REVIEWS

The frequency of injuries among CrossFit athletes: a systematic review

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Abstract
Background. CrossFit, a sports branch based on complex exercises and functional movements performed at high intensity, formed the basis of our work, namely HIIT training (High-intensity interval training).
Aims. The main objective of our study was to specify the musculoskeletal level of the human body most easily and frequently affected. An important aspect was to assess the incidence rate of injuries associated with CrossFit training.
Methods. The present systematic review was designed between October 2021 and April 2022 according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards using PubMed, Scopus and Web of Science databases.
Results. The initial search identified 50 titles in the databases described above, of which seven duplicate articles were automatically removed. The remaining 43 articles were analysed by title and abstract for relevance, resulting in a further 12 studies being removed. After eliminations in the eligibility phase, a total of 12 articles were included in the study.
Conclusions. Studies have shown us that the rate of shoulder injuries ranged from around 40-43% of all injuries. The lumbar spine and knees are easily affected areas, but there is a (lower) incidence in other joints of the human body.
Keywords: CrossFit, athletes, injuries.

Introduction

Movement is known as being the basis of life; in the contemporary concept, it has a significant role in maintaining our health and the various balances in the human body. Any change of place or position, whether we are talking about the body as a whole or referring only to its segments, is defined as a movement, which is actually based on the contraction of skeletal muscles by consuming energy from different sources.

The word therapy without any prefix or suffix is a broad concept, as far as the theoretical meaning is concerned. From radiation therapy to essential oil therapy, we find every kind of therapy that has some positive effect (short or long term) on our health.

Many side effects of sports bring health benefits, such as psychosocial development for both young and old, personal and sometimes professional development. Adverse consequences include the threat of breakdown, leading to impoverished psychological health, risk of injury, eating disorders, and burnout (a critical negative factor among performance athletes). Negative aspects are prevalent in elite-level athletics, in which reaching peak performance is often the ultimate goal (Malm et al., 2019).

The purpose of training can be different, as well as the effect of the types of exercise: the main effect of aerobic exercise is to improve the cardio-respiratory system, respectively the oxygenation of cells in the body, and anaerobic exercise is to increase muscle mass. To talk about examples: types of aerobic exercise (also known as “cardio”) are treadmill running, swimming, spinning, aerobic dance - Zumba, epileptic bicycle use, cycling, rowing, etc., respectively as types of exercise anaerobic we can list powerlifting, athletics, bodybuilding, barbell sprint, HIIT training (Chamari & Padulo, 2015).

Various studies have shown the positive effect of aerobic exercise in reversing and preventing cardiovascular disease. An interesting study was done in 2002 on adult female rats, demonstrating the benefits of aerobic training in the post-ischemic myocardium (Wisloff et al., 2002). Results demonstrated a 15% decrease in post-infarction...
left ventricular hypertrophy and a 12% and 20% decline in myocyte diameter and thickness (Patel et al., 2017). Along with aerobic exercise and its effect on lipid metabolism, anaerobic exercise has been shown to influence the lipid profile positively. A European research of 16 obese people found that an aerobic workout followed by anaerobic training was more beneficial than aerobic exercise alone. Subjects which experienced core preparation with aerobic and anaerobic workouts showed a more significant decrease in non-esterified fatty acids (Patel et al., 2017).

CrossFit is functional training that combines high-intensity exercise with multi-joint functional movements, and it is one of the world’s fastest-growing modes of high-intensity functional training. CrossFit has gained popularity among the civilian and military fire and police personnel, as it was initially developed for military strength training. CrossFit was developed as a core strength and conditioning program. Its objective is to contribute to an optimization of general physical competence. One of the main characteristics of CrossFit is that the exercises are performed quickly and repetitively while the athlete has little or no recuperation period between sets (Wagener et al., 2020).

Kellmann and Kallus (Kellmann & Kallus, 2001) described recovery as a multi-level (e.g., psychological, physiological, social) method to regain performance capacities over time. Recovery encompasses a proceeding-orientated element, and those self-instituted behaviors (proactive recovery) can be methodically employed to optimize conditions and replenish personal resources. Based on these, we can say that the definition demonstrates the complexity of post-training recovery and emphasizes the need for recovery activities.

In the modern world, rehabilitation following athletic trauma has emerged as a field of experts, and its development has undoubtedly got the physiotherapist, the sports doctor and the orthopedic surgeon collaboratively. Critical elements in accomplished athletics trauma rehabilitation procedures are applied to cutting-edge rehabilitation procedures beneath proper guidance, appropriate and well-timed surgical interventions and judicious usage of pharmaceutical agents. Injury-specific rehabilitation protocols are used worldwide but must also be proposed according to the character of the athletics, depending on the agility, balance and proprioceptive levels (Sopa, 2015; Sopa & Szabo, 2015; Sopa & Pomohaci, 2016; Szabo et al., 2020a; Szabo et al., 2020b; Szabo et al., 2021). What is often lacking in the developing world (and not only) is psychological support and a clear understanding by the athlete of her/his rehabilitation methods (Christakou & Lavallee, 2009).

From the point of view of the novelty elements present in the work, we can list CrossFit as a sports branch based on complex exercises in terms of movement technique, forming the basis of our work, namely HIIT training (High-intensity interval training). Next to them, we also include sports injuries that occur during training, the significant risk factors in the process of producing the injury, notions of CrossFit concerning the specific exercises, respectively the auxiliary equipment of the sports branch. With the help of these elements, we can establish the purpose of our work: establishing the frequency of injuries during CrossFit training, respectively listing the significant risk factors in the occurrence of these injuries. After determining the factors mentioned above, one of the main objectives of our study is to specify the musculoskeletal level of the human body most easily and frequently affected. An important consideration is assessing the incidence rate of injuries associated with CrossFit training.

Material and methods

The present systematic review was designed between October 2021 and April 2022, according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards, using PubMed, Scopus and Web of Science databases, with the following search strategies (Table I):

a) PubMed: ((the frequency of injuries) OR (most common injuries) OR (most common injured areas) AND ((in CrossFit) OR (in powerlifting)) AND ((male/female athletes) OR (and risk factors)).

b) Scopus: ((the frequency of injuries) OR (emergency injuries) OR (spine injuries)) AND ((in CrossFit) OR (in competitive CrossFit)) AND ((between teenage athletes) OR (male/female athletes)).

c) Web of Science: ((injury prevalence) OR (main risk factors) OR (CrossFit related injuries) OR (injuries)) AND ((in CrossFit) OR (and medical care)) AND (of the lumbar spine) OR (beginner or intermediate participants)).

The records identified from the databases with the key terms mentioned above were saved using the reference manager software EndNote X9; subsequently, the same software helped remove duplicate articles.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Inclusion criteria</th>
<th>Exclusion criteria</th>
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<tbody>
<tr>
<td>Population</td>
<td>Athletes who practice CrossFit professionally or regularly (hobby level) worldwide; after age 18, both sexes.</td>
<td>People who practice sport irregularly or not at all, or athletes from other areas of physical activity; presentation of the frequency of injuries in CrossFit in certain nationalities.</td>
</tr>
<tr>
<td>Intervention</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Results</td>
<td>Determining the frequency of injuries during CrossFit training, considering the whole body, i.e., all levels of the musculoskeletal system, and explaining risk factors.</td>
<td>Determining the incidence of specific musculoskeletal disorders, focused on a specific area or well-defined level of the human body in CrossFit; comparing two sports concerning injury frequency.</td>
</tr>
<tr>
<td>Study design</td>
<td>A systematic review, meta-analysis, case control, cross-sectional studies, literature reviews, and case reports. All articles published after 2013</td>
<td>Expert opinions, letters to the editor, and conference reports.</td>
</tr>
</tbody>
</table>

*Table I* Inclusion and exclusion criteria.
Data extraction

An Excel form was used to extract the data. From each article selected and included for review, the following information was extracted:

- The main objective of the study, namely injuries occurring during CrossFit training, e.g., easily affected joints, type of injuries.
- The primary purpose, i.e., to determine the frequency of injuries among CrossFit athletes, e.g., most frequently injured body areas, percentage of injuries at different body levels.
- Types of studies we analyzed: systematic review, meta-analysis, cross-sectional studies, case-control, case reports, literature reviews.
- According to the authors, the study sample represents numbers by gender of participants and by the level of expertise.

Results

The initial search identified 50 titles in the databases described above, of which 7 duplicate articles were automatically removed. The remaining 43 articles were analyzed by title and abstract for relevance, resulting in a further 12 studies being removed. The full texts of the remaining 31 articles were read and analyzed; thus, a further 18 articles were excluded for not meeting the inclusion criteria defined for the current study (Table I). Studies were excluded at the screening stage due to non-inclusion of sports injuries or inadequate study type (n=12). In the eligibility phase, there were several reasons for exclusion, namely: theme focusing on sports other than CF (n=8), the basis of the studies being CF injuries on a specific well-defined level/area(s) of the human body (n=3), presenting frequency of CF injuries in a specific nationality (n=3), articles were published in languages other than English (n=1), those forming a comparison between injuries in CF and other sports (n=3), those based on a study sample of only one gender (n=1), resulting in 12 articles included in the study. Fig. 1 represents the complete PRISMA diagram.

Table II

Details of studies - According to the original authors, the study sample is restricted to CF athletes and classified by performance level(s).

<table>
<thead>
<tr>
<th>Study details</th>
<th>Sample</th>
<th>Results</th>
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<tbody>
<tr>
<td>Reference</td>
<td>Main objective</td>
<td>Gender</td>
</tr>
<tr>
<td>(Feito et al., 2018)</td>
<td>Determine the injury rate in CF by analyzing athletes over four years.</td>
<td>F/M</td>
</tr>
<tr>
<td>Study details</td>
<td>Sample</td>
<td>Results</td>
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<tr>
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</tr>
<tr>
<td><strong>Reference</strong></td>
<td><strong>Main objective</strong></td>
<td><strong>Main purpose</strong></td>
</tr>
<tr>
<td>(Feito et al., 2020)</td>
<td>They are determining the injury rate at the competitive level.</td>
<td>To examine injury rates of individuals involved in CF training and the risk of injury associated with the competition.</td>
</tr>
<tr>
<td>(da Costa et al., 2019)</td>
<td>They are establishing baseline prevalences in CF training.</td>
<td>Determine the prevalence of injuries associated with CF training and assess the profiles of these injuries and affected athletes.</td>
</tr>
<tr>
<td>(Alekseyev et al., 2020)</td>
<td>Distribution of specific injuries with training associated with risk factors: baseline demographics, regional differences, training intensity and level of expertise at the time of injury.</td>
<td>Identify the most common musculoskeletal injuries sustained during CF training among athletes at different levels of expertise.</td>
</tr>
<tr>
<td>(Fernandes et al., 2021)</td>
<td>Analyze the effect of CF training on the human body, taking into account the injuries that occur during the practice of this sport.</td>
<td>Assess the incidence rate of injuries associated with CF training and indicate the area most affected by injuries.</td>
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<tr>
<td>(Aume &amp; Powers, 2017)</td>
<td>Confirmation or refutation of the following hypothesis: the injury rate in the extreme conditioning program is higher than the injury rate in weightlifting, i.e., most injuries occur to the shoulder and back.</td>
<td>Determining the overall injury rate in extreme conditioning training, i.e., identifying the area most commonly affected.</td>
</tr>
<tr>
<td>(Weisenthal et al., 2014)</td>
<td>Determining the injury rate in CF in both sexes.</td>
<td>Identify trends and associations between injury rates and demographic categories, gym characteristics, and athletic abilities of CF participants.</td>
</tr>
<tr>
<td>(Toledo et al., 2022)</td>
<td>Search for potential risk factors for accidents in both sexes.</td>
<td>Checking the incidence and rate of joint and muscle injuries in CF.</td>
</tr>
<tr>
<td>(Hülsmann et al., 2021)</td>
<td>Determining the most commonly affected region of the body in CF.</td>
<td>Existing literature was reviewed to determine injury rates in CF. Review systematic.</td>
</tr>
<tr>
<td>(Barranco-Ruiz et al., 2020)</td>
<td>Determine which body parts are most vulnerable to harm in people with CF.</td>
<td>To investigate the occurrence of injuries in training modalities such as CF, Cross Training, and High-Intensity Functional Training. Review systematic.</td>
</tr>
<tr>
<td>(Montalvo et al., 2017)</td>
<td>Determine the location, severity and number of injuries in CF over six months.</td>
<td>Examining injury epidemiology and risk factors for injury in CF athletes. F/M</td>
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</tbody>
</table>
This paper analyzes from the perspective of a systematic review the frequency of injuries among CF athletes of different levels, highlighting the musculoskeletal area most effortlessly and often affected. On the other hand, it is worth mentioning that most of the included studies listing the significant risk factors either refer to factors related to the athlete (age, body mass, previous injuries) or talk about factors related to equipment and sports hall. However, a note must be made towards the difficulty in analyzing data from studies, as there are some differences associated with authors and study sample in terms of determining the body level most affected in CF: most of the studies state that the shoulder joint is most exposed to injury (Feito et al., 2018; Feito et al., 2020; Weisenthal et al., 2014) but the lumbar spine (Aleksyev et al., 2020; Hülsmann et al., 2021) also appears first in the conclusions, together with the knee (Zecchin et al., 2021), and in 12 articles included in the study muscle injuries are also mentioned (Toledo et al., 2022). Another critical factor that may influence the data variability between studies is when data collection occurred (e.g., before or after the competition season in competitive athletes). The reviewed studies were organized into two axes: major risk factors and the most commonly affected musculoskeletal body level to better understand the determinants of injury occurrence in CF.

- **Risk factors:** When sports injuries come up in our discussions, we automatically think of the causes of injury, i.e., risk factors. This study also includes articles looking for significant risk factors for injury in CF. After reviewing the studies, it appears that previous injuries and the time practised in CF are primary risk factors, as it is proven in athletes with more than 12 months of experience. The probability of injuries is 82.2% higher than in novice athletes (CF experience < 12 months), which means that there are differences at different levels of this sport; the probability of injuries at the competitive level is five times higher than in novices. Intermediate athletes (recreational level) are two times higher than novices (da Costa et al., 2019). Given the “constantly varied” nature of CF it makes sense that those with the least experience may be more prone to injury due to strength and/or flexibility issues that may hinder their ability to complete some basic exercises (Feito et al., 2018). With the high intensity and fast pace associated with CF training, loss of form can occur, causing excess stress placed on, for example, the thoracic and lumbar spine, which would increase the risk of injury, therefore lack of concentration along with loss of form and motor technique of movement is a significant factor given the injuries that occur during training (Aleksyev et al., 2020). Most of the included studies state that gender is an essential factor in injury defence: men are more prone to sports injuries than women (Aleksyev et al., 2020; Fernandes, 2021; Weisenthal et al., 2014; Toledo et al., 2022). In addition, physical activity outside of CF has been significantly associated with injuries. A 2017 article published in the Journal of Sports Science and Medicine states that over 30% of those who participated in outdoor physical activity reported injuries in the past six months, while only 15% of those who did not engage in outdoor physical activity reported injuries (Barranco-Ruiz et al., 2020).

- **Most commonly affected body areas:** Most of the articles included in the study state that the upper body, especially the shoulder, is the most commonly affected joint during CF training (Feito et al., 2018; da Costa et al., 2019; Zecchin et al., 2021; Weisenthal et al., 2014; Toledo et al., 2022; Barranco-Ruiz et al., 2020; Montalvo et al., 2017, Aune & Powers, 2017). CF training can place the shoulders in positions that stress structures in the joint. Athletes may experience shoulder injuries such as torn labrums, rotator cuff tears, and subacromial impingement syndrome, in which the rotator cuff tendons become compressed. Overuse of the joint, i.e., overtraining, can also irritate and inflame the tissues. Better posture and strengthening the rotator cuff can increase mobility and reduce shoulder injuries. The shoulders were the most affected by the joint injuries, and this incidence result appears to be related to shoulder overuse. CF is a program that uses a lot of overhead weights in exercises, i.e., shoulder hyperflexion and gymnastic movements that are from hanging on the barbell or rings; these can potentially increase shoulder injuries because they require more body control, in addition to men having more incredible difficulty with joint mobility (Toledo et al., 2022).

Among the affected joints, the spine, especially the lumbar spine, received second place (Feito et al., 2018; da Costa et al., 2019; Weisenthal et al., 2014; Montalvo et al., 2017). Bending from the trunk and lifting weights can lead to back injuries, especially lifting weights with poor form. Lumbar strain, sciatic pain or disc herniation are some back injuries that CF athletes might experience. Three of the articles reviewed also mentioned the knee as an injury-prone joint (Zecchin et al., 2021; Toledo et al., 2022; Barranco-Ruiz et al., 2020). Movements such as squatting or jumping strain the knees. Injuries vary widely (meniscus injury, ligament tear). During exercises, the athlete must have control over the knees (and not only), preceding the valgum positions when genuflecting, e.g., for correct posture and position.

Based on the articles detailing muscle injuries, the local distribution of injuries of muscular origin can be established: upper train - deltoid muscle, trapezius muscle, biceps and triceps brachii, pectoralis major and upper back muscles, and lower train - gastrocnemius muscle, quadriceps femoris. Men differ from women regarding muscle injuries, i.e., they had a lower prevalence (three injury sites) than women (eight injury sites) (Toledo et al., 2022).

**Conclusions**

1. Given all the review criteria of the included studies, firm conclusions can be drawn regarding injury frequency among CrossFit athletes. First, at a skeletal level, the shoulder joint is the most prone to injury during the practice of this sport.

2. Studies have shown us that the shoulder injury rate ranges from around 40-43% of all injuries. The lumbar spine and knees are easily affected, but there is a (lower) incidence in other joints of the human body. An essential aspect worth mentioning is that men are much more prone
to injury than women.

3. In all the articles presenting risk factors, the following appear almost the same in the list: time practiced in CF, several training sessions per week, level of practice, and presence of previous injuries: the probability of injury increased with the period of practice and the level of competence of the athletes.

Conflict of interests
Nothing to declare.

References


