American Journal of
Health, Medicine and Nursing Practice
(AJHMN)

A Review of the Epidemiology of CrossFit-Related Injuries

Shaffick M. B

American Journal of Health, Medicine and Nursing Practice
ISSN 2520-4017 (Online)
Vol.8, Issue 3, pp 33 – 53, 2023

www.ajpojournals.org

A Review of the Epidemiology of CrossFit-Related Injuries

Shaffick M. B[1*]

[1]Ms.C Performance Coaching

*Corresponding Author's Email: stardust.co13@gmail.com

Article history

Submitted 15.04.2023 Revised Version Received 29.04.2023 Accepted 18.05.2023

Abstract

Purpose: This study aims to analyze the epidemiology of injury in CrossFit participants using a systematic review format.

Methodology: In total, 12 studies were selected for review. The Electronic Databases which were searched include; Google Scholar, Human Kinetics Journal, NCBI Journal of Sport Science, PUBMed and the SAGE Journals. The methodological quality of each study was assessed using the STROBE Criteria recommendations. Data was also collected by searching the NSCA Journal of Strength and Sport Conditioning Research databases. Reviewed items were selected using the PRISMA recommendations for systematic review. The inclusion and exclusion followed PICO recommendations.

Findings: CrossFit is an extremely varied sport with a large list of demands and due to its unpredictable nature it may seem to pose a high risk of injury to participants. However, CrossFit has been shown to be a relatively safe sport. Injuries were found to foremostly in the shoulders followed by the lower back and the knees. These injuries can be hypothesized to be a result of overtraining or excess workload. Considerations may be taken in the future to reduce the risk of injury in these areas. Factors which may influence the risk of injury in these areas were found during the review.

Unique Contribution to Theory, Practice and Policy: Recommendations include- emphasis on proper form and technique; gradually increasing training load; incorporating strength and mobility training; individualize programming and scaling; prioritizing rest days and recovery and educating participants on injury prevention.

Keywords: *Crossfit, Weightlifting, Powerlifting, Fitness, Injury Epidemiology, Systematic Review.*

1.0 INTRODUCTION

Crossfit is a sport originating in 2004 and developed by Greg Glassman. The Crossfit brand started as a website in 1999 made in collaboration with KnowWare, a Silicon Valley Software developer. The brand would start delivering daily workouts through online postings on it's website (www.CrossFit.com) titled as the Workout of the Day otherwise known as the WOD. (Morgan, B.E. and Oberlander, M.A., 2001) Over the course of 5 years from its original inception in 2001, Crossfit went from a small relatively unknown website to having around 75,000 visitors. Along the way, Greg Glassman and a group of fitness professionals such as Mike Bergener went on to develop a methodology around CrossFit and the idea of constantly varied high intensity functional movement. Subsequently a series of competitions known as the Crossfit Games were invented, which first began in 2007 with a group of 70 athletes on a ranch in California. The number of attendees would continue to grow, and by 2008 the CrossFit games would grow to 300 competitors accompanied by 800 spectators. By 2009, the CrossFit Games would evolve into a collection of CrossFit athletes from around the world and by 2010, due to the increased attendance rates the CrossFit Games would have to be moved to a Home Depot Center in Los Angeles. In 2011, the biggest change occurred for CrossFit when Reebok signed a 10 year sponsorship deal, which resulted in the CrossFit Games becoming a professional sport endorsed by mainstream media. Lastly, in 2020 Reebok would end their sponsorship and CrossFit would partner with the company NoBull, in addition to hosting the 2021 CrossFit Games online in response to the pandemic.

Apart from competition, CrossFit as a sport and recreational activity can be competitive in nature as participants will partake in WODs in which they can compete amongst each other in their groups or to record scores which can be compared to the global leaderboards on the CrossFit website. In terms of WOD's, athletes or recreational participants may choose to participate in the Rx (Prescribed) WOD or the Scaled WOD. The difficulty of the Rx version of WOD is typically done so with a global standard of competitiveness in mind and the difficulty of the Scaled WOD done so to suit the capabilities of individual participants or the recreational participation of the group. (Weisenthal, B.M., Beck, C.A., Maloney, M.D., DeHaven, K.E. and Giordano, B.D., 2014) During a WOD, an athlete or group of athletes getting the highest score on that particular WOD may mean that they have lifted the most weight, finished a set number of repetitions first, traveled the prescribed distance in the least amount of time, performed the most repetitions within a certain amount of time or even a combination of all the aforementioned variables. However, WODs CrossFit are not limited to the aforementioned variables, as this has been constantly changing over time. During a typical Crossfit competition, athletes are split into competitive heats and prescribed WODs either individually or as a team. Competitive heats can be divided based on the athlete's bodyweight, their 1 repetition maximums of different movements such as the back squat or snatch, and their ability to perform certain movements such as the muscle-up. The majority of these WOD's will have the athlete competing to complete the prescribed repetitions first, cover a certain distance first or to complete the most repetitions in an allotted time-frame while being closely monitored by a CrossFit judge who is assessing their technique in order to count their repetitions. During a CrossFit competition, failure to perform a full repetition or with the required technique will result in the CrossFit judge not counting the athlete's repetition.

In terms of competitions, the CrossFit games are known to be the largest and most important event of each year for the competitive CrossFit athlete, despite the existence of other CrossFit-based competitions. (Escalante, G., Gentry, C.R., Kern, B.D. and Waryasz, G.R., 2017) Before the

commencement of the annual CrossFit games, the CrossFit HQ releases a list of equipment and a series of WODs known as the Open. To qualify as a competitor in the CrossFit games, athletes must participate in this series of online challenges where the athlete competes to place amongst the top percentage on the designated leaderboards starting with the Open. As of 2021, to compete in the CrossFit games an athlete must first place amongst the top 10% in their continent during the online Open event with no equipment and participating in only Rx WODs then successfully place in the top percentage of the online semi-finals or pass the Last Chance Qualifier. The athlete may also participate in the CrossFit games if they make it into the top 20 of the Age-Group event. Due to its importance, the performance factors of a CrossFit athlete revolve around the content of the WODs determined by the annual CrossFit Games, specifically the Open. The content of the Open WOD and the equipment list, serve as the first indicators of performance for the CrossFit athlete's yearly competitive period. However, long-term performance or injury risk factors beyond the yearly competitive period revolving around the CrossFit Games may be difficult to determine because of the unpredictable nature of the content of each prescribed CrossFit WOD.

The revolutionary aspect of Crossfit, was considered to be its variety of movements from a vast range of methodologies and sports into a single competition and the communal aspect which has been built around it. Crossfit as a sport, is a combination of several other sports and activities ranging from weightlifting, cycling, running to sprinting, gymnastics, kayaking, and even bodybuilding. The idea of having movements from a variety of these sports would lead the way into building the "hybrid" athlete, capable of performing any sport at a reasonably high level of proficiency. Generally speaking, the sport of CrossFit typically revolves around its 9 foundational movements as described by Glassman (2010) which include; the air squat, front squat, overhead squat, shoulder press, push press, push jerk, deadlift, sumo deadlift, high pull and medicine ball clean. The 9 foundational movements of Crossfit as described by Glassman (2010) also include four additional movements which include the pull-up, thruster, muscle-up and snatch. In addition to the foundational movements, there are movements from sports such as Olympic weightlifting, track and field, gymnastics and powerlifting which are typically implemented in both Crossfit training and competition. Crossfit's movements which are derived from Olympic weightlifting are not limited to the main lifts such as the snatch or clean and jerk, but can also include training-specific movements such as the power jerk or drop snatch. Gymnastic movements such as the handstand, handstand walks, ring dips and L-sits are also frequently found in Crossfit competitions. (Montalvo, A.M., Shaefer, H., Rodriguez, B., Li, T., Epnere, K. and Myer, G.D., 2017) Track and field movements ranging from sprinting to long distance runs can also be found during the course of a Crossfit competition. Crossfit has even been known to include swimming and cycling in a triathlon styled format during competition, as was the case in the 2013 CrossFit games which featured a swimming event in addition to gymnastic movements.

To consolidate Crossfit's wide variety of physiological demands, Crossfit's inventor Glassman (2010) created a list of the ten general physical skills found within Crossfit, ranging from; cardiovascular/respiratory endurance, stamina, strength, flexibility, power, speed, coordination, agility, balance and accuracy. Furthermore, the theoretical template originally developed by Glassman (2003) also describes the general categorizations of the modalities found within Crossfit to be categorized as: mono-structural metabolic or cardiovascular conditioning (M), gymnastics or bodyweight exercises (G) and lastly, weightlifting, powerlifting and Olympic lifts (W). Despite these efforts, the stochastic nature of Crossfit adds to the difficulties of determining the specific

cause of injury or the areas at risk of injury. The objective of this study is to determine the rate of injury across all reviewed literature for CrossFit participants in addition to the main areas at risk of injury and the potential causes of injury

2.0 METHODOLOGY

Protocol

The review of the literature utilized the recommended criteria found in the PRISMA Statement - Preferred Reporting Items for Systematic Reviews and Meta-Analyses (*Table 2*).

Eligibility Criteria

The timeframe of articles was limited to the last 10 years (2011-2021). The methodology of the included articles were limited to a survey styled format in order to gather data, to have information on the area and type of injury sustained by the participants and participants over the age of 18 years. Articles were not limited to being written in the English language, however it was required for the article to be translated to English. Systematic reviews, case studies, editorials and non-scholarly resources were excluded. Inclusion criteria along the PICO methodology can be found on Table 1.

Table 1: PICO Recommended Inclusion and Exclusion Criteria

Inclusion Criteria		
P	Participate	CrossFit participants
I	Intervention	CrossFit
C	Comparison	Total sample population comparisons or control group and/or variated group.
O	Outcome	Injury and/or trauma.
Exclusion Criteria		
P	Participate	Non CrossFit participants and/or Non CrossFit style training
I	Intervention	Sports or other forms of training which are not specifically and/or do not involve CrossFit. Analysis not limited to specific areas of the body.
C	Comparison	N/A
O	Outcome	N/A

Information Sources

The search for related research was performed on the following electronic databases; Google Scholar, the Human Kinetics Journal, The National Center for Biotechnology Information (NCBI) Journal of Sport Science, The National Library of Medicine (NIH) PUBmed, SAGE Journals and the National Strength Conditioning Association (NSCA) Journal of Strength and Conditioning Research.

Search

The search took place in January 2021 and concluded in June 2021. The article search term consisted of the words “Crossfit” and “Injury” in order to provide the largest possible sample of results based on search engine indexing.

Study Selection

Only free-access scholarly articles that met both the inclusion criteria and selected using the PRISMA Statement guidelines were selected for use in the study (*Table 2*).

Data Collection Process

Data in each study was collected and interpreted independently prior to the comparison of related research. Once each study was analyzed for data, similar variables such as the injury rate per 1000 hours of participation and the prevalence of injuries per area of the body, were compared amongst the research gathered. The comparable data was then collected and placed into a table.

Data Item

Data items were sorted into hierarchical groups of importance based on the objectives of the research, ranging from; primary variables to tertiary variables.

Primary injury related variables which were searched for in the data collection process included the following; the participant's injury rate per 1000 hour of participation, main areas of injury, factors associated with injury and factors statistically deemed not to be associated with injury

Primary demographic related variables which were searched for in the data collection process included the following; the total sample size and the gender of participants.

Secondary demographic related variables which were searched for in the data collection process included the following; information which described the environment during the occurrence of injury, the activity which took place during the time of the injury.

Secondary demographic related variables which were searched for in the data collection process included the following; information which described the participant's activity levels (general physical activity or workplace related physical activity), competitive status within the sport of CrossFit, warm up or cooldown participation, age, smoking or drinking status and age.

Tertiary research related variables which were collected included; survey distribution or data collection methods.

Risk of Bias in Individual Studies

The primary methods of preventing the risk of bias was analyzing the data and interpreting the results independently. Secondarily, comparisons were made between the researcher's analysis and that of the author's analysis. The differences were then recorded into the summarization of the article in the review.

Summary Measures

The summary measures took into account the data of the sample population and the methods used to assess the participants. The summary also aimed to provide a rationale for the researcher's conclusions, so in addition to the researcher's interpretation of the data, the summary also provided the related statistical information found within each piece of research.

3.0 FINDINGS

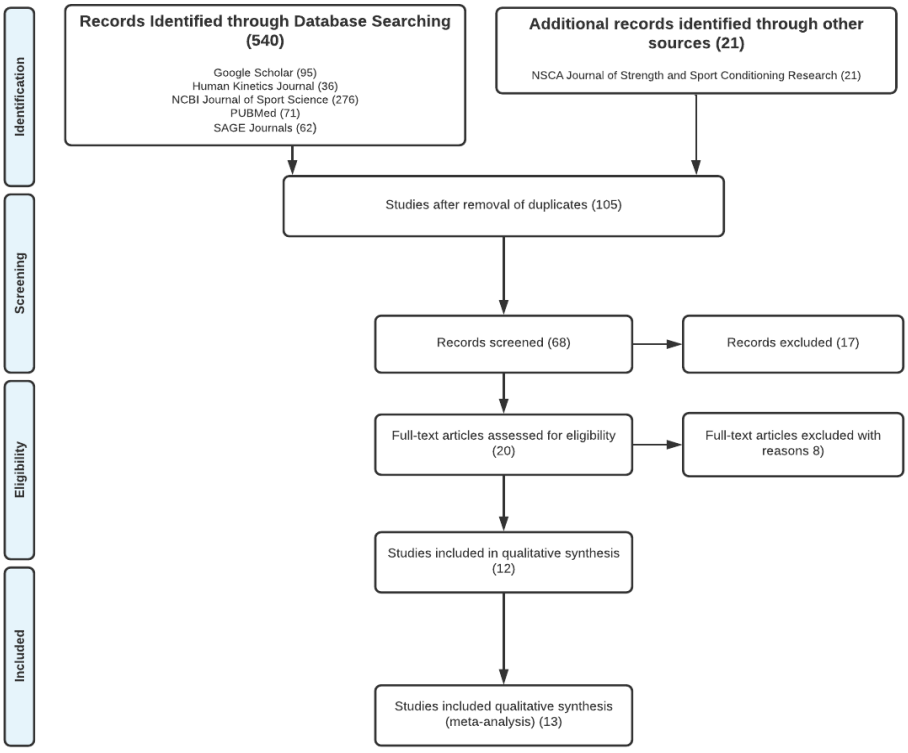
Study Selection

After the summarization of each article, comparable points of data were then assessed and collected. The comparable data was then placed into a table to visually represent the comparisons that were made across all studies.

Risk of Bias across Studies

The risks of bias across studies were addressed by the use of the STROBE criteria to assess the quality of each included piece of research

Table 2: PRISMA Statement Recommended Protocol



Study Characteristics

Injury Rate per 1000 Hours

Injury rates throughout the majority of studies reviewed, (7/12, *Table 5*) were calculated relative to 1000 hours of CrossFit participation. The overall injury rate per 1000 hours resulted in a range of 0.27-18.9 injuries and an average of 5.8.

Data collected from Da Costa et al (2019), Escalante et al (2017) and Hak et al (2013) all displayed similar injury rates per 1000 hours of participation, which range from 3.1 to 3.3. In terms of research design for the aforementioned studies, Da Costa et al (2019) arrived to this conclusion using participant's self-reported data collected on the participant's weekly hourly CrossFit participation while both Escalante et al (2017) and Hak et al (2013) calculated the injury rate using participant's self-reported data on the length of an individual CrossFit session and the number of

weekly CrossFit sessions. Similarly, Montalvo et al (2017) found a rate of 2.3 injuries per 1000 hours, utilizing data on the participant's weekly days, hours and sessions of CrossFit participation. The data collected from Da Costa et al (2019), Escalante et al (2017), Hak et al (2013) and Montalvo et al (2017), result in a range of 2.3-3.3 and an average of 2.985/1000hr.

The data collected by Fieto et al (2018) resulted in 0.27 injuries per 1000 hours of CrossFit participation, which was the lowest recorded rate of all the included studies, in addition Fieto et al (2018) also had the largest sample size out of the aforementioned studies (*Table 3*).

Larsen et al (2020) recorded 9.5 injuries per 1000 hours of CrossFit participation. However, in comparison to the previously mentioned studies, Larsen et al (2020) also had several differences in the method of calculating the participation hours and sample population (Table 5). The differences in participant experience may have resulted in differences of injuries when put in comparison to the aforementioned studies.

Szeles et al (2020) reported 18.9 injuries per 1000 hours of CrossFit participation, which was the highest recorded injury rate of all studies included in the analysis. Similarly, Szeles et al (2020) had a similar method to Larsen et al (2020) in terms of pre-estimated CrossFit session length in addition to a shorter injury surveillance period than previously mentioned studies (Table 5). In terms of research design characteristics, Szeles et al (2020) had been the only study to sequentially re-distribute the same questionnaire to the same population (*Table 4*). Szeles et al (2020) also had a similar sample size to that of the aforementioned studies (*Table 3*).

Injury by Location

The data collected from the included studies described the majority of injuries which occurred during the participation of CrossFit as taking place predominantly in the areas of the shoulders, lower back, hands/wrists and knees. In terms of the average rate of injury prevalence across all studies, the shoulders were the most common (28.91%). Excluding combined categories (*Chart A*), the lower back displayed the second highest average rate of injury prevalence across all studies (20.17%), followed by the hands/wrists (12.91%) and the knees (12.81%). Including combined categories, the lower back resulted in a higher average rate of prevalence (22.96%). Excluding combined categories, the areas which were also found to be at risk of injury based on their rate of prevalence across all studies included the elbows (7.25%), hips (4.54%) and upper back (3.9%).

Injury by Type

In terms of types of injuries, Weisenthal et al (2014) found that the majority of injuries were classified as general inflammation and pain (30.8% rate of prevalence) followed by injuries categorized as "other" (27.2%), sprains or strains (17.2%). Injuries which were classified as either ruptures (3.7%) or dislocations (2.5%) were infrequent in comparison. Similarly, Szeles et al (2020) found that the majority of injuries were classified as tendinopathies (12.96%), while injuries such as bruises (5.26%), shin splints (4.05%) and dislocations (3.64%) were far less common. Despite having reports of stress fractures, the resulting rate of injury prevalence (0.81%) had been found to be relatively miniscule in comparison to the aforementioned injuries.

Level of CrossFit Athleticism

A noted relationship found across several studies was that of the self-reported level of CrossFit athleticism and CrossFit training age to an increased risk of injury occurrence. Alekseyev et al (2020) grouped participants based on their self-reported level of CrossFit competency, finding a

significant relationship between a participant's CrossFit-related athleticism and their likelihood of injury. Alekseyev et al (2020) found that Advanced level participants were more likely to be injured than intermediate OR: 2.63, 95% CI: 1.73-4.02, $P < .0001$) or beginner participants (OR: 7.27, 95% CI: 4.36-12.14, $P < .0001$) in addition to finding that intermediate participants were more likely to be injured than beginners (OR: 2.76, 95% CI: 1.88-4.05, $P < .0001$). Similarly, the rates of injury prevalence reflected this data as Alekseyev et al (2020) found that participants who identified as beginners displayed a lower rate of injury prevalence (16.7%) than that of intermediate (35.6%) or advanced (59.3%) participants. Da Costa et al (2019) also found a relationship between level of CrossFit athleticism and injury prevalence, as self-identified beginner participants resulted in the lowest rate of injury prevalence (22.4%) compared to recreational (39.7%) or competitive participants (60.3%). Sprey et al (2016) had similar findings as subjects who participated in CrossFit competitions were found to be more likely to be injured (OR 1.02, 95% CI: 0.705-1.475, p= .917).

In addition, the self-reported CrossFit level of athleticism typically coincided with increased CrossFit participation duration or frequency. Montalvo et al (2017) found that the competitive Crossfit athlete demographic both trained for longer hours and sustained the most injuries when compared to the total (n=65, 26 injured, 7.1x hours) compared to the non-competitors demographic (n=126, 24 injured, 4.7x hours).

Training Age, Duration and Frequency

Alekseyev et al (2020) found a relationship between injury prevalence and participant's years of experience. Injury risk increased with the CrossFit related training age of participants, as participants with less than 1 year of experience resulted in the lowest rate of injury prevalence (14.9%), than that of participants of 1-2 years of experience (40.1%), 3-4 years of experience (44.8%) and 5 or more years of experience (63%). Da Costa et al (2018) found a similar relationship with the participant's self-reported experience in CrossFit training and injury rate as participants with more than 3 years of experience had a higher rate of injury prevalence (41.4%) than that of participants with 1-3 years (36.6%) or under 1 year of experience (41.4%). Sprey et al (2016) also found that participants with a practice time greater than 6 months resulted in a higher risk of injury (OR 1.697, 95% CI: 1.12-2.572, p = 0.13). In contrast to these results, Szeles et al (2020) identified CrossFit experience as a protective factor against CrossFit related musculoskeletal injuries (OR 0.7, 95% CI 0.5-1.0).

Alekseyev et al (2020) also found that injury prevalence increased consistently with the length of CrossFit-related training times. Participants who trained more than 15 hours per week resulted in the highest rate of injury prevalence (60%) compared to participants with 11-15 hours (48.9%), 7-10 hours (36.0%), 4-6 hours (30%) or 0-3 hours (31.7%). Escalante et al (2017) also found that the injury rate heightened with the overall duration of participation (n=29 0-6 months, n=51 6-12 months, n=85 12-24 months, n=87 >24 months) but not with per session training duration (n=4 <30mins, n=140 30-60mins, n=91 91-71mins, n=13 90-120mins, n=4 >120mins). However, Da Costa et al (2018) did not find a similar relationship between weekly CrossFit participation and injury risk. Although participants reported 5 days a week of CrossFit participation had a higher rate of injury than that of participants with 3 days per week (9%) of participation, the participants with 3-5 days per week of participation displayed the highest injury rate (52.6%) of the three categories. Sprey et al (2016) had similar findings as participants training sessions ≥1 hour resulted in a higher risk of injury (OR 2.216, 95% CI 0.819-5.992, p= .117) than those that did not.

CrossFit-Specific Activity Related to Injury Risk

CrossFit is known to contain several modalities of training within its overall methodology. Several studies which have been included in the review have taken the different modalities into consideration to determine potential risk factors and rates of injury.

In terms of specific movements, Alekseyev et al (2020) found that injuries predominantly occurred during squats (22%), deadlifts (18%) along with clean and jerks (10%). Movements such as box jumps, pull-ups and muscle ups all had a rate of 5%, in addition to running, overhead press and snatches which had a rate of 4%. The activity which Alekseyev et al (2020) found to result in the least amount of injuries was pull-ups (3%). However, it was noted that there were 2 categories labeled "Others" which resulted in a total rate of 15% and 3% respectively.

Mehrab et al (2017) created categories of CrossFit training modalities to identify the rates of injury during participation. It was found that WODs displayed the highest risk of injury to participants (n = 100, 39.7%), followed by strength training (n = 54, 21.4%), skill training (n = 23, 9.1%) and lastly, condition training (n = 10, 4.0%). The remaining unknown category (n = 42, 16.7%) also resulted in relatively high injury rates.

Similarly, Weisenthal et al (2014) also categorized CrossFit training modalities to quantify the rates of injury during participation, in addition to collecting data on the area of injury. Weisenthal et al (2014) categorized the training modalities into powerlifting, Olympic lifting, gymnastics, endurance, other and not associated. It was found that during powerlifting participation, injury rates were highest in the lower back (10.7%), followed by the knee (4.3%) and shoulder (2.3%). Injury rates during Olympic lifting participation were also the highest in the shoulder (4.3%), however this was followed by neck (2.3%), upper back (2.3%), elbow (2.3%) and wrist (2.3%). The injury rates of gymnastics movements were higher in the shoulder (8.3%) than that of the previous categories, but exhibited less drastic results in other areas such as the upper arm (2.3%) or knee (2.3%). Endurance type movements did not result in any shoulder injuries, but rather in the areas of the Achilles (3.5%), hip (2.3%) and groin (1.1%). Compared to the gymnastic category, the other category resulted in the relatively high rates of injury in the areas of the shoulder (8.3%), followed by the Achilles (3.5%) and lower back (2.3%). Lastly, the not associated category also accounted for the highest rate of shoulder injuries (8.3%), followed by the lower back (2.3%).

Warm-Up and Cool-Down Participation

The inclusion of a warm-up, cool-down and the contents of either have been hypothesized by several studies included in the review to influence the risk and rate of injury for participants of CrossFit.

Montalvo et al (2017) found that the inclusion of a warm-up may reduce injury risk. The majority of participants found in the data collected by Montalvo et al (2017) took part in a warmup (n=187, 97.9%) than participants that did not (n=4, 2.1%). Out of this total, a higher percentage of participants who had participated in a warm up during their CrossFit workout (n=137, 73.3%) were uninjured compared to those that had been injured (n=50, 26.7%). However, the entire population that did not participate in a warm up had also been uninjured (n=4, 100%). Mehrab et al (2017) found that neither the inclusion or content of a warmup resulted in any significant differences of injury risk between participants when grouping data into the following categories; General (95% CI 1.067(0.668-1.705) .786p), Specific (95% CI 0.963 (0.834-1.112) .607p), Static Stretching

(95% CI 0.955 (0.792-1.152) .632p), Dynamic Stretching (95% CI 0.889-1.141) .912p), No Warm-Up (95% CI 0.938 (0.731-1.202) .613p).

Out of the total population examined, Montalvo et al (2017) found high rates of cooldown participation (n=144, 75.4% of total respondents) in comparison to non-participants (n=47, 24.6% total respondents). However, Montalvo et al (2017) did not find any significant differences in injury patterns between the group which included cool-downs (n=106, 74.6% injured, n=38, 26.4% uninjured) versus the group that did not (n=35, 74.5% injured, n=12, 25.5% uninjured). Similarly, Alekseyev et al (2020) found that participants who stretched before exercises resulted in similar injury prevalence rates (35.5%) than those who did not (25.3%) which resulted in no significant differences (OR: 1.64, 95% CI: 1.14-2.34, P=.007). Alekseyev et al (2020) also found that stretching between exercises displayed similar results (32.7%) when compared to not stretching between exercises (33.5%) and also resulted in no significant differences (OR: .96, 95% CI: .69-1.34, P =.82)

Synthesis of Results

Demographic Information

Table 3: Demographic Information

Author(s)	Sample (n)	Gender	x̄ Age (years)	x̄ Height (m)	x̄ Weight (kg)	x̄ BMI
Alekseyev et al (2020)	885	589 male, 296 female	29	No reported	Not reported	Not reported
Da Costa et al (2019)	414	243 male, 171 female	31	1.72	73.7	24.8
Escalante et al (2017)	159	88 male, 71 female	31.3	1.74 male, 1.62 female	79.45 male, 60.75female	Not reported
Fieto et al (2018)	3049	1566 male, 3049 female	36.8	Not reported	Not reported	Not reported
Hak et al (2013)	132	93 male, 39 female	32.3	Not reported	Not reported	Not reported
Larsen et al (2020)	168	51 male, 117 female	29.2	Not reported	Not reported	24.3
Mehrab et al (2017)	449	266 male, 183 female	31.9	1.77	76.8	Not reported
Montalvo et al (2017)	191	94 male, 97 female	31.69	1.68	74.32	Not reported
Paiva et al (2021)	121	68 male, 53 female	Not reported	1.7	70.91	24.34
Sprey et al (2016)	566	323 male, 243 female	31.4	171.5	74.2	25.1
Szeles et al (2020)	406	198 male, 208 female	32.1	1.7	74.3	N/A
Weisenthal et al (2014)	386	231 males, 150 females	N/A	Not reported	Not reported	Not reported

Research Design Characteristics

Table 4: Research Design Characteristics

Author(s)	Methods	Testing Period	Inclusion Criteria
Alekseyev et al (2020)	Online Questionnaire posted on internet forums (Reddit.com [CrossFit subreddit], Bodybuilding.com, MuscleandStrength.com, and ShapeFit.com).	Posted online for a period of 6 months.	CrossFit participants.
Da Costa et al (2019)	Questionnaire distributed via Email then printed and completed by participants of CrossFit fitness centers located in the state of Sao Paulo.	Questionnaire distributed and collected between the dates of April 2015 to April 2016 throughout CrossFit gyms throughout Sao Paulo.	CrossFit participants ≥16 years and ≥6 months of CrossFit practice.
Escalante et al (2017)	Online questionnaire distributed through Qualtrics.com.	Questionnaire distributed and collected between the dates of 11/23/16 to 11/30/16 throughout CrossFit gyms in Costa Rica. Questionnaire was also distributed and collected during the largest Central American CrossFit event: The 2016 WODFest-Costa Rica.	CrossFit participants.
Fieto et al (2018)	Online questionnaire distributed through Google Forms to social media outlets, email and by word of mouth.	Questionnaires were distributed annually at the beginning of the competition season from the years 2013 to 2017, between mid-December and the end of February in the following year.	CrossFit participants >18 years of age with >3 months of CrossFit experience.
Hak et al (2013)	Online Questionnaire via CrossFit Forums.	Questionnaire data collected between the dates of February 2012 to May 2012.	Questionnaires distributed via forum posts which consisted of an anonymous link, following an internet search of the term “CrossFit forums” to the top ten ranked forums.
Larsen et al (2020)	Questionnaire distributed through the online survey platform SurveyXact to select CrossFit fitness centers.	Questionnaire data collected during an eight-week free-of-charge membership period from the date of March 2018.	Novice CrossFit participants ≥18 years of age and not current members of CrossFit Copenhagen.
Mehrab et al (2017)	Online questionnaire distributed through SurveyMonkey.com.	Questionnaire data collected between the dates of July 2015 to January 2016.	CrossFit participant’s ≥18 years of age and currently training at a CrossFit gym in the Netherlands.

Table 4: Research Design Characteristics

Montalvo et al (2017)	Questionnaire distributed in-Person to 4 CrossFit facilities throughout South Florida.	Questionnaires distributed and data collection took place in person, over the course of one day.	Current CrossFit members at the participating CrossFit affiliate facilities, no exclusion criteria otherwise.
Paiva et al (2021)	Questionnaire distributed via Email to select CrossFit centers located in Brazil.	Questionnaire data collected between the dates of August and December 2018.	CrossFit participants enrolled in a CrossFit program of at least 6 months.
Sprey et al (2016)	Questionnaire distributed via Email to CrossFit fitness centers located in Brazil.	Questionnaire data collected between the dates of May 2015 to July 2015.	CrossFit participants located in the 250 select specialized fitness centers in Brazil, both certified and registered in the CrossFit database.
Szeles et al (2020)	Initial questionnaire printed and distributed in-person to select CrossFit fitness centers located in a single metropolitan area of Brazil. Follow-up questionnaires developed and distributed using the platform www.surveymonkey.com to the same population.	Six follow-up questionnaires distributed once every 2 weeks from the date of the original questionnaire, for a period of 12 weeks in total.	CrossFit participants ≥18 years of age, not currently injured and participants at a CrossFit box.
Weisenthal et al (2014)	Questionnaire distributed electronically to CrossFit gym owners, coaches and participants throughout Rochester, NY, New York City, NY and Philadelphia, Pennsylvania.	Questionnaire developed and distributed between the dates of May 2012 to July 2012 after its initial pilot phase.	CrossFit participant's ≥18 years of age and training at a CrossFit gym inside of the United States.

Injury Incidence

Table 5: Injury Incidence

Author	Injury Surveillance Period	Training Frequency	Injury rate per 1000 hours of participation
Alekseyev et al (2020)	No time limit on surveillance period.	Hours per week of CrossFit participation	Not reported
Da Costa et al (2019)	No time limit on surveillance period.	Hours per week of CrossFit participation	3.24
Escalante et al (2017)	Limited to injuries sustained within the last 12 months of the questionnaire.	Instances per week of CrossFit participation. Length of CrossFit session.	3.3
Fieto et al (2018)	Limited to the time frame of survey availability per each period.	Hours per week of CrossFit participation Days per week of CrossFit participation.	0.27
Hak et al (2013)	No time limit on surveillance period.	Instances per week of CrossFit participation. Length of CrossFit session.	3.1
Larsen et al (2020)	Limited to injuries reported during the free-of-charge eight-week membership time frame.	Days per week of CrossFit participation were pre-estimated at two to three times per week.	9.5
Mehrab et al (2017)	Limited to one year before the date of the survey.	Days per week of CrossFit participation. Average length of CrossFit sessions.	Not reported
Montalvo et al (2017)	Limited to 6 months prior to the survey, however data had still been collected on injuries outside of this period.	Days per week of CrossFit participation. Instances per week of CrossFit participation. Hours per week of CrossFit participation.	2.3
Paiva et al (2021)	No time limit on surveillance period.	Not reported.	Not reported.
Sprey et al (2016)	No time limit on surveillance period.	Days per week of CrossFit participation. Average of CrossFit sessions.	Not reported
Szeles et al (2020)	Limited to the 12 week period of the study, however information was collected on if the participant sustained an injury prior to the study.	Days per week of CrossFit participation. Average length of CrossFit sessions were pre-estimated to last 60 minutes.	18.9
Weisenthal et al (2014)	No time limit on surveillance period.	Days per week of CrossFit participation. Average length of CrossFit session.	Not reported

Injury Prevalence by Area of Body

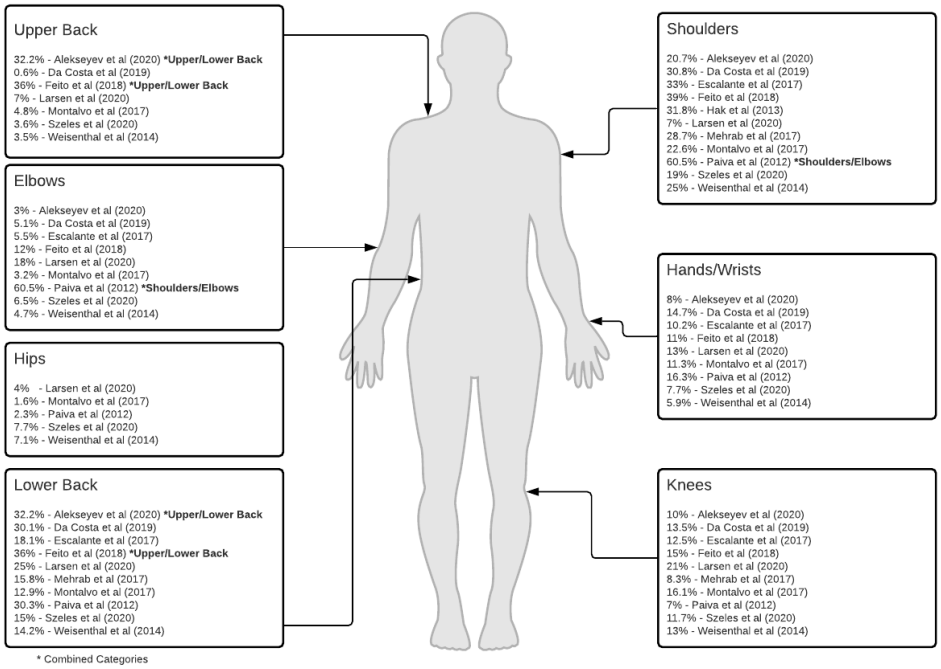


Figure 1: Injury Prevalence by Area of Body

Additional Analysis

The assessment of methodological quality according to the Criteria of STROBE> Adherence to the criteria varied between 68.1% and 100%.

Table 6: STROBE Criteria

Author(s)	Title and Abstract	Introduction	Method	Result	Discussion	Other information	Total Score (%)	Classification
Alekseyev et al (2020)	1/1	2/2	7/9	5/5	4/4	1/1	90.9%	A
Da Costa et al (2019)	1/1	1/2	8/9	4/5	4/4	1/1	86.3%	A
Escalante et al (2017)	1/1	1/2	9/9	2/5	4/4	1/1	81.8%	A-
Fieto et al (2018)	1/1	2/2	9/9	5/5	4/4	1/1	100%	A+
Hak et al (2013)	1/1	1/2	6/9	3/5	3/4	1/1	68.1%	C+
Larsen et al (2020)	1/1	2/2	9/9	5/5	4/4	1/1	100%	A+
Mehrab et al (2017)	1/1	2/2	9/9	5/5	4/4	1/1	100%	A+
Montalvo et al (2017)	1/1	2/2	9/9	5/5	4/4	1/1	100%	A+
Paiva et al (2021)	1/1	1/2	8/9	5/5	4/4	1/1	95.4%	A+
Sprey et al (2016)	1/1	2/2	9/9	5/5	4/4	1/1	100%	A+
Szeles et al (2020)	1/1	2/2	8/9	5/5	4/4	1/1	95.4%	A+
Weisenthal et al (2014)	1/1	2/2	9/9	5/5	3/4	1/1	95.4%	A+

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

Synthesis of Results

Table 7: Summary Items

Author(s)	Factors Associated with Injury	Results	Factors not Associated with Injury
Alekseyev et al (2020)	Level of CrossFit Athleticism CrossFit Training Age CrossFit Training Session Length CrossFit-Specific Activity related to Injury Risk	Injury prevalence increased with self-reported CrossFit competency, as self-identified advanced CrossFit participants were more likely to be injured than beginner participants. Injury prevalence increased with years of CrossFit training age and increased length of training times. Injuries were found to occur predominantly during squats, deadlifts along with clean and jerks.	The inclusion of stretching did not result in significant differences of injury risk.
Da Costa et al (2019)	Level of CrossFit Athleticism CrossFit Training Age	Injury prevalence increased with self-reported CrossFit competency, as self-identified advanced CrossFit participants were more likely to be injured than beginner participants. Injury prevalence increased with CrossFit training age.	Weekly CrossFit participation did not show relationships to increased injury risk.
Escalante et al (2017)	CrossFit Training Age	Injury prevalence increased with CrossFit training age.	Injury rate did not increase with per session training duration. The presence of a coach's supervision and previous Injuries showed no significant relationships to reported injuries. Previous or existing injuries did not influence the rate of injury prevalence.
Hak et al (2013)	N/A	N/A	N/A
Larsen et al (2020)	N/A	N/A	N/A
Mehrab et al (2017)	CrossFit specific Activity Related to Injury Risk	WODs resulted in the highest rates of injuries when compared to strength training, skill trainitary jobs had the highest rate. (n=106 mainly sedentary, n=66 standing and walking but no physical exertion, n=60 standing and walking with lifting and carrying, n=20 heavy work.)	The inclusion of Warmup or Cooldown participation or type did not yield significant results.

Table 7: Summary Items

Montalvo et al (2017)	CrossFit Training Age Level of CrossFit athleticism	Injury prevalence increased with CrossFit training age. The injury rates of competitive Crossfit participants were found to be higher than that of non-competitive CrossFit participants.	The inclusion of Warmup or Cooldown participation or type did not yield significant results.
Paiva et al (2021)	Training Intensity	Intense weight training resulted in a higher rate of injury than moderate or light intensity weight training.	
Sprey et al (2016)	Level of CrossFit athleticism CrossFit Training Age.	The injury rates of competitive Crossfit participants were found to be higher than that of non-competitive CrossFit participants. Injury prevalence increased with CrossFit training age	
Szeles et al (2020)	N/A	N/A	N/A
Weisenthal et al (2014)	CrossFit-Specific Activity Related to Injury Risk	Powerlifting movements resulted in the highest rates of lower back injuries. Gymnastics, Endurance, Other and Not associated type exercises resulted in the highest rate of shoulder injuries.	

Injury rates during the participation of CrossFit have been shown to increase concurrently with the total duration of participation in studies such as Alekseyev et al (2020), Da Costa et al (2019), Escalante et al (2017), Montalvo et al (2017) and Sprey et al (2016). The research from all studies included in the review found that the areas of the shoulder, lower back or lumbar area and the knee resulted in the highest rates of injury prevalence followed by the areas of the wrist and hip (*Chart A)*. It was found by Weisenthal et al (2014) that the general inflammation and pain had resulted in the highest rate of identified injuries in addition to sprains or strains. Szeles et al (2020) also found that tendinopathies accounted for a high rate of injury prevalence amongst other reported types of injury. The competitiveness of each participant in terms of CrossFit had an impact on the rates of injury as well, as it was found in the research from Montalvo et al (2017) and Sprey et al (2016) that competitive CrossFit athletes showed higher injury rates when compared to non-competitive athletes. Alekseyev et al (2020), Da Costa et al (2019), Escalante et al (2017), Montalvo et al (2017) and Sprey et al (2016) all found that injury prevalence increased with the participant's CrossFit training age. It was found in the data collected by Alekseyev et al (2020), Mehrab et al (2017), and Weisenthal et al (2014) that participation in certain forms of training may impact the rate and type of injury sustained by the participant (*Table 8)*. Injury rates were not found to be correlated to either warm up or cooldown participation, as described by Mehrab et al (2017). Lastly, injury rates were not found to be related to any particular demographic variable such as a participant's gender in any studies reviewed. *(Table 8).* An additional note, on the reported injuries, is that both Escalante et al (2017) and Larsen et al (2018) reported one case of rhabdomyolysis each while Escalante et al (2017) also reported one case of inguinal hernia.

Limitations

The limitations of this study were primarily in the differences between each study in terms of calculated variables and research objectives. In addition, the lack of raw data also impacted the overall synthesis of results found in the review.

Conclusion

CrossFit is an extremely varied sport with a large list of demands and due to its unpredictable nature it may seem to pose a high risk of injury to participants. However, CrossFit has been shown to be a relatively safe sport. Excluding the outliers, CrossFit has been found to have a similarly low injury rate of 2.985 injuries per 1000 hours of participation when compared to other sports such as Olympic Weightlifting which was described by Calhoon et al (1999) to have a rate of 3.3 injuries per 1000 hours of participation. Including the outliers, CrossFit still displays a relatively low injury rate of 5.9 per 1000 hours of participation when compared to other sports such as Major League Soccer which was described by Morgan et al (2001) to have a rate of 2.9 injuries per 1000 hours of practice participation and a rate of 35.3 injuries per 1000 hours of game participation.

Injuries were found to foremostly in the shoulders followed by the lower back and the knees. Considerations may be taken in the future to reduce the risk of injury in these areas. Factors which may influence the risk of injury in these areas were found during the review. Alekseyev et al (2020) found that injuries predominantly occur during squats, deadlifts or clean and jerks. Movements which all rely heavily on the main areas of injury. Weisenthal et al (2014) found that lower back injuries typically occur during powerlifting movements while gymnastic movements accounted for a relatively high rate of shoulder injuries. These results may be applicable to the training considerations of facilitators in the efforts to reduce injury rates in the future.

In terms of type of injury, the findings from Weisenthal et al (2014) and Szeles et al (2020) detail that the majority of injuries reported during the participation of CrossFit were either attributed to general inflammation and pain or tendinopathy. These injuries can be hypothesized to be a result of overtraining or excess workload. Data found in studies such as Alekseyev et al (2020) and Montalvo et al (2017) may contribute to this hypothesis as increased training hours or frequency resulted in a higher rate of injury for participants.

Recommendation

Emphasize proper form and technique: Since injuries often occur during movements like squats, deadlifts, and clean and jerks, it's crucial to prioritize proper form and technique. Coaches and trainers should provide adequate instruction and guidance to participants to ensure they perform movements with correct form, reducing the risk of injury.

Gradually increase training load: Overtraining or excessive workload can contribute to injuries, particularly inflammation, pain, and tendinopathy. It's important to gradually increase training load and volume, allowing participants' bodies to adapt and recover adequately between sessions. Periodization and smart programming can help manage training intensity and volume effectively.

Incorporate strength and mobility training: Building strength and improving mobility can enhance joint stability and reduce the risk of injuries, especially in the shoulders, lower back, and knees. Including specific strength and mobility exercises in CrossFit programming can help participants develop the necessary strength and flexibility to support their movements.

Individualize programming and scaling: CrossFit workouts can be scaled and modified to accommodate individual fitness levels and abilities. Coaches should assess participants' fitness levels, movement patterns, and limitations, and provide appropriate scaling options to ensure they are performing workouts safely and within their capabilities.

Prioritize recovery and rest days: Adequate rest and recovery are essential for preventing overuse injuries. Encouraging participants to prioritize rest days, incorporate active recovery strategies, and maintain a balanced lifestyle with proper sleep, nutrition, and stress management can help reduce the risk of injuries.

Educate participants on injury prevention: Providing educational resources and workshops on injury prevention can empower CrossFit participants to take an active role in their own safety. Teaching proper warm-up techniques, cool-down exercises, and injury prevention strategies can help participants understand how to minimize their risk of injuries.

REFERENCES

Alekseyev, K., John, A., Malek, A., Lakdawala, M., Verma, N., Southall, C., Nikolaidis, A., Akella, S., Erosa, S., Islam, R. and Perez-Bravo, E., 2020. Identifying the most common crossfit injuries in a variety of athletes. *Rehabilitation Process and Outcome*, *9*, p.1179572719897069.

Calhoon, G. and Fry, A.C., 1999. Injury rates and profiles of elite competitive weightlifters. *Journal of athletic training*, *34*(3), p.232.

CrossFit, History of the Games. *CrossFit*. Available at: https://games.crossfit.com/history-of-the-games [Accessed 2021]. da Costa, T.S., Louzada, C.T.N., Miyashita, G.K., da Silva, P.H.J., Sungaila, H.Y.F., Lara, P.H.S., Pochini, A.D.C., Ejnisman, B., Cohen, M. and Arliani, G.G., 2019. CrossFit®: Injury prevalence and main risk factors. *Clinics*, *74*. Escalante, G., Gentry, C.R., Kern, B.D. and Waryasz, G.R., 2017. Injury patterns and rates of Costa Rican CrossFit® participants-a retrospective study. *Medicina Sportiva: Journal of Romanian Sports Medicine Society*, *13*(2), pp.2927-2934.

Feito, Y., Burrows, E.K. and Tabb, L.P., 2018. A 4-year analysis of the incidence of injuries among CrossFit-trained participants. *Orthopaedic journal of sports medicine*, *6*(10), p.2325967118803100.

Glassman, G., 2010. Understanding CrossFit. *East Valley Crossfit Newsletter.(1)*, pp.1-115.

Glassman, G., 2003. Metabolic conditioning. *CrossFit Journal*, *1*(10), pp.1-2.

Hak, P.T., Hodzovic, E. and Hickey, B., 2013. The nature and prevalence of injury during CrossFit training. *Journal of strength and conditioning research*.

Larsen, R.T., Hessner, A.L., Ishøi, L., Langberg, H. and Christensen, J., 2020. Injuries in novice participants during an eight-week start up crossfit program—a prospective cohort study. *Sports*, *8*(2), p.21.

Mehrab, M., de Vos, R.J., Kraan, G.A. and Mathijssen, N.M., 2017. Injury incidence and patterns among Dutch CrossFit athletes. *Orthopaedic journal of sports medicine*, *5*(12), p.2325967117745263.

Montalvo, A.M., Shaefer, H., Rodriguez, B., Li, T., Epnere, K. and Myer, G.D., 2017. Retrospective injury epidemiology and risk factors for injury in CrossFit. *Journal of sports science & medicine*, *16*(1), p.53.

Morgan, B.E. and Oberlander, M.A., 2001. An examination of injuries in major league soccer: the inaugural season. *The American journal of sports medicine*, *29*(4), pp.426-430.

Paiva, T.M.D.M., Kanas, M., Astur, N., Wajchenberg, M. and Martins, D.E., 2021. Correlation between previous sedentary lifestyle and CrossFit-related injuries. *Einstein (São Paulo)*, *19*.

Sprey, J.W., Ferreira, T., de Lima, M.V., Duarte Jr, A., Jorge, P.B. and Santili, C., 2016. An epidemiological profile of crossfit athletes in Brazil. *Orthopaedic journal of sports medicine*, *4*(8), p.2325967116663706.

Szeles, P.R.D.Q., Costa, T.S.D., Cunha, R.A.D., Hespanhol, L., Pochini, A.D.C., Ramos, L.A. and Cohen, M., 2020. Crossfit and the epidemiology of musculoskeletal injuries: a prospective 12-week cohort study. *Orthopaedic journal of sports medicine*, *8*(3), p.2325967120908884.

Weisenthal, B.M., Beck, C.A., Maloney, M.D., DeHaven, K.E. and Giordano, B.D., 2014. Injury rate and patterns among CrossFit athletes. *Orthopaedic journal of sports medicine*, *2*(4), p.2325967114531177.