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Revision

Injury in CrossFit beginner / intermediary participants: a systematic review

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ABSTRACT

Objective: Sports injury can occur due to several factors, which makes it extremely difficult to conduct cause and effect studies by controlling and evaluating a specific variable. Common reason for the appearance of injuries is poor physical preparation for the proposed training load, a factor that is more present in high intensity sports.

CrossFit has been gaining a great deal of attention in recent years due to its dynamic mix of varied sports. Beginner and intermediary level participants are very common in CrossFit gyms, so the understanding the training effect for this group is very important for healthy practice (aiming for safety and injury rate).

Methods: Only original articles were included, between 2000 and 2019 (November), with the search for the word "CrossFit" in nine databases. It was accepted only studies in Portuguese, English or Spanish.

Results: After screening, only three studies met the inclusion criteria following Preferred Reporting Items for Systematic Reviews and Meta-Analyses assessment. The most common injury segments in beginner and intermediate practitioners were the shoulder and the knee. There are functional and morphological mechanisms that makes injury become more common, such as life habits and anatomic / physiological body disposition.

Conclusion: CrossFit beginners and intermediaries participants demonstrated moderate injury level. Studies with more subjects showed a lower injury level. The most injured segments found were knee and shoulder. According to our results the risk of injury in CrossFit beginner and intermediary participants is acceptable, and discussed in recent published reviews.

Keywords: CrossFit; Injury Rate; Gymnastics; Weightlifting.

Lesiones en participantes principiantes / intermedios de CrossFit: una revisión sistemática

RESUMEN

Objetivo: Las lesiones deportivas pueden ocurrir debido a varios factores, lo que hace que sea extremadamente difícil realizar estudios de causa y efecto, controlando y viendo una variable específica. La razón común para la aparición de lesiones es la falta de preparación física para la carga de entrenamiento propuesta, un factor que está más presente en los deportes de alta intensidad.

CrossFit ha ganado mucha atención en los últimos años debido a su variada dinámica deportiva. Los participantes principiantes e intermedios son muy comunes en los gimnasios de CrossFit; por lo tanto, comprender el efecto del entrenamiento para este grupo de atletas es muy importante para una práctica saludable (seguridad y control sobre la tasa de lesiones).

Métodos: solo se incluyeron artículos originales, entre 2000 y 2019 (noviembre), con la búsqueda de la palabra "CrossFit" en nueve bases de datos. Solo fueron aceptados estudios en portugués, inglés o español.

Resultados: después de buscar, solo tres estudios cumplieron los criterios de inclusión siguieron la evaluación *Preferred Reporting Items for Systematic Reviews and Meta-Analyses*. Los sitios lesionados con mayor frecuencia en practicantes principiantes e intermedios fueron hombro y rodilla. Existen mecanismos funcionales y morfológicos que hacen que la lesión sea más común, como los hábitos de vida y la disposición anatómica / fisiológica.

Conclusión: los principiantes y los participantes intermedios de CrossFit demostraron un nivel moderado de lesión. Los estudios con más sujetos mostraron un menor nivel de lesión. Los segmentos más lesionados encontrados fueron rodilla y hombro. Según nuestros resultados, el riesgo de lesiones para principiantes y participantes intermedios de CrossFit es aceptable y se discute en revisiones publicadas recientemente.

Palabras clave: CrossFit; Tasa de lesiones; Gimnasia; Levantamiento Peso.

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Lesão em participantes iniciantes / intermediários de CrossFit: uma revisão sistemática

RESUMO

Objetivo: Lesões esportivas podem ocorrer devido a vários fatores, o que torna extremamente difícil a realização de estudos de causa e efeito, controlando e avaliando uma variável específica. O motivo comum para o aparecimento de lesões é a falta de preparo físico para a carga de treinamento proposta, fator este, mais presente nos esportes de alta intensidade.

CrossFit vem ganhando muita atenção nos últimos anos devido à sua dinâmica de esportes variados. Os participantes iniciantes e intermediários são muito comuns nas academias *CrossFit*; portanto, a compreensão do efeito do treinamento para este grupo é muito importante para a prática saudável (visando a segurança e o controle sobre taxa de lesões).

Métodos: Somente artigos originais foram incluídos, entre 2000 e 2019 (novembro), com a pesquisa da palavra “*CrossFit*” em nove bases de dados. Foram incluídos apenas estudos em português, inglês ou espanhol.

Resultados: Após a triagem, apenas três estudos preencheram os critérios de inclusão após a avaliação do *Preferred Reporting Items for Systematic Reviews and Meta-Analyses*. Os segmentos de lesões mais comuns em praticantes iniciantes e intermediários foi ombro e o joelho. Existem mecanismos funcionais e morfológicos que tornam a lesão mais comum, como hábitos de vida e disposição anatômica / fisiológica do corpo.

Conclusão: participantes iniciantes e intermediários de *CrossFit* demonstraram nível moderado de lesão. Estudos com mais sujeitos mostraram um nível menor de lesão. Os segmentos mais lesionados encontrados foram joelho e ombro. De acordo com nossos resultados, o risco de lesão em participantes iniciantes e intermediários do *CrossFit* é aceitável e discutido em revisões recentes publicadas.

Palavras-Chave: CrossFit; Taxa Lesões; Ginástica; Levantamento Peso.

Introduction

CrossFit is a core strength and conditioning program that elicit multiple adaptational responses such as: enhance of maximum volume of oxygen (Vo₂max), respiratory exchange ratio (RER), metabolic acidosis resistance, lean mass, heart rate recovery, behavior, strength, stamina, flexibility and power.¹⁻⁴ The CrossFit became well known in 2000's and became one of the most popular and rapidly growing exercise regimens in the world. Currently there are more than 13000 CrossFit gyms around the world, and the workout of the day (named as WOD) are commonly practiced by thousands of people everyday.⁵ The WOD is made in high intensity mixing exercises with short or no rest periods, combining exercises in circuit-shaped.⁶ According to the contents of the WOD, there are three sessions modalities: gymnastic, which involve exercise such as pull-ups, sit-ups, push-ups, exercises in hand stand position, rope climb, ring rows, burpees, air squats, etc.; endurance, including cardiovascular exercises, most of them cyclic exercises such as, running, cycling, rowing, skip rope, etc.; and finally, weightlifting and throwing, consisting Olympic lifts (clean & jerk and snatch), deadlifts, weighted squats, overhead press using barbell, kettlebell, dumbbell or sandbags.⁷ Whoever, some WODs can offer more injury risk for participants according the repetitive use of technical exercises (complexes) at a high intensity.^{8,9} Recently, the most discussed and perhaps concerned characteristics of CrossFit model is the high intensity exercise, being done in depleted patterns of strength and aerobic resistance (fatigue). Fatigue put athletes and participants in general at a greater risk of injury decreasing focus on technical competence.¹⁰ Some authors have noted the potential risk of injuries related to CrossFit.^{4,11,12} While injury has been extensively studied (injury can be defined as a lesion that can be of various types: tissue (visceral or structural), there are not conclusive studies evaluating CrossFit injury focusing in beginner and intermediary participants. These subjects are mostly majority in the CrossFit gyms, and often there is no specific training for these subjects. Studies researching about the injury aspects in CrossFit beginner and intermediary participants are scarce and it's needed to elucidate potential risk of injury not overall, but in each training level, by time or performance.

Recently, there are new approaches about fatigue and injury in CrossFit. Tibana et al.¹³ investigated two consecutive days of CrossFit training on interleukins 6 and 10 and osteoprotegerin levels (IL-6 is related with inflammation; IL-10 is related with anti-inflammatory responses; and osteoprotegerin is related with cellular apoptosis). The results showed increasing of IL-6 levels

post WOD 1 and WOD 2, but decreasing values 24 hours after the first WOD and 24 and 48 hours after the WOD 2. Increasing of IL-10 levels after the WOD 1 but decrease values through the time; and the osteoprotegerin levels decreased after 48 hours of WOD2, concluding that two consecutive days of CrossFit training decrease anti-inflammatory cytokines responses without impairments in muscle power.¹³ This could be an alert to change the WOD intensity through the weeks even with the muscle power maintaining all the functions, to minimize any immune disturbances (e.g. chronic stress, open window, flu, etc.).

Another recent study evaluated 885 CrossFit participants to apply a questionnaire about injury.⁵ 33% of them were injured; back and shoulder were the principal injured segments (32% and 20% of injured, respectively). Squats and deadlift showed the most common exercises that caused injury. This could be another alert to change the WOD intensity often and rest more through the training week.

Here, we report a new view of CrossFit, exploring the injury aspects in beginners and intermediaries CrossFit participants, emphasizing injury levels in these population and comparing with another CrossFit participants (amateur and athletes).

The objective of this research is to determine the risk of single type of injury (segment), and to identify the factors that contribute to increase the risk. Finally, this study pretends formulate recommendations about injury and prevention in CrossFit and evaluate the quality of the selected studies.

Methods

Procedures: A literature search was conducted on November 25, 2019. The following database were consulted in our research: Pubmed, Cochrane, Google Scholar, Scopus, PEDro, Web of Science, Scielo, LILACS and Bireme/MedLine. Databases were searched until November 25 with English, Portuguese and Spanish language limitation. Only original full text was accepted. In case of do not find the full text, the selected author was contacted to provide the full text, if there was no answer, the selected manuscript was automatically excluded.

Literature Search: The literature search was conducted in accordance with the “Preferred Reporting Items for Systematic Reviews and Meta-Analyses” (PRISMA) guideline.¹⁴ In each database, the title, abstract or keywords were used, combined with the word “CrossFit” only, this fact was used because of CrossFit is a recent method, and the literature about related topics is still scarce, as used by Meyer et al. e Dominski et al.^{15,16} After conducting the initial search, the references list of the articles

retrieved were screened for any additional articles that had relevance.

Inclusion and exclusion criteria: Studies followed the recommendation of “problem, intervention, comparison and outcome” (PICO), detailed in [Table 1](#).

Table 1. Inclusion and exclusion criteria following PICO recommendation.

Inclusion Criteria	
P	Participate: CrossFit participants at beginner/intermediary level (0-6 months of practice; 6-12 months of practice)
I	Intervention: CrossFit
C	Comparison: Healthy, for a CrossFit affiliate box, control group or variated group
O	Outcome: Injury and / or trauma
Exclusion Criteria	
P	Participate: CrossFit participants at competition level or amateur (more than 12 months of practice) physical exercise in other place (non CrossFit)
I	Intervention: Manual Therapy, stretching, HIIT, Gym Workout, running, weight lifting, swimming, hiking, olympic gymnastic and alternative therapy
C	Comparison: -
O	Outcome: -

Two independent observers (ZOAM; SAP) reviewed the studies following the “Strengthening the Reporting of Observational Studies in Epidemiology” (STROBE) and then individually decided whether inclusion was appropriate.

In order to assess the quality of the selected studies, the STROBE was followed. The checklist of items was conducted to

evaluate each selected study. In the STROBE assessment are 22 items that receive a score from “0” to “1” (from 0 = “do not meet the criteria” to 1 = “meet the criteria”), and the total score was the sum of all items, according to the final score of the study, a classification was conducted following three categories: A – when the study fill more than 80% of the eligibility criteria by STROBE; B- when the study fill between 50% and 79% of the eligibility criteria by STROBE and; C- when the study fill less than 50% of the eligibility criteria by STROBE.¹⁷ The flow chart of each strategy and selection is exposed in [Figure 1](#).

Analysis Statistic

The concordance between the quality of the evaluators were evaluated again for obtained results using quality scale, calculating the Kappa coefficient, been the divergences resolved for consensus. If needed, a third author (PEF) evaluated the studies using STROBE as well.

Results

After the screening three studies were selected (each data phase screening is exposed in [Figure 1](#)) and the studies varied from participants and percentage of injury, ranging from 137 participants to 672 participants and the percentage of injury ranging from 18% to 56%. The data are presented in [Figure 2](#). Analyses revealed that, the bigger is the number of participants, smaller is the injury index.

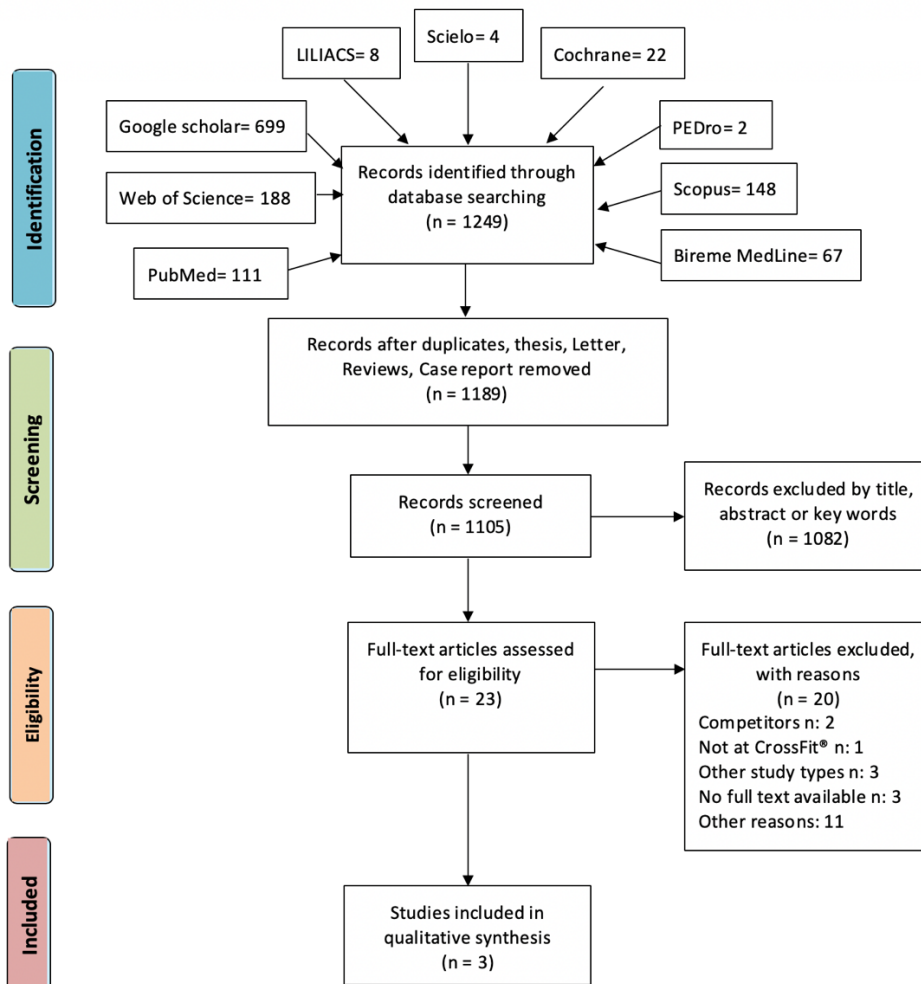


Figure 1. Flowchart of the selection process of the included studies.

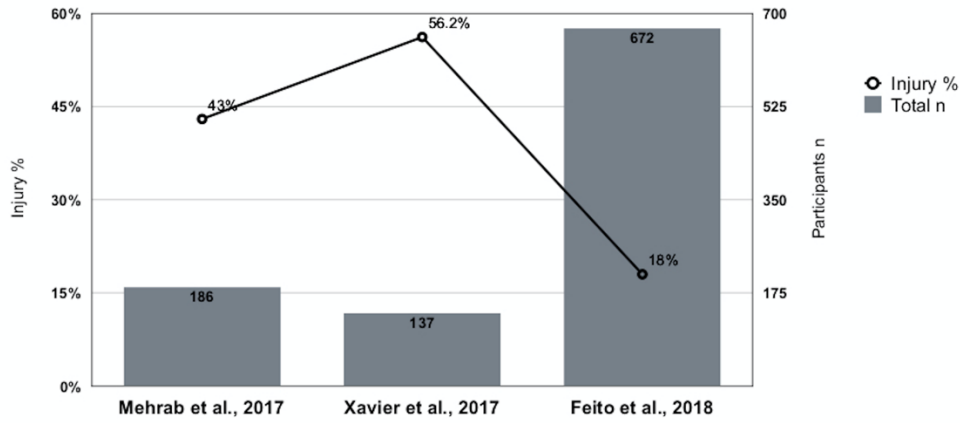


Figure 2. Chart of number of participants and injury of each study.

Figure 3 shows the organization of each injury segment found by each author. Feito et al.¹⁸ found in his study, between the beginner and intermediary injured (<1 year of practice), injury rate of 39% in shoulder, 36% in lumbar or dorsal (back), 15% in knee, 12% in elbow and 11% in wrist. Mehrab et al.¹⁹ found in his study 88 participants who trained CrossFit less than 6 months (29 injuries) and 98 participants who trained from six months to one year (51 injuries). Injury rate was 28% in shoulder, 15% in back and 8% in knee. Xavier et al.²⁰ found a mean of 9 months of CrossFit practice and the injury rate was 24% in shoulder, 22% in spine, 19% in knees, 12% in wrist, 8% in elbows, 6% in hip and 5% in ankle and neck.

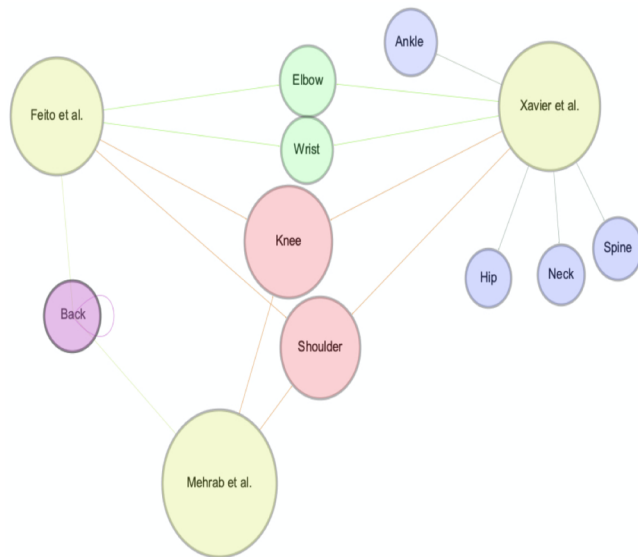


Figure 3. Relationship between authors and injured segments.

The classification of each study following STROBE criteria is exposed in Table 2, two studies reached classification B (Mehrab et al.¹⁹ and Feito et al.¹⁸), and one study reached the classification C (Xavier et al.²⁰).

Discussion

The injury aspects in CrossFit beginners and intermediate participants can prevent future injuries. Specific local technique and strengthening of the most common injured segments may prevent several forms of injuries in high intensity interval training (HIIT), (e.g. CrossFit).

This is the first systematic review investigating injury in beginners and intermediate CrossFit participants.

The present study searched studies that analyzed CrossFit injuries in beginners and intermediate participants in order to find the most injured segments, percentage of injury, relationship between number of participants of each study and injury index, and finally study quality (through STROBE).

First, the study investigated the relationship between number of study participants and injury percentage, as cited in "results". Hak et al., Huynh et al. and Laura et al.^{11,21,22} found high injury index in their studies, ranging from 35% to 73% injuries in overall CrossFit participants (without classification of training level); curiously these studies involved small participants (ranging from 34 to 132). Studies searching bigger number of overall CrossFit participants and injury index found only few cases, ranging the injury index from 5% to 25.4%, and participants number ranging from 386 to 1393, confirming the hypothesis that the bigger is the number of CrossFit interviewed participants, smaller is the injury rate.²³⁻²⁵

The injury site found was spread between ankle (5%), hip (6%), neck (6%) and spine (22%) only in Xavier's study;²⁰ elbow (8% and 12%, respectively) and wrist (8% and 11%, respectively) in Xavier's and Feito's study;^{18,20} lumbar and dorsal (back), (36% and 15.8%, respectively) in Feito's and Mehrab's study and the most common injury site found in CrossFit beginner and intermediary participants was knee (from 8% to 15%) and shoulder (from 24% to 28% and 39%).^{18,20} Hopkins et al.²⁶ in 2017 studied patients who presented to the hospital complaining of an injury sustained performing CrossFit (overall), and of 89 patients 18% of them presented shoulder injury and 15% of them presented knee injury. Hopkins et al.²⁶ found different levels of participants with respect to practice time.²⁶ Weisenthal et al.⁸ examined CrossFit injury through a questionnaire. There was different ability level between the participants, most of them ranging 18-29 years old, male. It was found 84 participants experiencing unless one injury during CrossFit practice. The most injured segments found was shoulder (25%), low back (14%) and knee 13%). Escalante et al., Lopes et al., and Minghelli et al.²⁷⁻²⁹ found higher CrossFit injury index in shoulder limb. Curiously Minghelli study concluded that participants who trained CrossFit less than three times a week appear to be more exposed to injury, suggesting that more practice in the week through the months could lead to injury prevent.²⁹ A recently study evaluated 885 former and current CrossFit athletes.⁵ They applied online questionnaire and searched for specific injuries with associated WODs, risk factors that affected injury including basic demographics, regional differences in reported injuries, training intensity and expertise level at time of injury. 33% (295) of them were injured. The most common injured site was back and shoulder, contradicting the results of the present study, which demonstrated a higher level of shoulder and knee injury, but only in beginner and intermediary. Athletes injured more than beginners, international participants

Table 2. Valuation, Score and Classification of each study following STROBE criteria.

Studies	STROBE CRITERIA							Score		Classification
	Title / Abstract	Introduction	Methods	Results	Discussion	Other Information	Total	%		
	Mehrab ¹⁹	1) 2/2*	2) 1/1 3) 0/1	4) 1/1 5) 1/1 6) 2/2* 7) 0/1 8) 1/1 9) 0/1 10) 1/1 11) 1/1 12) 4/5*	13) 3/3* 14) 2/3* 15) 1/1 16) 2/3* 17) 1/1	18) 1/1 19) 1/1 20) 1/1 21) 1/1	22) 1/1	16	72.72	
Xavier ²⁰	1) 1/2*	2) 1/1 3) 0/1	4) 0/1 5) 0/1 6) 1/2* 7) 0/1 8) 1/1 9) 1/1 10) 0/1 11) 0/1 12) 3/5*	13) 0/3* 14) 2/3* 15) 1/1 16) 3/3* 17) 1/1	18) 0/1 19) 0/1 20) 1/1 21) 1/1	22) 1/1	9	40.90	C	
Feito ¹⁸	1) 2/2*	2) 1/1 3) 0/1	4) 1/1 5) 1/1 6) 0/2* 7) 1/1 8) 1/1 9) 0/1 10) 0/1 11) 1/1 12) 2/5*	13) 1/3* 14) 2/3* 15) 1/1 16) 3/3* 17) 1/1	18) 1/1 19) 1/1 20) 1/1 21) 1/1	22) 0/1	14	63.63	B	

*: Only the item is acceptable if all the subtopics are included in the selected study.

were more likely to development an injury than domestic U.S. Experienced CrossFit participants (more than three years) were more likely to be injured than the others. This study revealed a new approach between training level and injury site.

Other sports separately included in CrossFit have been showing segment injury index very similar.³⁰⁻³² The National Electronic Injury Surveillance System of United States of America (NEISS) explored the weightlifting, estimating that between 2000 and 2017, 5609 cases were found with shoulder injury.³³ The injury found in weightlifting participants through 2000 to 2017 was 0,062% and 0,099% ($p < 0,001$), respectively. NEISS alerted about the injury increase in weightlifting through the years.

The weightlifting in CrossFit was related as the most fatigued kind of exercise due it's complexity of strength and mobility (specially in movements that required overhead position) and it can lead to injury development.⁷ The most commonly weightlifting movements that lead to injury in CrossFit are clean and jerk, deadlift and snatch variations.³⁴ Studies evaluating incidence of injury per 1000h of training demonstrated that bodybuilders reported an average of 0.24-1.00 injury per 1000h of training.³⁵⁻³⁷ Studies analyzing powerlifting injury demonstrated an average of 1.0-1.1 injury per 1000h of training.^{32,38} One study evaluating injury level in Strong Man athletes found an average of 5.5 injury per 1000h or training.³⁹ One study evaluating Highlander Games, that is a popular event in north Europe that celebrate the Scottish and Celtic culture with specific games, found an average of 7.5 injury per 1000h of training/competition.⁴⁰

In Olympic Gymnastics the level of mobility must be enough to sustain the body weight in different angles. The lack of specific mobility (e.g. shoulder mobility) and stability can increase the injury level, due the segment effort in many degrees.⁴¹ Paul-Taro et al.²¹ investigated the prevalence of injury during CrossFit training and it was reported that higher shoulder injury has relationship with high repetition and high intensity. This form of exercise could lead to placing the shoulder at extremes of motion in the risk position (e.g. kipping pull-up, where the shoulder placed in an

extreme position of hyper flexion, internal rotation and abduction). Movements such as push-up, kipping pull-up, cited above, ring muscle-up and ring dips demonstrated to be the major cause of gymnastic injury in CrossFit participants.⁴² In Olympic Gymnastics competition is common to report injury due it's complexity, in CrossFit using gymnastic movements with inappropriate technique can increase the risks.³⁰ The injury average found in 86 studies involving gymnastics sport was 1.4 injuries per 1000 hours of training for men and 1.5 injuries per 1000 hours of training in women.⁴³

Endurance training is a part of CrossFit program, and it do not lead to high intensity (study evolving blood lactate analysis), like weightlifting and gymnastic.⁷ Anyway, the cyclic characteristics of endurance training can overload the articulation, such as knee, each running step requires three times body weight in each knee, it is needed to strengthen the lower limbs to perform better endurance training inside CrossFit (e.g. running and cycling).⁴⁴ One study evaluated three workouts in 34 experienced participants.⁷ The first workout was gymnastic workout, the second was weightlifting workout and the third was metabolic workout. The researcher found higher level of fatigue in the gymnastic and weightlifting workout, but it was found decrease in fatigue at the end of metabolic workout. The authors attributed this find to rest intervals, allowing for the recovery of phosphocreatine stores. Workout that uses similar movements in high intensity and high volume can fatigue more, leading to depletion of high-energy phosphate, limiting the calcium inside the muscle target, decreasing the musculoskeletal Ph, activating less unit cells, and finally worsening the muscular contraction, becoming easier to developing an injury.

When asked to CrossFit participants what exercises they like to do outside of the CrossFit gym, running was the main choose exercise, and curiously, the majority didn't have professional help to practice running.⁴⁵

Videbaek et al.⁴⁶ investigated injury in endurance exercise (running); in their study of review and meta-analysis was found

higher risk of running injury in beginners than experienced practitioners (17.8 per 1000h of training and 7.7 per 1000h of training, respectively).

In the three selected studies in the present review, the average injury index found was 0.74 injuries per 1000 hours of training in Feito et al. study.¹⁸ Mehrab et al. and Xavier et al.^{19,20} did not expose injury in how many injuries for 1000 hours of training, they expose only in percentage (being a limitation cited for Mehrab).

Based on the study of Tibana et al.⁴⁷ evaluating the incidence of injury in CrossFit studies (overall), the injury average is 2.1 injuries per 1000 hours of training. Some CrossFit studies reported a bigger incidence ranging from 2.3 injuries per 1000 hours of training, 3.1 injury per 1000 hours of training to 3.3 injuries per 1000 hours of training.^{12,21,27,48}

STROBE is an assessment that evaluate methodological quality of individual studies. The present review found low to moderate quality scores (presented in “results” section).

All selected studies reached up to 40% of the criteria defined by STROBE. Mehrab et al.¹⁹ did not explain the objectives clearly in “introduction”. Regarding the limitations found, in “methods” Mehrab did not define clearly all outcomes, taking “B” score. Xavier et al.²⁰ did not expose the study design in “abstract”, did not expose specific objectives in “introduction” and did not followed a clear “method”, taking “C” score. Feito et al.¹⁸ in method, did not define clearly all outcomes in “introduction” section, in “methods” section they did not follow the eligibility criteria, taking “B” score.

Dominski et al.¹⁶ evaluate injury in CrossFit practitioners (overall) and evaluate the selected studies also using STROBE. 10 studies were included and nine studies were classified with “B” and only 1 with “A” score.

The role of injury in variated sports (high intensity sports, in special) have been extensively studied to develop strategies to minimize the potential risks. The results still not conclusive and this topic must be object of future studies, because of the prevention of injuries is very important topic for the sports science and sport medicine.⁴⁹

According to the present study, the injury rate found in CrossFit beginners and intermediaries participants is acceptable when compared with powerlifting, gymnastic and endurance sports.

The major limit of the selected studies is the method: the samples obtained focused on participants who practice overall CrossFit, not differentiating the injury through the participation time and percentage of injury for each group (beginner, intermediary, amateur, athlete). Another important bias still in method; the selected studies did not show the study design or the inclusion and exclusion criteria.

Conclusion

CrossFit beginners and intermediate participants showed moderate percentage of injury, presenting low injury percentage studies that had more participants. The most injured segments found were knee and shoulder and it becomes very important to use movements that strengthen these segments at the beginning of CrossFit practice.

Selected studies presented low to moderate study quality. This study can provide information about strategies for coaches to work with CrossFit beginners and intermediaries participants, differentiating from more experienced practitioners and athletes. Although the conclusion, only three studies were selected and used to assess the components of the injury. It is suggested more studies evaluating injury aspects of CrossFit beginner and intermediary participants to fully mechanism understand.

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