

Parallels between Artistic Gymnastics and CrossFit®: epidemiological, clinical, and biomechanical analysis of injuries in these modalities

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ABSTRACT

CrossFit® is one of the most widely practiced forms of physical conditioning worldwide, incorporating elements of Olympic weightlifting and artistic gymnastics (AG). Although its popularity has been accompanied by concerns about safety, recent epidemiological evidence indicates that injury rates in CrossFit® are comparable to those in other traditional sports and resistance training. However, simply quantifying the incidence is not sufficient to understand the etiological mechanisms of injuries associated with the practice. This narrative review proposes an integrated analysis of the epidemiological, clinical, and biomechanical convergences between CrossFit® and Artistic Gymnastics, recognizing the latter as a reference model for understanding the injuries observed in CrossFit® practitioners. There is a predominance of injuries to the shoulder, lumbar spine, and lower limbs in both modalities, attributed to the combination of complex gymnastic movements, high joint demands, and neuromuscular fatigue induced by concurrent training. In CrossFit®, movements traditionally restricted to experienced gymnasts are performed by recreational practitioners under conditions of high volume and/or intensity in the challenges characteristic of the sport, favoring the deterioration of motor control and increasing the risk of tissue overload. The review emphasizes that injury prevention should prioritize adequate load management, careful technical progression inspired by established practices in artistic gymnastics. Thus, CrossFit® is not inherently more harmful, but it requires rigorous application of biomechanical and physiological principles to ensure safety and longevity in the sport.

Keywords: exercise ; injuries ; joints ; weight lifting ; gymnastics

RESUMO

O CrossFit® é uma das modalidades de condicionamento físico mais praticadas mundialmente que incorpora elementos do levantamento de peso olímpico e da Ginástica Artística (GA). Embora sua popularização tenha sido acompanhada por preocupações quanto à segurança, evidências epidemiológicas recentes indicam que as taxas de lesão no CrossFit® são comparáveis às de outras modalidades esportivas tradicionais e a prática de treinamento resistido. No entanto, a simples quantificação da incidência não é suficiente para compreender os mecanismos etiológicos das lesões associadas à prática. Esta revisão narrativa propõe uma análise integrada das convergências epidemiológicas, clínicas e biomecânicas entre o CrossFit® e a Ginástica Artística, reconhecendo esta última como um modelo de referência para a compreensão das lesões observadas em praticantes de Crossfit®. Há uma predominância de lesões no ombro, coluna lombar e membros inferiores em ambas as modalidades, atribuídas à combinação de movimentos gímnicos complexos, altas demandas articulares e fadiga neuromuscular induzida por treinos concorrentes. No CrossFit®, movimentos tradicionalmente restritos a ginastas experientes são executados por praticantes recreativos sob condições de elevado volume e/ou intensidade nos desafios característicos a modalidade, favorecendo a deterioração do controle motor e o aumento do risco de sobrecarga tecidual. A revisão enfatiza que a prevenção de lesões deve priorizar a gestão adequada da carga e a progressão técnica criteriosas inspirados nas práticas consolidadas da Ginástica Artística. Assim, o CrossFit® não é inerentemente mais lesivo, porém exige rigor na aplicação de princípios biomecânicos e fisiológicos para garantir segurança e longevidade esportiva.

Palavras-chave: exercício físico; lesões; articulações; levantamento de peso; ginástica

Introduction

Over the past decade, the global fitness landscape has been reshaped by the rise of CrossFit®, a training modality characterized by constantly varied functional movements performed at high intensity. What began as a heterodox training method evolved into a competitive “fitness sport,” with millions of practitioners worldwide [1,2]. CrossFit® is based on methodological hybridism, incorporating Olympic weightlifting, metabolic conditioning, and, crucially, elements of Artistic Gymnastics (AG), such as muscle-ups, handstand push-ups, and suspended swinging movements (kipping).

The widespread adoption of this modality, however, has been accompanied by growing concern within the medical and scientific communities regarding practitioner safety. The configuration of challenges employed in training sessions (Workouts of the Day—WODs), such as every minute on the minute (EMOM), as many rounds/reps as possible (AMRAP), and rounds for time (For Time), favors competition against the clock in an attempt to complete a given volume within up to one minute while using the remaining time for recovery in successive minute-by-minute cycles (EMOM), perform more repetitions within a given period (AMRAP), or complete a prescribed volume in the shortest possible time (For Time) [3]. Due to their competitive nature, such strategies have raised hypotheses regarding a disproportionate risk of musculoskeletal injuries [1,4].

However, reviews indicate that the injury incidence rate in CrossFit®, ranging approximately between 2.3 and 3.1 injuries per 1,000 training hours, is comparable, and in some cases lower than that observed in traditional modalities such as powerlifting, long-distance running, and Artistic Gymnastics itself [5,6]. This evidence suggests that CrossFit® per se is a safe modality and that it incorporates teaching and progression strategies that help preserve practitioner safety, particularly when training is supervised by qualified professionals [7,8].

Despite parity in overall incidence rates, mere quantification is insufficient to understand the etiology of injuries in these practitioners. It is imperative to analyze movement quality and the specificity of the loads imposed on tissues. By integrating gymnastic movements, some of which exhibit high complexity, within a concurrent training regime, in which aerobic and anaerobic pathways compete, generating distinct physiological responses and pronounced neuromuscular fatigue [9], CrossFit® exposes practitioners, often recreational, to force vectors and joint loads historically restricted to elite gymnasts, even when technical instruction and progressions are provided.

In this context, Artistic Gymnastics emerges as the “gold standard” for the clinical and biomechanical understanding of the pathologies observed in CrossFit®. Gymnastics has decades of robust evidence on overload-related pathologies, ranging from osteochondritis dissecans of the capitellum at the elbow to lumbar spondylolysis, resulting from repetitive impact forces and axial hyperextension [10,11]. Whereas

in CrossFit® the management of these loads is a relatively recent phenomenon and is sometimes neglected during WOD execution, given that competitive stimuli lead practitioners to prioritize outcomes, that is, perform more movements or complete the task as quickly as possible. In high-performance gymnastics, load management is a central pillar of injury prevention, and the emphasis is predominantly placed on execution form; moreover, within a gymnastic routine, training volume is low [12,13].

Therefore, an isolated analysis of CrossFit® is reductionist. To mitigate risk and optimize performance, it is essential to draw direct parallels with Artistic Gymnastics. This narrative review aims to examine the epidemiological, clinical, and biomechanical convergences between these two modalities. Through analysis of the current literature, we explore how injury patterns, particularly the predominance of injuries to the shoulder, spine, and lower limb [14,15], manifest in both sports, and how the clinical knowledge accumulated in gymnastics can inform improved prevention protocols for practitioners of the modality.

Comparative Epidemiology: Myths and Reality

The epidemiological analysis of CrossFit® has historically been obscured by anecdotal reports and sensationalist media coverage, which frequently associates the modality with an imminent risk of catastrophic injury or exertional rhabdomyolysis [4]. However, for an accurate clinical assessment, it is imperative to dissociate public perception from statistical evidence. When subjected to a detailed analysis through descriptive epidemiology, the hypothesis that CrossFit® poses a disproportionate danger compared with other sports modalities finds no robust support in the current scientific literature.

Incidence rates and comparative context

The standard metric for quantifying injury risk is the injury rate per 1,000 hours of exposure. The most relevant systematic reviews and cohort studies indicate that the incidence of injuries in CrossFit® ranges between 2.3 and 3.1 injuries per 1,000 hours [1,6]. These values are statistically comparable, and often lower than those observed in endurance modalities such as long-distance running and triathlon, contact sports such as rugby [5], and resistance training practice [16]. In addition, Klimek *et al.* [5] demonstrate that these rates are analogous to those observed in Olympic weightlifting (OW) and recreational artistic gymnastics. Therefore, the notion that CrossFit® is an “extreme” activity in terms of injury incidence is a myth that must be refuted. The risk lies not in the modality itself, but rather in the variability of load application and the level of technical supervision.

The competitor paradox and training volume

A fundamental aspect, often overlooked in generalized analyses, is the heterogeneity of the practitioner population. Montalvo *et al.* [6] elucidate that injury

risk is not uniform. There is a direct positive correlation between competitive level, weekly training volume, and injury incidence. The data suggests that competitive athletes exhibit a significantly higher probability of injury (approximately 40%) compared with recreational practitioners (19%). This phenomenon can be explained by cumulative exposure: competitors accumulate more training hours under fatigue and manipulate higher absolute loads, bringing their risk profile closer to that of elite gymnasts, in whom repetition volume and task technical complexity are well-established predictors of musculoskeletal pathologies [2]. It is also noteworthy that WODs enable even recreational practitioners to experience competition against prior performances or training partners, which may expose them to stimuli capable of exacerbating injury risk.

Injury topography: convergence with gymnastics

If the frequency of injuries in CrossFit® is comparable to that of other sports, their anatomical distribution reveals a distinct biomechanical signature that reinforces the parallel with Artistic Gymnastics. The literature consistently identifies the Shoulder–Lumbar Spine–Knee triad as the areas of highest prevalence [1,14].

In particular, the predominance of shoulder injuries in CrossFit® mimics the patterns observed in elite male gymnastics, in which weight-bearing support on the upper limbs (on rings and parallel bars) imposes loads for which the glenohumeral joint is evolutionarily less adapted than the hip joint [17]. Nicolay *et al.* [4] further emphasize that the nature of overhead movements in CrossFit®, combined with ballistic gymnastic movements (kipping), creates a scenario of “functional subacromial conflict” similar to that observed in gymnasts.

Conversely, lower-limb injuries in CrossFit®, although less frequent than shoulder injuries, resemble in etiology those observed in female artistic gymnastics: they are often the result of poorly dissipated ground reaction forces during repetitive landings (e.g., box jumps, burpees, or dismounts from apparatus) [15].

In summary, current evidence allows CrossFit® to be categorized as a low to moderate relative risk modality compared with other sports [16], while presenting a technically complex injury profile. Global statistical “safety,” however, should not obscure clinical reality: when injury occurs, it tends to follow patterns of structural overload typical of gymnastic and weightlifting sports. This epidemiological finding compels a transition from a purely numerical analysis to a biomechanical and clinical analysis, focusing specifically on the joints that bear the greatest technical load: the shoulder complex and the vertebral column.

Biomechanical and clinical analysis: the upper limb

The epidemiological predominance of upper-limb injuries in both modalities is not a statistical coincidence, but rather a consequence of an evolutionary functional inversion. The human anatomy of the shoulder girdle was selected for mobility

and manipulation in an open kinetic chain. However, both Artistic Gymnastics (AG) and CrossFit® subvert this function by requiring the shoulder–elbow–wrist complex to act as the primary vector of weight support and propulsion in a closed kinetic chain. This “functional inversion,” when combined with high repetition volumes and fatigue, exposes joint structures to axial loads and rotational torques for which they exhibit lower biological tolerance compared with the pelvic girdle.

The shoulder complex: kipping dynamics and the labrum

The glenohumeral joint is the epicenter of pathology in CrossFit®, mirroring the incidence observed in male gymnastics on rings and high bar [17]. The biomechanical feature linking these modalities is the ballistic oscillatory movement known in gymnastics as the tap swing and in CrossFit® as kipping.

According to Nicolay *et al.* [4], the execution of kipping pull-ups or muscle-ups involves a violent transition from passive hyperflexion (during the forward swing phase) to explosive active extension. This cycle generates substantial shear forces at the superior glenoid labrum interface. In elite gymnasts, this load is introduced progressively over the course of a decade, allowing tissue adaptations in the tendon of the long head of the biceps and in scapular stabilization. In CrossFit® practitioners, often adults without prior gymnastic background, the abrupt introduction of these loads, even when pedagogical progressions are used, results in a greater likelihood of superior anterior and posterior labral injuries.

Additionally, muscular fatigue plays a deleterious role in shoulder kinematics. When the dynamic scapular stabilizers (lower trapezius and serratus anterior) fail under fatigue due to successive repetitions of the movement, for example, in volume-focused WODs, superior migration of the humeral head occurs, reducing the subacromial space. This precipitates the classic presentation of “functional subacromial conflict,” in which the rotator cuff is compressed against the coracoacromial arch, not due to osseous deformity, but rather to fatigue-induced scapular dyskinesis [4,14].

The elbow: valgus stress, axial load, and the lesson from Desai

While the shoulder suffers from instability, the elbow suffers from rigidity and compression. Desai *et al.* [10] highlight severe structural pathologies in gymnastics that are beginning to be observed in CrossFit® practitioners: osteochondritis dissecans of the capitellum and insufficiency of the ulnar collateral ligament.

In CrossFit®, exercises such as handstand push-ups and the reception of heavy snatches impose massive axial loads on the elbow in full extension or slight hyperextension. This “locking” joint position transfers compressive forces through the radiocapitellar joint. Desai *et al.* [10] warn that repetitive microtrauma in this region may lead to softening of the articular cartilage and eventual osseous fragmentation (loose bodies), a condition historically prevalent in adolescent gymnasts but now emerging in young adults who subject their elbows to high-impact gymnastic loads.

Moreover, the kipping movement on rings or bars introduces significant valgus torque at the elbow. As observed in baseball pitchers, this repetitive valgus stress may compromise the integrity of the medial ligamentous complex, leading to chronic instability, a pathology that frequently requires surgical reconstruction and may initially be misinterpreted as simple “elbow pain” [4,10].

The wrist and hand: the dorsiflexed load-bearing interface

The wrist joint represents the weakest link in the upper-limb kinetic chain. CrossFit® biomechanics frequently require the wrist to bear loads in positions of extreme dorsiflexion (>90 degrees), as observed in the front rack position (front squat, thruster) and in handstands.

Kruse *et al.* [17] identified that wrist injuries are disproportionately common due to ground reaction forces transmitted through the carpus in male gymnastics. In CrossFit®, this mechanical demand is exacerbated by external loads (dumbbells and barbells). Repetitive compression of the dorsal aspect of the wrist may lead to “gymnast’s wrist” (dorsal impaction or distal radial epiphysitis in skeletally immature practitioners).

Of greater concern for the adult CrossFit® population is the load imposed on the triangular fibrocartilage complex and the risk of stress fractures of the scaphoid. The inability to maintain adequate thoracic extension—common in the general population due to sedentary postural habits—forces practitioners to compensate with excessive wrist hyperextension to maintain the bar overhead, thereby increasing the risk of traumatic and overuse injuries [10].

The demographic nuance: the male profile

It is crucial to note, according to Kruse *et al.* [17], that upper-limb injuries are not uniformly distributed. In elite gymnastics, men exhibit a significantly higher incidence of shoulder and wrist injuries compared with women, due to the emphasis on pure strength and support-based apparatuses (rings, pommel horse, parallel bars).

This pattern is mirrored in CrossFit®, as male practitioners tend to favor training sessions with a higher volume of strength-based gymnastics (ring muscle-ups, strict handstand push-ups) and heavier Olympic weightlifting loads. Therefore, from a clinical standpoint, the screening of a male CrossFit® athlete presenting with shoulder pain should maintain a high index of suspicion for structural labral or ligamentous pathology. Women, in turn, tend to experience greater exposure of the lower extremity and spine to overload, due to hypermobility and landing mechanics [6,17].

In summary, the biomechanical analysis of the upper limb in CrossFit® reveals that “functional movements” may become dysfunctional when the technical complexity of gymnastics collides with the high metabolic demand commonly observed in WOD scenarios. The injuries observed are not fortuitous; they represent a reproduction of common artistic gymnastics pathologies, exacerbated by challenges that encourage participants to exceed their limits, even when long-term pedagogical pro-

gression is attempted by coaches. The shoulder suffers from instability under fatigue, the elbow from axial compression, and the wrist is stressed in forced dorsiflexion.

Biomechanical and clinical analysis: spine and lower limb

If the upper limb in CrossFit® suffers from the imposition of a weight-bearing role for which it was not evolutionarily designed, the spine and lower limb suffer from the cumulative excess of their primary function: dissipation of axial loads and management of ground reaction forces. The literature demonstrates that the lumbar spine and the knee rank, respectively, second and third in injury prevalence [6,14]. The challenge lies in distinguishing two distinct pathological mechanisms that co-exist in the CrossFit® practitioner: the repetitive extension mechanism (inherited from gymnastics) and the flexion-under-load mechanism (inherited from powerlifting).

The lumbar spine: between spondylolysis and disc herniation

The lumbar spine of the CrossFit® practitioner is subjected to a biomechanical “crossfire.”

The Gymnastic Mechanism (Extension): In Artistic Gymnastics, the most feared lumbar pathology, particularly among young athletes, is spondylolysis—a stress fracture of the pars interarticularis. Desai *et al.* [10] and Mekić *et al.* [11] explain that this condition arises from repetitive hyperextension and rotational movements of the spine, which are common during jump landings and apparatus dismounts. In CrossFit®, this mechanism is replicated during successive repetitions or cumulative exposure to overhead movements and global extension throughout a training period. During the return phase of the GHD sit-up or during the arching phase of kipping, practitioners, often with restricted shoulder or hip mobility, compensate through lumbar hyper lordosis. This repetitive load on the facet joints mimics the osseous stress observed in gymnasts, predisposing individuals to stress fractures and spondylolisthesis (vertebral slippage) if load management is inadequate [13].

The Lifting Mechanism (Flexion): In contrast, Hak *et al.* [1] highlight the risk associated with deadlifts and squats performed in timed WODs. As fatigue develops, the trunk stabilizing musculature (core) loses efficiency, resulting in loss of neutral lordosis and a shift toward lumbar flexion under axial load. This mechanism is associated with disc pathology (posterior herniations), diverging from the purely gymnastic pattern and approximating injuries observed in strongman disciplines. Therefore, the CrossFit® practitioner is exposed both to the posterior osseous risk (extension/impact) typical of gymnastics and to the anterior discal risk (flexion/load) typical of weightlifting, even though at lower absolute levels of demand than those usually encountered in Artistic Gymnastics.

The lower limb and the science of landing

In gymnastics, landing is considered a fundamental “technical skill,” evalua-

ted both for aesthetics and safety. Thomas and Thomas, in their systematic review, identify landing as the critical moment for acute traumatic injuries (sprains, fractures, ligament ruptures) [13]. In CrossFit®, successive landings in activities such as box jumps, double-unders, and the reception of Olympic lifts are an important factor contributing to increased impact exposure.

The critical difference relative to Artistic Gymnastics lies in the landing surface and footwear. Gymnasts land on shock-absorbing mats, often barefoot, which increases proprioception but reduces external cushioning. CrossFit® practitioners frequently land on rigid surfaces (wood or compact rubber) while wearing footwear that, although providing lateral stability, may alter the natural mechanics of the foot.

The knee joint is particularly vulnerable to landing errors. When quadriceps and gluteal muscles fatigue over successive repetitions of box jumps, neuromuscular control decreases, potentially leading to dynamic valgus collapse. Charpy *et al.* [15] warn that, in female gymnasts, anterior cruciate ligament injuries are prevalent due to landings performed near full knee extension or under valgus/rotational alignment. In CrossFit®, activities that encourage the highest possible number of repetitions (AMRAP) exacerbate this risk due to fatigue [9]. An athlete performing a 50th box jump does not exhibit the same landing kinematics as during the first repetition, thereby increasing stress on the patellofemoral joint (patellar tendinopathy) and the risk of ligament rupture.

Ankle and foot: impact and dorsiflexion

Ankle injuries, although often considered “minor,” represent a significant cause of training time loss. Edouard *et al.* [12] discussed the importance of preventing lateral ankle sprains in gymnastics through proprioceptive training. In CrossFit®, a specific pathology warrants particular attention: Achilles tendinopathy and, in extreme cases, tendon rupture. A high number of successive repetitions of jump rope exercises (double-unders) and box jumps imposes high-velocity stretch-shortening cycles that place substantial demands on the gastrocnemius-soleus complex. Achilles tendon stiffness, combined with limited dorsiflexion (commonly observed in sedentary adults who initiate practice), creates an excessive traction vector at the calcaneal insertion or the myotendinous junction.

Gender nuance: female predisposition

While men predominantly sustain shoulder injuries, women more frequently experience lower-limb injuries. Charpy *et al.* [15], when analyzing female gymnasts, identified a disproportionate incidence of knee and ankle injuries compared with upper-limb injuries. Anatomical factors (greater Q-angle, wider pelvis) and hormonal factors (ligamentous laxity) are often cited; however, landing biomechanics represent the most relevant modifiable factor.

When transposed to CrossFit®, Weisenthal *et al.* [2] and Montalvo *et al.* [6] corroborate that, although the overall injury rate is similar between sexes, women

report a higher prevalence of knee-related problems. This suggests that injury prevention protocols for female CrossFit® practitioners should prioritize neuromuscular control during landing and strengthening of the posterior chain (hamstrings/gluteals) to protect the ACL, following “FIFA 11+” protocols or gymnastics-specific prevention programs [12].

Thus, CrossFit® inherits the impact-related risks of gymnastics but removes the controlled environment (shock-absorbing mats) and adds the critical variable of systemic fatigue and elevated external loads, depending on the WOD configuration. The lumbar spine is affected by the extension–flexion duality, and the knees become victims of technical deterioration under high volumes of landings. This suggests that “work capacity” should never supersede the “tissue capacity” to absorb impact.

The physiological factor: fatigue and motor control

The fundamental distinction between Artistic Gymnastics and CrossFit® lies in the manipulation of load imposed on the individual through the characteristics of training sessions and competitions. While elite gymnasts perform short-duration routines (approximately 90 seconds) followed by long and controlled recovery periods, CrossFit® athletes frequently operate under a high-intensity “concurrent training” paradigm, in which gymnastic technical demands collide with fatigue. This intersection induces fatigue-related deterioration of motor control, thereby increasing injury risk.

The concurrent training conflict

Martinho *et al.* [9] characterize CrossFit® by the simultaneous engagement of aerobic and anaerobic pathways. The study demonstrates that during a typical WOD, blood lactate levels may reach extreme values ($> 10\text{--}12$ mmol/L), concomitant with heart rates approaching maximum. Physiologically, this imposes an “interference” challenge. The neuromuscular system is forced to recruit high-threshold motor units (required for the explosive strength of a muscle-up or snatch) within a cellular environment characterized by low pH and saturation of hydrogen ions and inorganic phosphate. This differs from gymnastics, in which spacing between repetitions allows fatigue minimization, which is prioritized to ensure precision.

Reduced dynamic stabilization

The direct consequence of fatigue is the loss of “dynamic stabilization.” Mekić *et al.* [11] describe that, in gymnastics, proprioception (awareness of joint position) is vital for injury prevention. However, central and peripheral fatigue impair sensory afference and central processing.

In the context of the shoulder, as previously discussed by Nicolay *et al.* [4], fatigue of the scapular stabilizers (lower trapezius and serratus anterior) occurs before fatigue of the large mobilizers (latissimus dorsi and deltoid). When an athlete performs kipping pull-ups under fatigued conditions:

1. Scapulohumeral rhythm becomes uncoordinated.
2. The scapula fails to upwardly rotate efficiently.
3. Mechanical impingement of the rotator cuff occurs, not due to a lack of absolute strength, but due to delayed muscle activation (timing).

This explains why many injuries do not occur during the first repetition (in which technique is perfect or close to it), but rather during the final repetitions of a set, when active muscular protection fails and load is transferred to passive structures (ligaments and labrum).

Core collapse and force transfer

Another critical point raised by Martinho *et al.* [9] is the constant demand placed on trunk musculature (core) for force transfer. The core acts as a transmission “pivot” between the power generated at the hip and execution by the upper limbs. Under systemic fatigue, the ability of deep muscles (transversus abdominis, multifidus) to maintain intra-abdominal pressure decreases. Hak *et al.* [1] suggest that this reduction in muscular capacity leads athletes to adopt compensatory strategies. For example, during a deadlift or squat performed at the end of a training session, failure of the spinal extensors forces the athlete into lumbar flexion, exposing the intervertebral disc to shear forces. Conversely, in a gymnastic movement (toes-to-bar), fatigue of the abdominal flexors leads to compensatory lumbar hyperextension, re-activating the pars interarticularis injury mechanism described by Desai *et al.* [10].

Rhabdomyolysis: extreme physiological failure

Although its incidence is rare, any discussion of physiology in CrossFit® would be incomplete without addressing exertional rhabdomyolysis. Nicolay *et al.* [4] and Martinho *et al.* [9] describe this condition as the pathological result of repetitive eccentric contractions under severe energy depletion. Unlike gymnastics, in which technical failure leads to immediate interruption of the exercise (a fall from the apparatus), the culture of CrossFit®, when not properly supervised, may encourage athletes to continue the movement through aberrant motor patterns. This not only increases the risk of massive cellular muscle damage (myoglobin release), but also confirms that, in CrossFit®, the “mind” often pushes the body beyond the threshold of tissue safety.

Prevention

The comparative analysis conducted thus far reveals a paradox: although CrossFit® incorporates movements from Artistic Gymnastics, the configuration of training sessions, particularly WODs, substantially increases the challenge of maintaining proper execution technique throughout the session. Therefore, injury pre-

vention must be based on rigorous load monitoring and strict progression criteria. Primary prevention lies in deconstructing the fallacy that training volume should be perpetually increasing. Edouard *et al.* [12], when addressing load in sport, establish that injury risk increases exponentially when acute load (work performed in one week) disproportionately exceeds chronic load (the average of the previous four weeks) [12].

In CrossFit®, where community culture often encourages practitioners to complete the WOD “as prescribed,” regardless of daily readiness, load management becomes the central pillar of prevention. The clinical application of the guidelines proposed by Edouard *et al.* [12] suggests that coaches and athletes should monitor not only external loads (weight lifted), but also internal load (subjective perception of effort and residual soreness). The presence of “pre-participation” pain is a strong predictor of future injury; therefore, training modification (scaling) should not be viewed as regression, but rather as a tissue-preservation strategy.

Location-specific prevention

Shoulder and Wrist (Male Focus / Strength-Based Gymnastics): Mandatory implementation of thoracic mobility routines and isolated strengthening of the posterior rotator cuff and scapular stabilizers (Y-T-W drills), regardless of the WOD of the day. Wrist health requires protocols for stretching the flexors and strengthening the extensors to tolerate the front rack position.

Lower Limb (Female Focus / Landing): Inclusion of proprioceptive training and technical landing practice (“soft landing mechanics”) as a standard warm-up before any WOD involving jumps. Strengthening of the posterior chain (hamstrings and gluteals) is vital to protect the anterior cruciate ligament and the lumbar spine from anterior shear forces [15].

Prevention in CrossFit® requires recognition that intensity is the ultimate objective and that each WOD must be planned according to the practitioner’s level of conditioning. By adopting the “Load Management” principles proposed by Edouard *et al.* [12], we reduce the likelihood of injuries during practice and increase the efficiency of rehabilitation and return-to-training processes.

Conclusion

Based on the available literature, it is possible to deconstruct the stigma of inherent danger associated with CrossFit® and replace it with a contextual biomechanical understanding. Epidemiological evidence is clear: CrossFit® is not statistically more injurious than weightlifting or running. However, it is more complex in terms of motor control. By democratizing gymnastic movements for the general population, CrossFit® has inherited not only the aesthetic elements of the discipline, but also its specific structural pathologies, ranging from shoulder labral instability to lumbar spondylolysis.

The “missing link” in injury prevention for the functional athlete does not lie in modifying the movements themselves, but in managing the physiological context in which they occur. We identified fatigue, resulting from concurrent training combined with the challenges imposed by WODs, as the factor that precipitates technical failure and transforms tolerable loads into potentially injurious ones. Unlike the pure gymnast, who operates with longer recovery intervals, the CrossFit® practitioner performs gymnastic skills under time constraints or maximal-volume conditions. Therefore, the evolution of practice and injury prevention in CrossFit® requires:

Surveillance: Recognizing that elbow or wrist pain may conceal serious bone pathologies (osteochondritis), requiring early imaging-based diagnosis.

Load monitoring and session adjustment: Adopting “Load Management” models that prioritize chronic load over acute load, especially among recreational and master athletes.

Ultimately, CrossFit® and Artistic Gymnastics share numerous biomechanical similarities. The key to longevity in the box lies in training with the intensity of the former, but with the technical discipline and load-management intelligence of the latter.

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