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ORIGINAL RESEARCH

Injury profile in CrossFit® practitioners: Prevalence and associated factors during a year of sports practice

Perfil de lesões em praticantes de CrossFit®: prevalência e fatores associados durante um ano de prática esportiva

Perfil de lesiones en practicantes de CrossFit®: prevalencia y factores asociados durante un año de práctica deportiva

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ABSTRACT | This study aimed to investigate the prevalence of injuries in CrossFit® practitioners and the influence of sports practice and demographic characteristics on these injuries. A retrospective cohort study was carried out with 180 CrossFit® practitioners who answered a questionnaire with demographic characteristics (age, body mass, height, and sex), sports characteristics (number of years practicing CrossFit®; training frequency, duration, and training program; and practice of other sports), and presence of any injury suffered and its characteristics (number of injuries, region, and type of injury). The Mann-Whitney U test investigated the difference in continuous variables between those with and without injury history. The chi-square test and Fisher's exact test investigated the association between categorical variables and the presence or not of injury over the last year. The chi-square goodness-of-fit test investigated if the frequency of injuries per body location and type differed from the expected one. Injury prevalence was 63%. Participants with a history of injury showed a shorter time of CrossFit® practice. The presence of injury history was associated with lesser weekly and daily training frequency, shorter training duration, and Scale training program. The frequency of injuries on leg, knee, lumbar spine, shoulder, and wrist, and the muscle and tendon was greater than expected. The other variables were neither different between groups nor associated with injury presence. Thus, most participants presented injury over the last year, influenced by the sports characteristics but not by demographic characteristics.

Keywords | Injuries; Epidemiology; CrossFit; Sports.

RESUMO | Este estudo teve como objetivo investigar a prevalência de lesões durante um ano em praticantes de CrossFit® e a influência das características da prática esportiva e demográficas nessas lesões. Foi realizado estudo de coorte retrospectivo com 180 praticantes de CrossFit®, que responderam a um questionário sobre: características demográficas (idade, massa corporal, altura e sexo), características da prática esportiva (tempo de prática esportiva, frequência e duração de treino, formação de carga e prática de outro esporte) e ocorrência e características da lesão (quantidade, região lesionada e estrutura acometida). Por meio do teste de Mann-Whitney U, investigou-se a diferença nas variáveis contínuas entre aqueles com e sem histórico de lesão. Utilizando o teste de qui-quadrado e o teste exato de Fisher, avaliou-se a associação entre variáveis categóricas e a presença ou não de lesão. O teste de qui-quadrado *goodness-of-fit* foi aplicado para investigar se a frequência observada de lesões por região do corpo e por tipo era diferente da esperada. A prevalência de lesão foi de 63%, e aqueles com histórico de lesão tinham menor tempo de prática esportiva. A presença de histórico de lesão foi associada a menor frequência semanal e diária e menor duração de treinos, assim como à formação de carga Scale. A frequência de lesão em perna, joelho, coluna lombar, ombro e punho, assim como do tipo músculo e tendão foi acima da esperada. As demais variáveis não apresentaram diferença entre grupos ou não foram

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This study results were partially showed at the 10th Brazilian Conference, 7th SONAFE-Brazil International Conference 2021.

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associadas à presença de lesão. Logo, a maioria dos investigados relatou lesão que foi influenciada pelas características da prática esportiva, e não pelas demográficas.
Descritores | Lesões; Epidemiologia; CrossFit; Esporte.

RESUMEN | Este estudio tuvo como objetivo investigar la prevalencia de lesiones en practicantes de CrossFit® durante un año y la influencia de las características deportivas y demográficas en estas lesiones. Se trata de estudio de cohorte retrospectivo, realizado con 180 practicantes de CrossFit®, quienes respondieron a un cuestionario que contenía: características demográficas (edad, masa corporal, altura y sexo), características de la práctica deportiva (tiempo de práctica deportiva, frecuencia y duración del entrenamiento, carga de entrenamiento y práctica de otro deporte) y ocurrencia y características de la lesión (cantidad, región lesionada y estructura afectada). Para el análisis de la diferencia en las variables continuas entre los practicantes con y sin antecedentes de lesiones, se utilizó la prueba U de Mann-Whitney. Se evaluó la asociación entre las variables categóricas y la presencia o ausencia de lesión mediante la prueba de chi-cuadrado y la prueba exacta de Fisher. La prueba de chi-cuadrado *goodness-of-fit* se aplicó para investigar si la frecuencia de lesiones por parte del cuerpo y por tipo era distinta de lo esperado. La prevalencia de lesión fue del 63%, y los practicantes con antecedente de lesión tenían menor tiempo de práctica deportiva. La presencia de antecedentes de lesión se asoció con una menor frecuencia semanal/diaria y una menor duración del entrenamiento, así como con la formación de la carga de Scale. La frecuencia de lesiones en la pierna, la rodilla, la columna lumbar, el hombro y la muñeca, así como de tipo muscular y tendinoso fue mayor a la esperada. Las demás variables no mostraron diferencia entre grupos o no se asociaron con la presencia de lesión. Por lo tanto, la mayoría de los participantes reportaron presentar una lesión que estuvo influenciada por las características de la práctica deportiva, y no por la demografía.
Palabras clave | Lesiones; Epidemiología; CrossFit; Deporte.

INTRODUCTION

CrossFit® is one of the new sports trends included among the practices classified as extreme conditioning programs, with many professional and amateur practicioners[1]. Its practice is characterized by sessions called workout of the day (WOD), in which exercises are quickly performed, with little or no recovery time between sets, with large loads and focusing on the constant variation of functional movements[1,2]. This variation mimics the challenges found in sports, such as in combat sports[2]. Usually, a CrossFit® session lasts approximately for one hour and includes a warm-up period, training aimed at strengthening and/or training specific tasks, and a cooling-down period[1]. CrossFit® encompasses multiple exercises, for example: weightlifting, gymnastics, running, cycling, plyometric exercises, and rowing[2]. Furthermore, this modality requires an advanced technique for performing maximum repetitions of timed exercises[2]. These characteristics can overload the practitioner's body, generating early fatigue, additional oxidative stress, and greater perceived exertion[3,4]. Thus, this high demand of sports practice on the CrossFit® practitioner's musculoskeletal system may favor injuries different from those of other sports[5]. Recognizing typical sports injuries is the first step in planning their prevention in the field of Sports Physical Therapy[6].

The literature shows a great variation regarding the epidemiological indices related to injury in CrossFit® practitioners[4,7]. For example, Claudino et al.[4] identified different rates of injury prevalence with a systematic review, ranging from 19% to 74%. While another review identified an incidence of 35%, the most injured sites were: shoulders, torso/lumbar, and knees[7]. Thus, the different findings in the literature reinforce the need for further studies on the subject.

In addition to recognizing the prevalence of injuries in CrossFit® and the most affected sites, the injury profile can also be related to the typical characteristics of this sport[8]. Factors such as time of sports practice, weekly and daily training frequency, duration of training, performance of other sports practice and training program characterize this sport and may be associated with injury profile. Factors related to the level of participation, volume and training load, as well as demographic characteristics have already been considered in investigations on the profile of injuries in different sports[9-11]. For example, a literature review indicated that a greater amount of training hours and a large increase of load were associated with shoulder injuries in sports with overhead movements[11]. Some studies with CrossFit® practitioners have identified similar results, suggesting that the greater the exposure, the greater the chance of injury[12]. On the other hand, other studies did not identify differences in the injury rate according to the weekly frequency and training duration[13,14], as well as the joint practice of another sport[15]. Also, some studies have identified a higher risk of injury among less experienced practitioners, who train less frequently and who practice

another sport[12,16]. The type of training program is a little investigated factor, but it has already been associated, by another study, with musculoskeletal injuries in sport[15].

Demographic characteristics are also commonly considered in the analysis of injury profile; however, the literature findings are conflicting regarding CrossFit®. While some studies suggest a relationship between frequency of injury, male and older age[12], others have not identified the influence of sex and age on the occurrence of injuries, as well as other characteristics such as height and body mass[14,15]. Thus, new studies that investigate demographic characteristics and sports practice can contribute to the understanding of the different outcomes related to the injury profile in CrossFit®.

Thus, this study aimed to investigate the prevalence of injuries in a one-year period among CrossFit® practitioners and the influence of demographic and the sports characteristics on these injuries. The hypothesis of this study is that both sports and demographic characteristics should be related to the history of injuries in a one-year period of sports practitioners. The results of the study may contribute to the understanding of the injury profile of CrossFit® practitioners and to the planning of preventive actions.

METHODOLOGY

This retrospective cohort study was conducted based on the data collected by a self-administered questionnaire to identify the characteristics of injuries that occurred during 2019 in 180 CrossFit® practitioners. These practitioners were recruited by convenience sampling in a licensed CrossFit® box, in Belo Horizonte, Minas Gerais. The inclusion criteria were individuals aged over 18 years and having trained CrossFit® during the 12 months of 2019. The exclusion criteria were individuals who did not completely fill the questionnaire and belong to another training box. All participants signed the informed consent form.

Procedures

The questionnaire was made available to practitioners during August and September 2020, disseminated via digital platforms. The initial questions were related to demographic characteristics—age, body mass, height, and sex—, and the following questions to sport characteristics—time of practice, weekly and daily training frequency, daily training duration, practice of other sports and training program (RX/Scale, intermediate or other). Finally, the participants were asked to inform the number of injuries occurred in the studied year of sports practice and, in the presence of injury, the injured body region and the affected structure (muscle, tendon, bone, joint, ligament, or others). Injury was considered as any damage caused by physical trauma to body tissues, which may be a single trauma or the result of repeated long-term loads[17]. These injuries should have occurred during the training or as a result of them, resulting in a reduction or complete withdrawal of the practitioners of the activity[17]. This definition of injury was presented in the questionnaire.

Statistical analysis

Participants were organized into two groups: with and without a history of injury. The prevalence of injuries was calculated by the proportion of CrossFit® practitioners who presented injuries in 2019. Descriptive statistics were used to calculate mean and standard deviation of continuous variables (age, body mass, height, and time of sports practice). The categorical variables (sex, weekly and daily training frequency, daily training duration, practice of another activity, and training program) were presented as observed frequency and percentage per group.

For the inferential statistical analysis of continuous variables, the Shapiro-Wilk test revealed that the data did not present a normal distribution. Thus, the Mann-Whitney U test was used to investigate the difference between the groups with and without a history of injury for these variables.

For the inferential statistical analysis of categorical variables, the association with the presence or absence of a history of injury was investigated using the chi-square test or Fisher's exact test. The choice between these tests occurred according to the analysis of the expected frequency in the cells of the contingency table. In cases where the expected frequency was less than five, Fisher's exact test (weekly training frequency and training program) was chosen and in the other cases the chi-square test (sex, daily training frequency, daily training duration, and practice of other physical activity) was used. In the presence of a significant association, the adjusted residual analysis was used to identify which cell of the contingency table made a significant contribution to the result. In this analysis, if the adjusted residual value was greater than ±1.96, this indicated that the number of cases in the contingency table cell was different from the expected. Furthermore, the chi-square goodness-of-fit test was used to investigate whether the observed frequency of injuries by body region and type was different from

that expected. A significance level of 0.05 was adopted for all analyses.

RESULTS

Among the 180 practitioners, 113 (63%) suffered injuries in 2019. Table 1 shows the demographic characteristics according to the presence or absence of injury in the last year and the p-value of the inferential analysis. The groups showed no difference in age, body mass, and height. Moreover, no association was observed between the sex of the participant and history of injury.

Table 2 shows the sport characteristics according to the presence or absence of injury in the last year and the p-value of the inferential analysis. The groups differed regarding the time of sports practice, and those with a history of injury had less time of sports practice. There was no association between the presence of a history of injury and the practice of other physical activity.

Table 1. Participant demographic characteristics

	No history of injury in the last year n=67	With a history of injury in the last year n=113	P-value
Age (years)*	26.5 (3.4)	26.2 (4.1)	0.14
Body mass (kg)*	74.2 (15.1)	74.0 (13.6)	0.96
Height (cm)*	171.7 (12.1)	169.2 (11.9)	0.17
Sex			
Female (%)	32 (47.8%)	62 (54.4%)	0.39
Male (%)	35 (52.2%)	52 (45.6%)	

*: Age, body mass and height are expressed as mean (standard deviation).

Table 2. Characteristics of the participants' sports practice

	No history of injury in 2019 n=67	With a history of injury in 2019 n=113	P-value
Time of sports practice (years)	4.4(1.4)	3.5 (1.5)	<0.001*
Weekly training frequency			<0.001*
2×	0 (0.0%)	6 (5.3%)	
3×	3 (4.5%)	51 (44.7%)	
4×	3 (4.5%)	3 (2.6%)	
5×	8 (11.9%)	3 (2.6%)	
6×	53 (79.1%)	51 (44.7%)	
Daily training frequency			<0.001*
1× per day	15 (22.4%)	63 (55.3%)	
>1× per day	52 (77.6%)	51 (44.7%)	
Daily training duration			<0.001*
1 hour per day	14 (20.9%)	66 (57.9%)	
>1h per day	53 (79.1%)	48 (42.1%)	
Practice of other sporting activity			0.85
No	65 (97.0%)	110 (96.5%)	
Yes	2 (3.0%)	4 (3.5%)	
Training program			<0.001*
RX	51 (76.1%)	43 (37.7%)	
Scale	5 (7.5%)	58 (50.9%)	
Intermediary	10 (14.9%)	13 (11.4%)	
Other	1 (1.5%)	0 (0.0%)	

*: statistical difference between groups, p<0.05.

The tests revealed an association between history of injury and the following variables: weekly training frequency, daily training frequency, duration of training per day, and training program. For each of these associations, the adjusted residual analysis was performed.

For the association between injury history and weekly training frequency, those who trained three times a week (Z=5.7) were the ones that contributed the most among those with injury history. Among those without history of injury, those who trained five (Z=2.5) or six (Z=4.5) times contributed more to the association.

Regarding the daily frequency of training, there was a greater contribution to the association of this variable with the history of injuries among participants with a history of injury who practiced no more than once a day (Z=4.3) and among participants without a history of injury who practiced more than once a day (Z=4.3).

There was a greater contribution to the association of injury history with training duration among those with a history of injury who trained up to 1h per day (Z=4.8) and among those without a history of injury who trained more than 1h per day (Z=4.8).

For the association of history of injury and training program, there was a greater contribution among those with a history of injury who had a Scale formation (Z=5.9) and among those without a history of injury who had an RX formation (Z=5.0).

The observed frequency of injuries by body region and type of injury is shown in Tables 3 and 4, respectively. The chi-square goodness-of-fit test was significant for both the injured body region ($p<0.001$) and the type of injury ($p<0.001$). The frequency of injury observed in the leg, knee, lumbar spine, shoulder, and wrist was higher than expected, as well as that observed in muscle and tendon.

Table 3. Injured body region

Injured body region	Quantity (%)
Lumbar spine	98 (37.0%)
Shoulder	56 (21.1%)
Knee	38 (14.3%)
Leg	31 (11.7%)
Wrist	22 (8.3%)
Calf	5 (1.9%)
Ankle	4 (1.5%)
Forearm	3 (1.1%)
Elbow	2 (0.8%)
Thigh – posterior region	2 (0.8%)
Thigh – anterior region	1 (0.4%)
Hand	1 (0.4%)
Foot	1 (0.4%)
Hip	1 (0.4%)
Head	0 (0.0%)
Cervical spine	0 (0.0%)
Thoracic spine	0 (0.0%)
Total	265 (100%)

Table 4. Type of injury

Type of injury	Quantity (%)
Muscle	99 (45.0%)
Tendon	70 (31.8%)
Bone	30 (13.6%)
Joint	14 (6.4%)
Ligament	5 (2.3%)
Others	2 (0.9%)
Total	220 (100%)

DISCUSSION

This study investigated the injuries that occurred in CrossFit® practitioners during 2019 and analyzed the influence of demographic characteristics and sports practice on these injuries. The observed prevalence was 63%, similar to the study by Mehrab et al.[16], which identified 56.1% in one year of sports practice, and the study by Elkin et al.[5], which identified 60.7% in two years. Thus, the prevalence identified corroborates similar studies that indicate a proportion of more than 50% of the sample with a history of injury.

The variables age, body mass, and height did not differ between groups, and no association was observed between sex and history of injury. The influence of these demographic characteristics on the injury profile is typically considered in studies on other sports[9,10]. In addition, these results corroborate findings of other studies with practitioners of CrossFit®[14,18]. A review on weightlifting sports identified that the influence of age and sex on the injury profile is minimal[9]. Thus, it is suggested that demographic characteristics are not the main factors related to injury in CrossFit® practitioners.

The practice of another physical activity was not associated with the history of injury, as observed in another study[14]. The other characteristics of sports practice investigated were related to the history of injury. Practitioners with and without a history of injury

differed regarding time of sports practice, in which those with a history of injury had a shorter time of practice. This result corroborates another study that demonstrated that the risk of injuries was higher among participants new to CrossFit® than the experienced ones[19]. A possible explanation for this finding is that practitioners with less experience may not have adequate knowledge of the training techniques, as well as not having the physical preparation necessary to meet the demand required for the sport. The observed association between training program and injury history can be interpreted similarly.

Training program is defined from the average pattern of movements and loads used in the benchmarks and WODs proposed in each championship, in order to exploit the athletes' physical capacity to the maximum level. Individuals are classified according to the years of sports practice and the training of the practitioner: (1) beginner: usually up to two months of practice, depending on individual evolution, with basic movements; (2) Scale: less than one year of practice and performing only a few movements of the WOD; (3) intermediate or evolution: over one year of practice, performs more movements of the WOD compared to the RX, but with lower loads; and (4) RX: two to four years of experience in the modality, performing all movements of the WOD with the suggested loads. The results suggested that those with a history of injury who presented Scale training and those without a history of injury who presented RX training were the ones who most contributed to this association. Thus, the expertise for the execution of movement and adequate physical conditioning can be key points to be considered in an injury prevention program.

Training with lowest weekly frequency, once a day, for one hour was associated with the history of injury. This finding corroborates a study that observed that CrossFit® practitioners who trained up to twice a week showed a 3.24 times higher probability of injury than those who training sessions three or more times[20]. In this perspective, those individuals with fewer weekly training sessions may have less experience and skill in the techniques of the modality and less adaptation to the load stimuli. Thus, these practitioners may not have the necessary ability to deal with the burden of sport and, thus, present negative effects on their health[21].

Most injuries were observed in the lumbar spine. While this region corresponded to 37% of the reported injuries in our investigation, other studies report percentages raging from 17.9% to 36% of injuries in this region among CrossFit® practitioners[18,20,22,23]. The result may be related to the characteristics of the gestures performed, which are generally defined by repetitive movements at high speed and load[1,2,24]. Furthermore, the imposed axial load requires the thoracic and lumbar spine to be aligned[23]. The high axial load added to the large number of repetitions can lead to early fatigue, and the practitioner may adopt an inadequate posture, such as performing the movement while maintaining the lumbar spine flexed[23].

Shoulder was the second most injured region, followed by knee, leg, and wrist. The shoulder and wrist are joints commonly injured in gymnastic and weightlifting movements[25]. These joints receive a high load during these movements, often in extreme amplitudes[26,27]. Lower limb injuries, such as knee and leg injuries, are commonly related to weightlifting movements[13]. Deep squats with the bar above the head are an example of movements that the athletes indicate as those more likely to cause injury to the lower limbs, due to excessive effort and the various precautions necessary for execution[13,28]. In addition, most injuries were muscular, followed by those tendon-related. These findings reinforce the high demand on the musculoskeletal system during the practice of CrossFit®[29], since the injuries are typically related to excessive tension forces, specifically the frequent repetitive eccentric movements and the imposed load[28,30].

This study has limitations, such as considering possible factors related to injuries in only one CrossFit® box practitioners. Other factors such as characteristics of the musculoskeletal system (e.g., asymmetry in torque generation capacity) have not been investigated and may contribute to the injury profile. Also, this study did not investigate the time loss and the type of treatment received by practitioners of this modality, which limits the interpretation of the impact of injury on sports practice. Other factors not investigated may also be associated with injuries, such as history of previous musculoskeletal injuries, history of practice of other physical activity before CrossFit®, level of supervision, and characteristics of periodization in sports planning. Furthermore, the registration of injuries may present memory biases[31], since practitioners tend to report only the injuries that most impacted their practice. The restriction of injuries to those that occurred in the previous year rather than in a longer period was the strategy adopted to minimize these biases. Injury registration was also performed based on self-report. Although this procedure is similar to

those used in other studies[5,14,18,24,25], it can be influenced by the interpretation of the questionnaire and by the understanding of the injury. Thus, future investigations may consider other factors that may be associated with the history of injury in CrossFit® practitioners, as well as the implementation and analysis of a database with standardized records.

This study results can contribute to the planning of preventive interventions by sports physical therapists. Due to the high prevalence of injuries, most CrossFit® practitioners would probably benefit from an assessment that would track aspects to be addressed preventively. In addition, the findings suggest that greater preparation may be beneficial for the practitioner, since those with a history of injury had less time of sports practice and the presence of a history of injury was associated with training in lesser weekly and daily frequency and with shorter duration, as well as the Scale training program. Probably, the high demand required by several CrossFit® activities requires a great capacity of the musculoskeletal system to deal with the stresses generated in the exercises[32]. Finally, the preventive intervention should consider possible injuries located in the legs, knees, lumbar spine, shoulders, and wrists, especially those related to the muscle and tendon because they are the most frequently reported location and type of injury.

CONCLUSION

Most CrossFit® practitioners had a history of injury, with a prevalence of injuries to the muscle and tendon and located in the leg, knee, lumbar spine, shoulder, and wrist. The demographic characteristics investigated did not influence the injury profile, unlike the characteristics of sports practice, since a relationship was found between injury history and shorter time of sports practice. Moreover, the report of injury was associated with Scale training with lowest weekly frequency, once a day, and for one hour.

REFERENCES

1. Wagener S, Hoppe MW, Hotfiel T, Engelhardt M, Javanmardi S, Baumgart C, et al. CrossFit® – development, benefits and risks. Sportorthopa¨die-Sporttraumatologie. 2020;36(3):241-9. doi: 10.1016/j.orthtr.2020.07.001.
2. Glassman G. A theoretical template for CrossFit's programming. Crossfit Journal Articles. 2013;(6):1-5.
3. Maté-Muñoz JL, Lougedo JH, Barba M, García-Fernández P, Garnacho-Castaño MV, Domínguez R. Muscular fatigue in response to different modalities of CrossFit sessions. PloS One. 2017;12(7):e0181855. doi: 10.1371/journal.pone.0181855.
4. Claudino JG, Gabbett TJ, Bourgeois F, Souza HS, Miranda RC, Mezêncio B, et al. CrossFit overview: systematic review and meta-analysis. Sports Med Open. 2018;4(1):11. doi: 10.1186/s40798-018-0124-5.
5. Elkin JL, Kammerman JS, Kunselman AR, Gallo RA. Likelihood of injury and medical care between CrossFit and traditional weightlifting participants. Orthopaedic J Sports Med. 2019;7(5):2325967119843348. doi: 10.1177/2325967119843348.
6. van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. Sports Med. 1992;14(2):82-99. doi: 10.2165/00007256-199214020-00002.
7. Gean RP, Martin RD, Cassat M, Mears SC. A systematic review and meta-analysis of injury in Crossfit. J Surg Orthopaedic Adv. 2020;29(1):26-30.
8. Jones CM, Griffiths PC, Mellalieu SD. Training load and fatigue marker associations with injury and illness: a systematic review of longitudinal studies. Sports Med. 2017;47(5):943-74. doi: 10.1007/s40279-016-0619-5.
9. Keogh JWL, Winwood PW. The epidemiology of injuries across the weight-training sports. Sports Med. 2017;47(3):479-501. doi: 10.1007/s40279-016-0575-0.
10. Engebretsen L, Soligard T, Steffen K, Alonso JM, Aubry M, Budgett R, et al. Sports injuries and illnesses during the London Summer Olympic Games 2012. Br J Sports Med. 2013;47(7):407-14. doi: 10.1136/bjsports-2013-092380.
11. Asker M, Brooke HL, Waldén M, Tranaeus U, Johansson F, Skillgate E, et al. Risk factors for, and prevention of, shoulder injuries in overhead sports: a systematic review with best-evidence synthesis. Br J Sports Med. 2018;52(20):1312-9. doi: 10.1136/bjsports-2017-098254.
12. Rodríguez MA, García-Calleja P, Terrados N, Crespo I, del Valle M, Olmedillas H. Injury in CrossFit®: a systematic review of epidemiology and risk factors. Phys Sportsmed. 2022;50(1):3-10. doi: 10.1080/00913847.2020.1864675.
13. Weisenthal BM, Beck CA, Maloney MD, DeHaven KE, Giordano BD. Injury rate and patterns among CrossFit athletes. Orthopaedic J Sports Med. 2014;2(4):2325967114531177. doi: 10.1177/2325967114531177.
14. Sprey JWC, Ferreira T, de Lima MV, Duarte A Jr, Jorge PB, Santili C. An epidemiological profile of CrossFit athletes in Brazil. Orthop J Sports Med. 2016;4(8):2325967116663706. doi: 10.1177/2325967116663706.
15. Szeles PRQ, Costa TS, Cunha RA, Hespanhol L, Pochini AC, Ramos LA, et al. CrossFit and the epidemiology of musculoskeletal injuries: a prospective 12-week cohort study. Orthop J Sports Med. 2020;8(3):2325967120908884. doi: 10.1177/2325967120908884.
16. Mehrab M, de Vos RJ, Kraan GA, Mathijssen NMC. Injury incidence and patterns among Dutch CrossFit athletes.

Orthop J Sports Med. 2017;5(12):2325967117745263. doi: 10.1177/2325967117745263.

17. Bahr R, Clarsen B, Derman W, Dvorak J, Emery CA, Finch CF, et al. International Olympic Committee Consensus Statement: methods for recording and reporting of epidemiological data on injury and illness in sports 2020 (including the STROBE Extension for Sports Injury and Illness Surveillance (STROBE-SIIS)). Orthop J Sports Med. 2020;8(2):2325967120902908. doi: 10.1177/2325967120902908.
18. Feito Y, Burrows EK, Tabb LP. A 4-year analysis of the incidence of injuries among CrossFit-trained participants. Orthop J Sports Med. 2018;6(10):2325967118803100. doi: 10.1177/2325967118803100.
19. Larsen RT, Hessner AL, Ishøi L, Langberg H, Christensen J. Injuries in novice participants during an eight-week start up CrossFit program-a prospective cohort study. Sports (Basel). 2020;8(2):21. doi: 10.3390/sports8020021.
20. Minghelli B, Vicente P. Musculoskeletal injuries in Portuguese CrossFit practitioners. J Sports Med Phys Fitness. 2019;59(7):1213-20. doi: 10.23736/S0022-4707.19.09367-8.
21. Verhagen E, Gabbett T. Load, capacity and health: critical pieces of the holistic performance puzzle. Br J Sports Med. 2019;53(1):5-6. doi: 10.1136/bjsports-2018-099819.
22. Lima PO, Souza MB, Sampaio TV, Almeida GP, Oliveira RR. Epidemiology and associated factors for CrossFit-related musculoskeletal injuries: a cross-sectional study. J Sports Med Phys Fitness. 2020;60(6):889-94. doi: 10.23736/S0022-4707.20.10364-5.
23. Hopkins BS, Cloney MB, Kesavabhotla K, Yamaguchi J, Smith ZA, Koski TR, et al. Impact of CrossFit-related spinal injuries. Clin J Sport Med. 2019;29(6):482-5. doi: 10.1097/JSM.0000000000000553.
24. Hak PT, Hodzovic E, Hickey B. The nature and prevalence of injury during CrossFit training. J Strength Cond Res. 2013 Nov 22. doi: 10.1519/JSC.0000000000000318.
25. Summitt RJ, Cotton RA, Kays AC, Slaven EJ. Shoulder injuries in individuals who participate in CrossFit training. Sports Health. 2016;8(6):541-6. doi: 10.1177/1941738116666073.
26. Benjamin HJ, Engel SC, Chudzik D. Wrist pain in gymnasts: a review of common overuse wrist pathology in the gymnastics athlete. Cur Sports Med Rep. 2017;16(5):322-9. doi: 10.1249/JSR.0000000000000398.
27. Hulstyn MJ, Fadale PD. Shoulder injuries in the athlete. Clin Sports Med. 1997;16(4):663-79. doi: 10.1016/S0278-5919(05)70047-8.
28. Järvinen TA, Kääriäinen M, Järvinen M, Kalimo H. Muscle strain injuries. Curr Opin Rheumatol. 2000;12(2):155-61. doi: 10.1097/00002281-200003000-00010.
29. Fisker FY, Kildegaard S, Thygesen M, Grosen K, Pfeiffer-Jensen M. Acute tendon changes in intense CrossFit workout: an observational cohort study. Scan J Med Sci Sports. 2017;27(11):1258-62. doi: 10.1111/sms.12781.
30. Aicale R, Tarantino D, Maffulli N. Overuse injuries in sport: a comprehensive overview. J Orthop Surg Res. 2018;13(1):309. doi: 10.1186/s13018-018-1017-5.
31. Portney LG, Watkins MP. Foundations of clinical research: applications to practice. 3rd ed. Philadelphia: F. A. Davis; 2015.
32. Fonseca ST, Ocarino JM, Silva PLP, Aquino CF. Integration of stresses and their relationship to the kinetic chain. In: Magee DJ, Zachazewski JE, Quillen WS, editors. Scientific foundations and principles of practice in musculoskeletal rehabilitation. St. Louis: Saunders Elsevier; 2007. p. 476-86.