearly half of the participants had been engaged in training for more than two years at the time of the survey, while only 7.8% had trained for less than 6 months. The majority of respondents trained for more than two hours per week in a supervised group setting. Additionally, 27.9% of the respondents had participated in CrossFit® competitions.

Table 1 Participant Demographics

Characteristic	Item	Cases (N)	Percentage (%)
Participants	N	308	100.0
Age	<18 years	1	0.3
	18–20 years	5	1.6
	21–25 years	54	17.4
	26–30 years	81	26.3
	31–35 years	80	26.0
	36–40 years	43	14.0
	41–45 years	17	5.5
	46–50 years	14	4.5
	51–55 years	3	1.0
	56–60 years	9	2.9
>60 years	1	0.3	
Duration of Participation in CrossFit®-training	< 6 months	24	7.8
	6–12 months	46	14.9
	12–24 months	86	27.9
	>24 months	151	49.0
	Not specified	1	0.3
CrossFit®-training time	1 hour / week	5	1.6
	1–2 hours / week	38	12.3
	2–3 hours / week	88	28.6
	> 3 hours / week	177	58.0
Group size in regular training	Alone	23	7.5
	With partner	24	7.8
	Group	261	84.7
Supervisor	No supervision	19	6.2
	Training Partner	18	5.8
	Trainer	269	87.3
Participation in competitions	Yes	86	27.9

Approximately one-third of the participants reported participating in the sport for health issue prevention, while another third practiced it for athletic training in a different sport (Figure 1).

The majority of athletes use chalk to enhance their grip, with only 37% of participants using tape (Figure 2). Thirty-one percent of athletes use protectors, 22% employ a weightlifting belt, and 19% utilize lifting straps or gloves. Joint bandages are used by only 15% of participants.

Sixty-five percent of the surveyed athletes also participate in another sport (Figure 3). Running is the most popular secondary sport, with 57% of the respondents engaging in it.

Types of Injuries

28.6% of surveyed athletes participating in CrossFit® reported experiencing injuries during their training. The distribution of these injuries revealed that 61.4% of individuals had encountered a single injury, while 25% experienced two injuries, and an additional 6.8% had three or more injuries. In total, 85 participants out of the 308 surveyed incurred

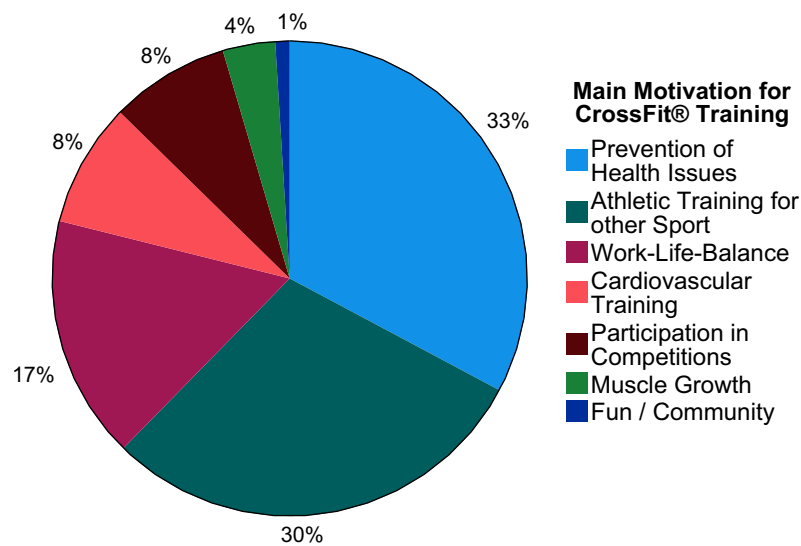


Figure 1 Main Motivation for CrossFit® Training.

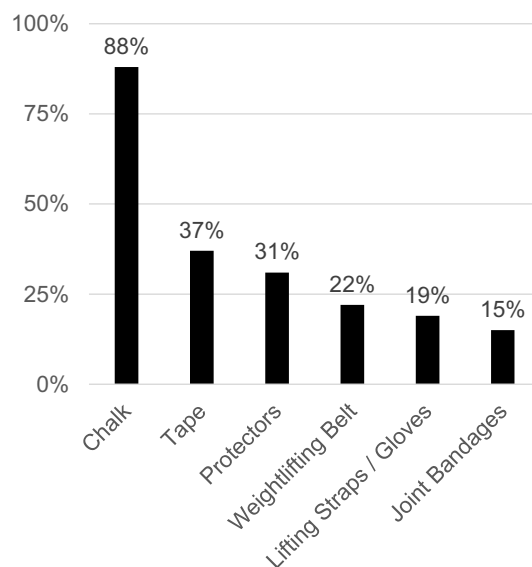


Figure 2 Gear used for CrossFit® Training.

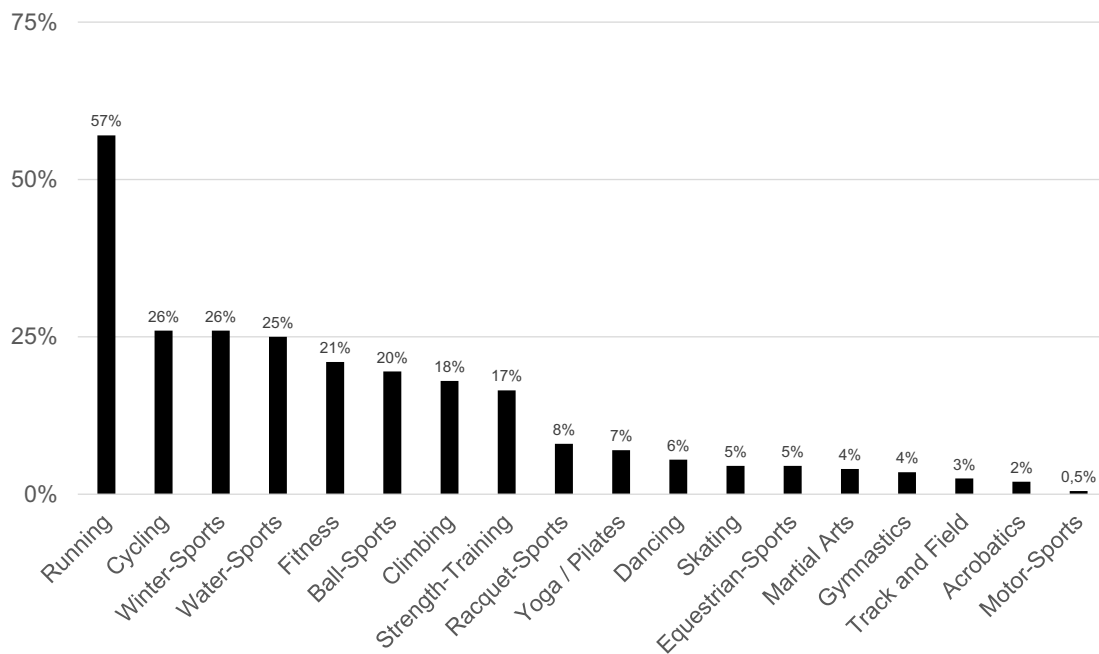


Figure 3 Sports performed additionally to CrossFit® Training. Numbers are given as percentages of participants, who perform a sport additionally to CrossFit® (65% of participants).

injuries, resulting in a cumulative occurrence of 172 injuries. There was no significant difference in injury frequency between male and female athletes or between groups of different duration of CrossFit® training.

The timing of injuries varied, with 55.3% occurring in the middle of the Workout of the Day (WOD), 12.9% at the beginning and 8.2% during the last exercise of the WOD. 23.5% of injuries occurred during individual exercises without time pressure.

Almost all injured individuals (96.5%) had a time-loss injury, with the duration of rest ranging from one day to more than three months. Specifically, 45.9% paused for one day to one week, 24.7% for one week to one month, 18.8% for one to three months, and 7.1% for more than three months.

In terms of injury types, 23.3% were classified as wounds, with 20 wounds exclusively located on the lower leg (Table 2). Additionally, 30.8% were classified as contusions, sprains, or strains. 2.9% of the injuries were fractures.

Combination injuries were primarily observed in the shoulder and knee, with 15 complex shoulder injuries and 7 complex knee injuries reported.

Table 2 Regions of Injuries

Body region	Injury	Cases (N=172)	Percentage of participants (% of 308)
Head	Contusion	2	0.6
	Tooth Injury	2	0.6
	Comotio Cerebri	1	0.3
Spine / Pelvis	Lumbalgia	9	2.9
	Contusion	8	2.6
	Cervical Spine Sprain	4	1.3
	Lumbar sciatica	2	0.6
	Cervical Disc Prolapse	1	0.3
	Lumbar Disc Prolapse	1	0.3

(Continued)

Table 2 (Continued).

Body region	Injury	Cases (N=172)	Percentage of participants (% of 308)
Shoulder	Sprain	10	3.2
	Wound	7	2.3
	Rotator Cuff Lesion	5	1.6
	Anterior Labrum Tear	4	1.3
	Cartilage Damage	3	1.0
	Shoulder Dislocation	2	0.6
	Posterior Labrum Tear	1	0.3
Upper Arm	Biceps Tendon Tear	4	1.3
	Strain	3	1.0
	Muscle Fiber Tear	2	0.6
Elbow	Wound	3	1.0
	Epicondylitis Ulnaris Humeri	2	0.6
Lower Arm	Strain	2	0.6
Wrist	Sprain	6	1.9
	Ligament Tear	2	0.6
	Fracture	1	0.3
Hand	Wound	7	2.3
	Scaphoid Fracture	1	0.3
Finger	Capsule Injury	7	2.3
Groin	Strain	3	1.0
Upper Leg	Strain	6	1.9
	Muscle Fiber Tear	4	1.3
Knee	Meniscus Lesion	4	1.3
	Wound	3	1.0
	Cartilage Lesion	2	0.6
	Sprain	2	0.6
	Patella Luxation	1	0.3
Lower Leg	Wound	20	6.5
	Strain	3	1.0
Ankle	Ligament Injury	11	3.6
	Fracture	2	0.6
	Cartilage Lesion	1	0.3
Achilles Tendon	Rupture	1	0.3
Foot	Sprain	4	1.3
	Tendon Rupture	2	0.6
	Fracture	1	0.3

Notably, 50.6% of the injured individuals did not require medical treatment, 34.1% underwent physiotherapy, 21.2% received medication and 8.2% needed surgical intervention. Surgical interventions were performed on seven individuals, addressing three lower leg wounds, a scaphoid fracture as well as a complex knee injury with the individual injuries patella luxation, cartilage lesion, inner and outer meniscus lesion. Furthermore, two complex shoulder injuries were

addressed operatively, with one athlete having injured the rotator cuff, the anterior and posterior labrum and the cartilage and another person having sustained a shoulder dislocation with an anterior labrum tear and a cartilage lesion.

Exercises Causing Injury

In total, 146 movements were identified as contributing to all recorded injuries (Table 3). Notably, Barbell exercises, particularly the more challenging ones such as Snatch and Clean, emerged as the primary culprits. Barbell Exercises accounted for 36.3% of all injuries, with 53 incidents associated with them. The Box Jump stood out as the exercise with the highest isolated injury susceptibility (14.3%), responsible for all 20 lower leg wounds and one complex foot injury. Additionally, the Bar Pull-Up demonstrated a heightened vulnerability to injuries, especially hand injuries and falls (8.2%). The combination of Conditioning and running represented another prominent source of injuries, contributing to a total of 25 injuries (17.1%).

Table 3 Injury Causing Exercises

Cluster of movement	Exercise	Cause of Injury (N=146)	Percentage of injury causing exercises (% of 146)
Barbell	Snatch	13	8.9
	Clean	12	8.2
	Deadlift	7	4.8
	Squat	7	4.8
	Jerk	5	3.4
	(Push) Press	4	2.7
	Clean and Jerk	3	2.1
	Bench Press	2	1.4
	Total	53	36.3
Body weight	Box Jump	21	14.4
	Burpee	5	3.4
	Push-Up	2	1.4
	Lunges	2	1.4
	Rope Jump	2	1.4
	Total	32	21.9
Bar	Bar Pull-Up	12	8.2
	Bar Muscle-Up	2	1.4
	Toes to Bar	2	1.4
	Bar Knee Raises	1	0.7
	Chest to Bar	1	0.7
	Total	18	12.3
Conditioning	Total	15	10.3
Running	Total	10	6.8
Handstand	Handstand Push-Up	4	2.7
	Handstand Walk	2	1.4
	Wall Climb	1	0.7
	Total	7	4.8
Rope Climb	Total	6	4.1
Rings	Ring Muscle-up	2	1.4
	Ring Dips	1	0.7
	Total	3	2.1
Kettlebell Swing	Total	2	1.4

In terms of specific injury causes, a fall during Pull-Ups was identified as the primary factor for *Comotio cerebri*. Lumbar disc herniation occurred during the execution of a Deadlift, while the cervical prolapse lacked a clear attribution. Shoulder injuries were documented predominantly during Handstands, Overhead Pressing, and activities on the bar (Pull-Ups and Muscle-Ups). Biceps tendon ruptures occurred during Muscle-Ups, Pull-Ups, Snatching, and Overhead Squatting. The occurrence of a wrist fracture was documented after a Clean, while wrist ligament injuries were reported after both the Clean and Rope Climb. Hand injuries, characterized as burn injuries, consistently arose during Rope Climbing or due to an incorrect grip on the bar. Finger capsule injuries were observed during ground exercises, Handstand Walks, Pull-Ups, Rope Climbing, and Barbell Exercises. Knee injuries were reported after Barbell Exercises and Conditioning.

Specifically, injuries to the lower leg, particularly wounds, were exclusively linked to slipping during Box Jumps. Ankle- and foot injuries were evident following Box Jumps, Rope Climbing, conditioning workouts, and Barbell exercises.

Changes Made After Injury

Following injuries, changes in training were reported by 39 individuals (45.8%). The adjustments made included a reduction in weight for two individuals (14.1%), a decrease in the number of repetitions for seven individuals (12.7%), discontinuation of exercises when experiencing discomfort for 15 individuals (17.6%), training only under supervision for six individuals (7.1%), modification of exercises for ten individuals, and an increased focus on warm-up and stretching routines for six individuals. Additionally, two athletes mentioned regularly taking pain medication after their injuries.

Discussion

This study provides an epidemiological investigation into the types and causes of injuries during CrossFit® training in Germany. Among the 308 study participants, 85 individuals (28%) experienced injuries, leading to a total of 172 occurrences. The shoulder and knee joint exhibited the highest susceptibility to injuries. Barbell exercises, box jumps, and bar pull-ups were identified as the primary contributors to most injuries.

In comparison to other studies reporting prevalences ranging from 12.8% to 73.5%, our findings align with the existing data available in the literature.^{10–14} In comparison to other recreational sports such as football or basketball, the injury rate was shown to be lower.⁸

The shoulder and knee were identified as the primary locations for the highest number of injuries, as well as for combination injuries. Similar findings regarding elevated injury rates in the shoulder and knee have been reported by other research groups.^{8,10–12,15–19} Nevertheless, Alekseyev et al, who investigated a group of 885 participants, observed that the most common injuries were related to the back and shoulder.¹⁹ The variation in these findings may be attributed to the fact that, in the aforementioned study, CrossFit® is not exclusively practiced within CrossFit® Affiliate gyms. In gyms where CrossFit® exercises are taught but the training does not strictly adhere to CrossFit® guidelines, powerlifting may be more frequently integrated into the regimen. This difference is also noteworthy in terms of the distribution of the most common injuries; our cohort primarily experienced injuries during complex barbell exercises such as snatch and clean, while the cohort studied by Alekseyev et al incurred injuries during the squat and deadlift. Feito et al could also show, that training at an official CrossFit® affiliate appeared to have a protective effect from injury.²⁰

Shoulder injuries, along with biceps tendon ruptures, were predominantly associated with complex exercises such as handstands, overhead pressing, and activities on the bar. This pattern aligns with the findings of a study by Weisenthal et al, which involved 486 individuals in a prospective study.²¹ The occurrence of these injuries may be attributed to inadequately trained shoulders combined with the complexity of the exercises. This explanation is further supported by numerous studies, including one by Mehrab et al, which comprised 449 athletes, indicating that individuals with less experience in CrossFit® tend to sustain injuries more frequently than those with a longer history of practicing the sport.^{10,18,20} Notably, athletes engaged in competitions, indicative of higher training volumes, exhibited lower susceptibility to injuries.

While barbell exercises often led to complex injuries, the Box Jump emerged as the exercise with the highest isolated injury susceptibility (14.3%), accountable for all 20 lower leg wounds and one complex foot injury. This heightened risk is attributed to the frequent inclusion of Box Jumps in the Workout of the Day and the relatively straightforward execution of the exercise. Consequently, participants may prioritize speed over proper form, potentially compromising correct execution. Furthermore, fatigue during the course of the workout leads to a reduced maximal jump height. The common use of wooden boxes in most gyms exacerbates the risk, as insufficient jumping distance can result in injury to the anterior lower leg. The findings of this study suggest that the acquisition of foam boxes by CrossFit® facilities could be a judicious investment to mitigate the risk of injuries.

The elevated occurrence of injuries during Box Jumps is also reflected in the temporal distribution of injuries, with the majority occurring in the middle of the workout (55.3%). The second-highest peak was observed during individual exercises (23.5%), which typically involve heavy barbell workouts or intricate exercises on the bar, such as muscle-ups, carrying a high susceptibility to hand injuries and falls.

Among the 85 individuals with injuries, seven persons (8.2%) required surgical intervention. This aligns closely with the findings of a review by Rodriguez et al, which synthesized 25 studies and reported that 8.7% of participants necessitated surgery for CrossFit®-related injuries.¹⁶ Since three athletes had to be operated on due to a lower leg wound sustained from box jumping, the operation rate could be lowered to 4.7% if foam boxes were used.

In summary, 28% of monitored athletes sustained an injury in CrossFit®. The highest risk of injury is associated with barbell exercises, box jumps, and bar pull-ups. Therefore, injury prevention, especially for injuries that may require surgery, should primarily focus on technical and strength training, as well as the acquisition of soft boxes. Furthermore, training at an official CrossFit® box, high quality of coaching and other protection gear such as grips could lower risk of injury.

This study has limitations due to its study design. Due to the retrospective survey design, only athletes expressing interest were included in the study. This methodology might have led to potential over-reporting, as participants could have enrolled with the intention of documenting their injuries. Furthermore, the accuracy of the reported information could not be verified. The study design also precluded the precise allocation of injuries to specific points in the participants' athletic careers, preventing the calculation of incidences and the correlation of injuries with age or training status. The general categorization of injuries and associated movements additionally hindered the retrospective investigation of the exact causes of each injury.

Further investigation is needed to identify the specific factors contributing to the observed injuries. This could involve a detailed analysis of potential factors such as biomechanical forces, environmental conditions, or individual physiological differences.

Nevertheless, the primary objective of the study was to empirically document types and causes of injuries in CrossFit within a cohort of athletes in Germany, a goal that was successfully achieved.

Conclusion

This study provides an epidemiological investigation into types and causes of injuries of CrossFit® training in Germany. The shoulder and knee joint exhibited the highest susceptibility to injuries. Barbell exercises, box jumps, and bar pull-ups were identified as the primary contributors to most injuries. The authors conclude that prevention through technical training and the incorporation of soft boxes could significantly reduce the risk of injuries in CrossFit®.

Abbreviations

WOD, Workout of the Day.

Ethics Statement

The study protocol was approved by the Ethical Reviewer Board of the Medical University of Wuerzburg (ID7/20-me).

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Disclosure

The authors report no conflicts of interest in this work.

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