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Research article

Incidence and prevalence of injuries in some sports – review

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Abstract: Injuries are an inherent risk associated with sports participation, impacting the health and performance of athletes across various disciplines. This review aims to provide a comprehensive analysis of the incidence and prevalence of injuries in selected sports, shedding light on the magnitude and patterns of injuries observed within each sport. To conduct this review, an extensive search was performed across electronic databases and relevant sports medicine literature. The findings reveal significant variability in injury rates and patterns among different sports. Sports such as football, handball, and volleyball, exhibit higher overall injury rates, with musculoskeletal injuries being most prevalent. Conversely, sports such as running, and cycling tend to demonstrate lower injury rates, with a focus on overuse injuries. Common injury types observed across sports include sprains, strains, fractures, contusions, and concussions, while body regions such as the lower extremities, head and neck, and upper limbs are frequently affected. Various factors contribute to the occurrence of injuries in sports, including player age, gender, skill level, training intensity, equipment usage, playing surface, and rule modifications. Contact and collision sports carry a higher risk of traumatic injuries compared to non-contact and individual sports. Understanding the incidence and prevalence of injuries in different sports is crucial for the development and implementation of injury prevention strategies. This review highlights the need for tailored approaches that address sport-specific risk factors, focusing on athlete education, proper training techniques, equipment modifications, rule changes, and enhanced medical support.

Keywords: injuries, sports,musculoskeletal injuries, overuse injuries, sprains, strains, fractures, contusions, athlete education, training techniques, equipment modifications.

1. Introduction

Sport is a prominent phenomenon that exemplifies modern and contemporary-era characteristics. This phenomenon can be attributed to the enjoyment derived from physical activity in outdoor environments and the persistent aspiration to enhance and surpass one's own psychological and physical boundaries [1]. Sport is defined as the set of movements that develop the state of health, physical capacity, and performance of an individual [2].

From a European perspective, the notion of "sport" includes all forms of occasional, recreational, organized, deliberate, and repetitive physical activity, basic sports, and competitive sports. Sport and physical activity have long been used as tools to improve mental (brings positive energy, and discipline, strengthens the body, improves memory and muscle coordination), physical and social well-being. Physical activity can be defined solely from a physiological perspective as any bodily movement that results in an increase in energy use beyond normal levels of rest [3]. In the disciplinary sciences, the connection between mental and motor function as well as its development was called psychomotricity, being considered as the result of the integration of mental and motor functions, highlighting the subject's relationship with his body and the environment [4].
Dragnea et al. (2002) [5] elaborated a scheme of terms deriving from the fundamental notion - sport-: sport for all; maintenance, in free time; by family; for the elderly; performance (elite sport, for established athletes, for children and juniors, extreme); adapted sport (therapy sport, performance adapted sport).

As a social activity, the sport enjoys a wide interest, becoming a social phenomenon, and a fundamental feature of the sport is both the competition and the formative character present in performance sport, but also in everyday sport [6].

Amateur sports and professional sports are two different structures of sporting competition that are distinguished by the level of experience, skill and remuneration of the athletes involved.

Amateur athletes receive no financial compensation for their participation and performance being driven by a love of sport and a desire to improve their skills rather than the promise of financial gain [7].

Amateur sports are an essential part of any community, providing numerous benefits to individuals with a significant impact on physical health, maintaining normal weight, strengthening muscles and bones and minimising the possibility of acquiring long-term conditions such as inflammatory diseases, cardiovascular disease, diabetes and cancer.

Amateur athletes can participate in group sports (football, handball, volleyball or hockey); contact and combat sports (karate, judo, mixed martial arts, Jiu Jitsu, Kickboxing, freestyle wrestling, boxing, fencing); resistance training [(weight exercises, cardio exercises (walking; jogging; jumping jacks; jumping rope; cycling; jumping squats; stepper exercises); "plank" exercises; burpees exercises); winter sports (skiing, sledding, skating, snowboarding)].

They can also participate in extreme sports: water sports; in air and ground sports, which bring some benefits: improved concentration, help control of fears, improved self-confidence, help burning more calories. Amateur athletes frequently practice: football, baseball, handball, field and table tennis, volleyball, swimming and triathlon, horse riding, running, cycling, extreme sports, downhill skiing, and boxing just for fun, meeting on weekends or after work for a pick-up game or to compete against other recreational teams [8]. Although, participation in sports and leisure activities is an important factor in improving public health, injury to athletes that may occur as an unwanted side effect reduces the benefits of participation and acts as a deterrent factor to future physical activity [9].

Musculoskeletal injuries are defined as a set of pathologies that affect muscles, tendons, ligaments, joints, nerves, vertebral discs, cartilage, blood vessels, or associated soft tissues and can be caused or aggravated by physical activity [10,11]. Musculoskeletal injuries are prevalent among athletes across various proficiency levels, and their etiology is often multifactorial, making the identification of the precise injury mechanism challenging [12]. According to many studies, the etiology of sports injuries is inherently complex involving the interaction of intrinsic (physical and psychological) as well as extrinsic risk factors and events [13,14]. Factors that increase a player's risk of injury include their age and gender [15,16,17,18,19,20,21,22,23,24], a history of injuries [25], their current playing level, their flexibility, joint instability, lean mass and fat mass influence bone health [26], generalized joint laxity, their ability to strengthen their muscles, their aerobic fitness, their functional performance, their reaction time, their body mass index, their height, and their

anatomical alignment. The findings of systematic reviews have demonstrated a correlation between prior injury and subsequent re-injury in various lower extremity injuries, including hamstring strains, anterior cruciate ligament (ACL) injuries, Achilles tendon injuries, and ankle dislocations.

Previous research has proposed a potential link between re-injury and the presence of neuromuscular deficits following an initial injury [27,28,29,30,31,32]. The psychological risk factors that have been documented include stress levels, a propensity for conflict, and engagement in risky behaviors [33, 34, 35, 36]. Various extrinsic risk factors have the potential to impact the probability of sustaining injuries in sports. These factors include the playing surface, player being exposed, performing position, duration of the match, equipment and clothing used, weather conditions, coaching practices, and game rules.
Epidemiological research conducted in the field of sports has demonstrated a range of injury rates among athletes, spanning from 10% to 65% [37,38,39].

2. Incidence and prevalence of injuries in football

Football is a collective athletic activity involving the participation of two teams, each including 11 individuals. During the onset of the 21st century, the sport of soccer received participation from approximately 270 million individuals hailing from over 200 nations, consequently defining itself as the most widely embraced sport globally [40, 41]. According to FIFA and sports researchers, 200-260 million people play professional, semi-professional, or amateur football, including men, women, and juniors, representing about 4% of the world population [42,43].

Soccer is a sport characterized by the necessity of engaging in high-intensity sprinting, kicks, and quick, high-speed shifts of direction [44,45,46]. There are several factors that can contribute to the occurrence of injuries [47].

Engaging in football has been found to result in notable physical advantages, such as enhanced overall health [48], extended lifespan, and decreased susceptibility to various prevalent non-communicable conditions [49]. Football is widely recognized as the sport that exhibits the greatest incidence of injuries and the most significant injury rate for each unit of exposure [50,51]. Injuries are a common occurrence in football games and training sessions, primarily attributed to the amalgamation of high velocities and full-body collisions. Football injuries can be categorized into two distinct groups: acute injuries, which include sprains, strains, and fractures, and chronic injuries. An acute injury manifests abruptly following an incident such as a fall, impact, or direct contact. A chronic injury is characterized by its gradual onset, typically attributed to prolonged or repetitive use of a particular body part.

The most common injuries reported in football are knee injuries (29%; knee cartilage tear, anterior and medial cruciate ligament injury, meniscus tear, 8%); shoulder and hand injuries (rotator cuff disorders, wrist, elbow injuries, numbness, tingling or weakness in the shoulder or arm), ankle injuries (19%; ankle sprains - mild or complete ligament tears, tendinitis of Achilles), head injuries (concussion), muscle injuries (strains - excessive stretching and tearing of muscle fibers or tendons, muscle strain especially in the hamstrings and quadriceps muscles, 15%), hip indicator - a bruise painful that occurs as a result of direct trauma, often from a blow, back pain), injuries to the spine (9%), trauma (81.5%; collision with another player, the ball or the field can cause a traumatic injury including broken bones, contusions or hematomas, wounds, muscle or tendon strains, and joint sprains, injuries due to excessive usage, especially in young soccer players (18.5%; metatarsal stress fractures, shin splints, patellar tendinitis), heat injuries (exhaustion, sunstroke, and dehydration) [52,53,54,55,56].

The findings of multiple studies demonstrated a range of football injury incidence rates, spanning from 0.5 to 45 injuries per 1000 hours of both training and competitive play. The lower extremity exhibited the highest prevalence, ranging from 61% to 90%. According to previous studies [57,58,59], the incidence of acute injuries was found to be 2.05 per 1000 player hours, while chronic injuries occurred at a rate of 0.67 per 1000 player

hours. The incidence of injury in amateur football is comparatively lower when compared to the reported rates observed among professional players.

According to Sousa et al. (2013) [60], the study findings revealed that amateur soccer players experienced a prevalence of 79% for traumatic accidents, 21% for overuse injuries, and 10% for re-injuries. The duration of time lost because of injury was recorded as 20.3 days. It was observed that the occurrence of injuries among amateur football players was more prevalent during matches played on artificial turf compared to training sessions. The prevalent diagnoses observed in the study included thigh strain/muscle tear, accounting for 18.3% of cases, as well as ankle and knee strain/ligament injury, which constituted 17.3% and 11.3% of cases, respectively.

As reported by van Beijsterveldt et al. (2014) [57], the predominant diagnoses were muscular and tendon injuries (38%) or joint and ligament injuries (23%) affecting the lower extremities. The study revealed that amateur soccer players experienced an average of 0.11 injuries per player per year, with 2.5% of these injuries classified as recurrent. Out of the aggregate number of documented injuries, 34.3% are attributed to midfielders, 33.8% to defenders, 24.2% to forwards, and 7.7% to goalkeepers. The knee joints were identified as the most prevalent site of injuries, accounting for 29.9% of cases, followed by the ankle joints at 12.4%. Additionally, sprains and ligament tears constituted a significant proportion of the overall injury occurrences, representing 32.1% of the total injuries observed.

Based on the findings of Kekelekis et al. (2022) [61], the predominant causes of injury for hamstring and adductor-related groin injuries were identified as high-speed running (84.4%) and change of direction (44.4%), as well. Individuals who are 24 years or older exhibited a significantly increased risk of experiencing a hamstring injury, with a sevenfold higher likelihood, compared to individuals below this age threshold. However, these older individuals demonstrated a lower risk of sustaining an adductor-related groin injury. This information is supported by previous studies [61,62].

Originally, football matches have predominantly occurred on natural grass surfaces, although amateur soccer players have been known to utilize a range of playing surfaces including sand, earth, clay, concrete, asphalt, and hardwood. In certain regions, there has been a growing trend of substituting natural grass playing surfaces with artificial turf among amateur soccer players [63]. The forces displayed on the tissues of soccer players exhibit variability across different surfaces, potentially impacting athletes' performance and injury patterns. Soccer injuries, which have been linked to the playing surface, can be attributed to the rigidity of the surface and the interaction between the surface and the footwear [64,65].

The predominant form of injury observed in the hard-court cohort was acute skin injury, specifically abrasion and laceration. Conversely, in the artificial turf cohort, the prevailing type of injury was rupture and ligament injury, with hematoma, contusion, and ecchymosis following suit [66].

In amateur soccer players, ankle sprains are contact injuries that occur, mainly in defenders, both during games and training. Players with previous ankle injuries experience more injuries. The incidence of injuries tends to increase during the latter stages of a game, with a particular concentration observed within the initial two months of the football season [67].

Epidemiological data, regarding injuries involving soccer players, cannot be generalized to soccer players [68,69] due to anthropometric and physiological, performance, response, and fatigue differences between the sexes [68]. Research has indicated that female players exhibit slower speed, cover shorter total distances, experience quicker fatigue, and demonstrate diminished performance in later stages of the game, in contrast to their male counterparts [69].

Females exhibit a higher susceptibility to severe injury compared to males, as evidenced by the significantly elevated incidence of anterior cruciate ligament (ACL) injuries in girls, which is estimated to be three to five times greater than that observed in boys. The observed phenomenon can be attributed to the relatively lower muscular strength in

women around the hip and pelvic regions. This muscular weakness leads to increased rotational movement of the knees during running, thereby exerting additional stress on the ligaments, particularly the anterior cruciate ligament (ACL) [70]. The non-dominant leg experiences a greater reduction in hamstring stability when fatigued [71].

Systematic reviews and meta-analyses in recent years indicate a higher risk of ankle sprain [72], concussion [73], and anterior cruciate ligament injuries [74] in women. The data presented in the study indicate that there is a greater likelihood of women experiencing ankle sprains compared to men, with rates of 13.6 per 1,000 exposures for women and 6.94 per 1,000 exposures for men. Similarly, children have a higher risk of ankle sprains compared to adolescents, with rates of 2.85 per 1,000 exposures for children and 1.94 per 1,000 exposures for adolescents. Furthermore, adolescents have a higher risk of ankle sprains compared to adults, with rates of 1.94 per 1,000 exposures for adolescents and 0.72 per 1,000 exposures for adults. The activities associated with the highest risk of ankle sprains are indoor and field sports, as reported in the study [72]. According to Hollander et al. (2021) [75], there exists a disparity in the risk of running-related injuries between females and males. The primary risk factors for thigh and groin injuries may include engaging in high-intensity running activities and performing kicking movements. On the other hand, ankle and ACL injuries are often associated with participation in duels or similar activities. However, it is worth noting that there is a lack of consensus among existing literature regarding the exact relationship between these activities and injuries [76].

3. Incidence and prevalence of injuries in handball

Football is a collective athletic activity involving the participation of two teams, each including 11 individuals. During the onset of the 21st century, the sport of soccer received participation from approximately 270 million individuals hailing from over 200 nations, consequently defining itself as the most widely embraced sport globally [40, 41]. According to FIFA and sports researchers, 200-260 million people play professional, semi-professional, or amateur football, including men, women, and juniors, representing about 4% of the world population [42,43].

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4. Incidence and prevalence of injuries in volleyball

Volleyball is a team-oriented athletic activity characterized by two groups of six participants positioned on opposite sides of a net. Each team attempts to accumulate points by strategically placing a ball on the opposing team's court while adhering to the prescribed and obligatory regulations of the game [108]. Volleyball is one of the most popular and successful, competitive and recreational sports worldwide, occupying second place after football. The game is taken part in by an estimated 200 million individuals globally, encompassing both professional and amateur players [109]. It's a fast-paced sport, exciting and with the action explosive; volleyball compresses several crucial elements of ball striking, whose complementary interactions give it its uniqueness across phases of play and the potential to cause injuries.

Statistically, volleyball injuries are not as common as those in football, basketball or hockey, but more common than in other non-contact sports such as tennis, skiing and gymnastics. Unlike contact sports, volleyball injuries are most often the result of falling, hitting or blocking the ball during play.

Despite the widespread popularity and substantial participation in volleyball, there is a paucity of prospective studies examining volleyball injuries and their prevention, particularly among amateur players [110]. Due to the absence of physical contact between players from opposing teams, as facilitated by the presence of a net, it is anticipated that the occurrence of injuries in volleyball would be relatively minimal. Nevertheless, as a result of the swift and forceful motions executed by the entire body, encompassing both horizontal and vertical movements (such as repetitive jumping, landing on the feet, deceleration, and directional changes), the substantial forces associated with these actions can inevitably result in injuries [111].

In a three-year prospective study conducted by De Loës (1995) [112], it was observed that volleyball ranked eighth in terms of injury incidence among individuals aged 14-20.

The study reported an injury incidence rate of 3.0 per 1000 hours of play for this age group. In a study conducted by Schafle et al. (1990) [113], it was discovered that the incidence of injuries during a six-day United States Volleyball Association tournament was 2.3 per 1000 hours.

Two distinct one-season cohort studies conducted in national divisions in Norway and the Netherlands have documented the incidence of injuries during competition and training. The studies reported a range of three to four injuries per 1000 player hours during competition, and one to two injuries per 1000 training hours [114,115].

Injuries are predominantly observed in the lower limbs, specifically the ankles and knees, during landing. Additionally, injuries in the lower limbs can occur in the shoulder girdle, resulting in tear and damage to the rotator cuff and supraspinatus tendinopathy of the shoulder joint. Furthermore, injuries to the fingers and wrist may occur when blocking the ball with one hand. The occurrence of these injuries may vary depending on the location.

Several authors have documented an incidence of match injuries at a rate of 3.8 per 1000 hours of play. Notably, this incidence was found to be higher among senior players compared to junior players. Interestingly, no significant difference in injury rates was observed between male and female players. The ankle was identified as the body part with the highest incidence of injury, accounting for 25.5% to 25.9% of reported cases. This was followed by the knee, which accounted for 15.2% to 25.5% of injuries. The fingers/thumb were also commonly affected, with a prevalence of 10.7%. The lower back was identified as another significant site of injury, with a prevalence of 8.9%. The occurrence of injuries was found to be more prevalent among center players and less prevalent among frees in comparison to other player positions [116,117]. According to Abdelnour Hassan and TwetwaAdiswa (2008) [117], there is an elevated incidence of injuries among volleyball players, particularly those in the front row positions (left and right).

Knee injuries in volleyball can be attributed to the repetitive nature of explosive jumps, which impose significant strain on the patellar tendon, leading to localized pain. Patellar tendinitis, colloquially referred to as "jumper's knee," is a prevalent condition affecting approximately 40-50% of volleyball athletes. This condition manifests as an inflammation of the tendon responsible for connecting the patella to the tibia. The predominant location of pain is at the point of attachment between the patellar tendon and the lower pole of the patella. The prevalence of this condition is higher among males compared to females and among professional athletes in contrast to individuals engaged in recreational sports. In the context of amateur athletes, the prevalence of the condition tends to be higher among individuals at the extremes of age (adolescent boys or elderly individuals) as well as among those who are overweight.

Anterior cruciate ligament (ACL) ruptures are considered to be more severe injuries, commonly observed in the sport of volleyball, particularly during cutting moves or instances where athletes land in an awkward manner afterward to a jump. The potential elevation in stress on the passive support structures of the knee in females may potentially contribute to a greater prevalence of non-contact anterior cruciate ligament (ACL) injuries in females as compared to males. According to previous research, there is a correlation between the sport of volleyball and an increased incidence of non-contact injuries [118].

Ankle sprains are the predominant acute injuries observed in volleyball athletes, accounting for 41% of all injuries associated with the sport. These incidents typically occur at the net, wherein an opposing player inadvertently lands on the foot of another player. Moreover, it should be noted that a history of prior injury has been identified as a potential risk factor for the occurrence of an ankle sprain [119].

Most volleyball finger injuries include fractures, joint sprains, dislocations, and tears of tendons and ligaments. They appear especially during blocks, dives, or lifting the ball from the ground. Stress fractures occurring in the foot frequently happen because of excessive utilization or repetitive force exerted on a rigid surface. Acute injuries (sprains and bruises) mainly affect the fingers and ankles, while chronic injuries occur in the knees and shoulder girdle (bursitis and tendinitis). Excessive use of shoulder muscles for attacks and

serve excessive range of motion in the shoulder, and improper arm lifting technique can frequently cause overuse injuries [120].

5. Incidence and prevalence of injuries in cycling

Cycling is the movement on the ground using a bicycle as a means of transport, set in motion by human muscles. Cycling is used for recreation among people of all ages, exercise, and sport. It is divided into several genera: road cycling, and off-road cycling (mountain biking). The popularity of organized recreational bicycle tours is on the rise in the United States and various other nations. However, it is crucial to address the issue of bicycle safety [121,122].

Injury rates and severity of injuries, found by several authors during recreational cycling trips, were relatively low [123,124,125,126]. Various factors, including human factors such as age, cycling experience, and personal medical history, as well as specialist equipment, speed, riding surface, and weather conditions, have been identified as contributing to a diverse range of both traumatic and non-traumatic injuries among recreational cyclists across different levels of experience [127,128,129,130,131]. Most recreational cyclist injuries are associated with overuse or improper bike choice. High speeds predispose riders to muscle strains, crashes, and falls. Athletes contact bicycles at the pedals, seat, and handlebars, each of which is associated with a specific type of cycling injury [132]. Bicycle injuries can be categorized into three main types: bicycle contact injuries, traumatic injuries, and overuse injuries. The injuries most commonly observed in the study were abrasions, lacerations, and hematomas, accounting for a range of 30.9% to 60% of all documented injuries. Fractures constituted the second most prevalent form of injury, which includes a range of 6-15% of all reported cases. Head injuries, which encompass contusions, accounted for 5-15% of the overall injuries observed. Similarly, muscle-tendinous injuries constituted 2-17.5% of the total injuries recorded. The incidence of injury was found to be higher in the lower limb (50.4%) compared to the upper limb, indicating a greater vulnerability of the lower limb. Furthermore, it was observed that amateurs exhibited a higher susceptibility to injury or disease compared to professionals. The most commonly observed injury was a fracture of the clavicle, while the initial diagnosis for overuse injuries was patellofemoral syndrome [133,134,135].

In accordance with the results of Tan et al. (2022) [136], there was a high prevalence of upper limb injuries associated with bicycle-related incidents, which had notable implications for morbidity outcomes. The shoulder was the most frequently affected region, accounting for 48% of cases, followed by the wrist and hand, which accounted for 19% each. The majority of the injuries were a result of vehicular collisions. Approximately 33% of the patients affected by the condition necessitated hospitalization, while 25% of them required surgical intervention, as indicated by a 27% proportion.

The majority of injuries were observed in the male population and were found to be linked to brisk walking at high speeds. It is noteworthy that the most severe injuries and fatalities were predominantly caused by motor vehicle accidents. While superficial soft tissue injuries and musculoskeletal trauma are frequently encountered, it is important to note that head injuries account for a significant proportion of fatalities and long-term disabilities. Overutilization injuries have the potential to contribute to a range of musculoskeletal ailments, compressive neuropathies, as well as perineal and genital complaints [137].

Acute injuries represented (51.8%), overuse injuries (12.3%), and medical diseases (35.9%). Cyclists with no previous touring experience or who were at least 50 years old had a higher risk of injury/illness than their counterparts [134].

The sport of mountain biking continues to maintain its popularity, primarily among the demographic of young males, despite a recent decrease in participation rates. The largest group of individuals engaged in cycling for leisure purposes consists of recreational cyclists. However, there exists an absence of knowledge regarding the demographic characteristics and injury patterns among non-competitive mountain bikers. Studies conducted on mountain bike races have revealed injury rates of less than 1% among participants. The

injury mechanism observed in this context entails the act of falling forward over the handlebars, typically occurring during a descent, which subsequently leads to direct trauma to the head, trunk, and upper extremities. The occurrence of a fall can be attributed to various factors, including but not limited to irregularities present on the runway surface, mechanical malfunction, and loss of control. In the context of mountain bike racing, it has been observed that women may face a comparatively greater risk of sustaining injuries when compared to their male counterparts. Minor injuries, such as abrasions and contusions, are commonly observed but typically exhibit a low level of severity. Fractures typically affect the torso or upper limbs, with shoulder injuries being frequently observed [138].

6. Incidence and prevalence of injuries in Weight Training Sports

Weight training, also known as resistance training, encompasses various sports such as weightlifting, powerlifting, bodybuilding, strongman, Highland Games, and CrossFit. Sports often have distinct divisions for both men and women, adapting to various age groups, competitive levels, and body weight categories. It is worth noting that these sports can be deemed hazardous due to the substantial loads typically employed during training and competitive events [139]. Weightlifting is a sport in which people lift large weights that are made up of discs of different weights placed on the ends of a bar. It is an Olympic, dynamic, and power sport that can be practiced by elites and amateurs. There are two styles: plucked and thrown [140].

Weightlifting consists of two distinct events: the jerk and the clean and jerk. Powerlifting, a highly competitive athletic discipline, comprises three distinct events, including the squat, bench press, and deadlift. The primary objective of both sports is to achieve the highest possible weightlifting performance in each respective event.

Weightlifting sport and powerlifting are athletic disciplines that subject the human body to substantial mechanical stresses, which raises the risk of sustaining injuries. Weightlifting injuries are infrequently documented in a limited number of studies. The occurrence of injuries in powerlifting varied between 2.4 and 3.3 injuries per 1000 hours of training, with a further range of 1.0 to 4.4 injuries per 1000 hours of training. According to several studies [141,142,143], bodybuilding exhibited the lowest incidence of injuries among lifters, with rates ranging from 0.12 to 0.7 injuries per lifter per year and 0.24 to 1 injury per 1000 training hours. Muscle strain, tendinitis, knee injuries, shoulder injuries, and back injuries were prevalent in bodybuilding [144,145].

The prevalence of sprains and strains associated with weightlifting is highest in the lower trunk (29.4%), followed by the shoulder (22.6%), upper trunk (17.3%), neck (6.5%), arm (5.6%), wrist (4.8%), knee (3.4%), and elbow (2.6%). The knee joint exhibits a relatively restricted degree of flexibility, thereby resulting in a limited range of motion within the human body. The performance of abrupt, uncontrolled movements executed without appropriate technique has the potential to cause damage to the connective tissue within the knee joint or impose strain on the joint itself, thereby impacting both balance and comfort. Virtually all weightlifting exercises impose an augmented and indeterminate load on the dorsal region, which serves as the structural foundation for the various muscle groups comprising the upper body.

Similar to other researchers, Calhoon et al. (1999) [141] found that the back, knees, and shoulders had the highest number of injuries (64.8%). The incidence of acute injuries (59.6%) and chronic injuries (30.4%) was significantly higher compared to recurrent injuries and complications. In approximately 90.5% of cases, it was advised that individuals experiencing injuries ought to avoid missing more than one day of training. The predominant type of back injury observed was strains, accounting for 74.6% of cases. The majority of knee injuries observed in the study were diagnosed as tendinitis, accounting for 85.0% of the cases. The predominant type of shoulder injuries observed in the study were identified as strains, accounting for 54.6% of the cases.

Sprains or strains emerged as the predominant form of injury in resistance training, constituting 46.1% of the total injury occurrences [146]. The majority of injuries observed in the study were classified as acute, accounting for approximately 60-75% of the total cases. These injuries exhibited a wide range of types and severities, as indicated by previous research [147,141]. Overuse injuries have been linked to chronic resistance training, constituting the remaining proportion (25-40%) of injuries. These injuries tend to be more prevalent among older athletes who experience tendinopathy, tendon rupture, and degenerative joint disease. In the context of weightlifting, it has been observed that technical errors account for 31% of reported injuries, while fatigue is implicated in 81% of cases. Additionally, overloading and dropping weights are factors associated with injuries, with a prevalence of 65.5% [139].

In a study conducted by Raske et al. (2002) [142], a distinction in injury patterns was observed between elite weightlifters and powerlifters. The former group predominantly experienced back and knee injuries, while the second group exhibited a higher prevalence of shoulder injuries. There was no observed correlation between shoulder injuries and any particular exercise.

Injuries among Paralympic powerlifters were systematically studied by those who tracked the incidence rate of lesions during the 7-day competition period of the London Paralympic Games in London in 2012. A comprehensive record was made of 38 instances of injury among a sample size of 163 individuals engaged in powerlifting. The injury incidence rate for the entire sample was calculated to be 33.3 injuries per 1000 athlete days, while the overall injury incidence rate was determined to be 23.3 injuries per 100 athletes. The preponderance of injuries observed in the study was classified as chronic overuse injuries, accounting for 61% of the total cases. The anatomical region that experienced the highest frequency of injuries was the shoulder/clavicle, accounting for 32% of all reported injuries. This was followed by the chest and elbow, each accounting for 13% of the total injuries.

The risk of injury in both sports exhibited a degree of similarity to that observed in non-contact sports that similarly necessitate strength and power, although demonstrating a lower incidence when compared with contact sports. The included studies demonstrated variations in the severity of the lesions [143]. There was significant variation observed in the occurrence of injuries and illnesses across different sports. The incidence of athlete injuries was found to be significantly higher in the sports of taekwondo, soccer, BMX, handball, mountain biking, athletics, weightlifting, hockey, and badminton. Conversely, the occurrence of injuries was observed to be comparatively lower in the sports of archery, canoe slalom and sprint, track cycling, rowing, shooting, and riding. It is anticipated that 35% of injuries will result in the athlete's inability to engage in competitive or training activities. The prevalence of illnesses among women athletes was found to be 60% higher compared to their male counterparts, with rates of 86.0 and 53.3 illnesses per 1000 athletes, respectively.

7. Incidence and prevalence of injuries in functional training

Functional training is a training modality that primarily focuses on movements executed utilizing the body's built-in weight, akin to the activities commonly performed in our daily lives. Functional training is a comprehensive approach that integrates exercises derived from various disciplines, including artistic gymnastics, aerobics (such as running and rowing), fitness, bodybuilding, weightlifting, and athletics.

Functional training allows: obtaining a metabolic and cardiovascular effect, which helps to disperse adipose tissues in the body and improve the aerobic and anaerobic systems; injury prevention; improving posture and abilities to perform daily tasks; improving strength, power, speed and flexibility and muscular endurance. Functional exercises without equipment include burpees, push-ups, lunges, squats, abdominal crunches, but various accessories such as dumbbells, dumbbells, pull-up bar, elastic bands, steppers, kettlebells, medicine ball can also be used, bells, bags, ladders, hurdles, speed bumps,

boxing equipment, benches and more. Functional training is self-limiting, your own body limits the activities in which it will be involved.

CrossFit is a training and conditioning program that has garnered considerable recognition and piqued the interest of numerous professional and amateur athletes across different age cohorts since the turn of the millennium. This interest is contingent upon the program being executed within a secure setting and under the guidance of properly qualified professionals. CrossFit training is a unique sport that combines weightlifting, gymnastics and metabolic conditioning into one program. This type of training teaches athletes how to manage their body weight in all planes of motion. In addition to improving physical condition, CrossFit exercises help maintain the health of the cardiovascular and respiratory systems, improve coordination skills, flexibility and agility with which specific movements are executed. This training is mainly used by the military, by performance athletes, but also by patients recovering from injuries or suffering from disabilities.

The main difference between CrossFit and functional training is that, more often than not, the latter does not involve the use of sophisticated equipment or heavy weights.

Because functional training and CrossFit training are relatively new sports, the associated injury rates and incidences are not well known. The specialized literature presents a relatively limited number of studies on injuries during functional training. The majority of studies employed a retrospective study design with a moderate level of rigorous methodology. The primary variables examined in these studies included prevalence rates, the spatial distribution of lesions, and the factors associated with their occurrence.

The reported prevalence of musculoskeletal injuries was 32.8-36%, and the incidence of injuries per 1000 hours of training ranged from 0.21 to 3.6 [148,149,150,151,152,153,154,155]. Bradley et al. (2020) [156] report wider variations for injuries incidence (12.8-73.5%), but similar injury rates (0.27-3.3/1000 training hours).

The studies revealed that the shoulder was the most commonly affected body location, with a prevalence ranging from 26% to 35.9%. This was followed by the lumbar spine, which had a prevalence ranging from 17.9% to 33.3%. The knee was also identified as a frequently affected body location, with a prevalence ranging from 14.1% to 18%. The most commonly observed injuries were those affecting the muscle (23.1-51.3%), joint (26.6-30.8%), and ligament/tendon. The predominant injuries observed in the study were muscle strains, accounting for 41.0% of the total injuries. Overuse injuries constituted 26.2% of the injuries, while contusions accounted for 17.3% of the injuries. Fractures and dislocations constituted 5.6% of the total number of cases, as evidenced by the data points [152,151,157,158]. Vassis et al. (2023) [158] report a percentage of 49.6% tendinopathies, a significantly lower percentage of tendinitis was found by [159].

It was found that shoulder and spine injuries were the most prevalent, while there were no reported cases of rhabdomyolysis [160]. The shoulder injuries observed can be classified as either acute or overuse injuries, resulting from a combination of biomechanical and physiological factors. These factors can be effectively identified, addressed, and rectified. The occurrence of back injuries is primarily concentrated in the lumbar region. The injuries observed encompassed a spectrum of conditions, including both traumatic injuries and overuse injuries. The primary factors associated with injuries are lumbar kinematics and physiological components. These injuries can be mitigated through the modification of training methods, utilization of suitable machinery, and implementation of protective equipment. Knee injuries can be attributed to the biomechanical and physiological alterations resulting from the repetitive flexion and extension movements involved in weight-bearing exercises. Furthermore, the presence of anatomical irregularities in the knee joint increases susceptibility to injury [161]. The incidence of injuries necessitating surgical intervention was relatively low, comprising 2.6-8.7% of the overall cases. This finding aligns with the relative frequency distribution observed on the severity scale, where a majority of cases (89.1%) were classified as mild to moderate lesions, while severe and very severe lesions accounted for a smaller proportion (10.9%), that's why we consider physical exercise to be an important element in the whole process [152,162].

The chances of sustaining an injury among athletes who engaged in CrossFit training for a duration over 12 months was found to be 82.2%, surpassing the corresponding probability observed among novice participants. athletes. Competitive athletes exhibited a significantly elevated likelihood of sustaining injuries, with a fivefold increase compared to their less experienced counterparts. Similarly, recreational athletes demonstrated a substantially increased probability of injury, approximately twice as high as that observed among beginners. There was a lack of evidence indicating a correlation between the occurrence of injuries during CrossFit training and various athlete characteristics, including age, gender, participation in other sports, weight, and height. Furthermore, it was observed that there was no discernible disparity in the incidence of injuries between the cohorts engaged in alternative sports activities apart from CrossFit and the athletes who refrained from participating in any form of physical exercise [152,151].

The incidence of injuries in CrossFit is similar to that observed in other recreational or competitive sports, exhibiting a comparable pattern to weightlifting, strength training, weight training, Olympic gymnastics, and running. Based on existing evidence, it can be inferred that the potential for injury resulting from CrossFit training is similar to that of Olympic weightlifting, long-distance running, athletics, rugby, soccer, and ice hockey [152,155,163].

Given the widespread popularity and rapid growth of CrossFit strength training as a training regimen, it becomes imperative to closely monitor the safety of individuals engaging in this program. In order to enhance the safety of CrossFit, sports physicians should take into account various factors such as competition involvement, rest intervals, as well as the duration and frequency of training [158].

8. Incidence and prevalence of injuries in running

Engaging in street or park running is widely recognized as a highly popular athletic activity on a global scale, with significant implications for enhancing overall well-being and enhancing one's quality of life. Running offers several advantages, including the management of body weight and the mitigation of chronic health conditions like cardiovascular disease, leading to a decrease in the overall risk of mortality [164,165,166,167,168,169,170,171]. Body weight and health are interdependent, influencing each other, so maintaining an optimal body weight is one of the most important ways to avoid the risk of disease [172]. Regular running is correlated with enhancements in blood glucose levels, concentrations, and fractions of cholesterol, as well as percentages of lean and bone mass [173].

Several recent studies have provided evidence suggesting that engaging in running activities carries a comparatively elevated likelihood of sustaining injuries [174,175]. The annual incidence rates among amateur runners vary between 3.2% and 84.9% [176,177,178,179,180,181,182]. The observed discrepancies among studies can potentially be attributed to variations in the definitions of lesions, characteristics of the subjects, durations of follow-up, and the study models employed.

In a research study published by Lun et al. (2004) [183], it was observed that a significant proportion of recreational runners, specifically 79%, experienced injuries following a six-month training period. These individuals typically engaged in an average of three training sessions per week. The incidence of knee injuries was found to be higher among males, whereas females exhibited a higher prevalence of leg injuries. Risk factors for running injuries can be categorized into three domains: personal factors (including age, sex, height, genetic characteristics, and biomechanical imbalances such as leg length inequality), running/training factors (such as the number of weekly running days, distance covered, and choice of running shoes), and health and lifestyle factors (such as smoking, medication usage, alcohol consumption, history of comorbidities, arterial hypertension, asthma, and nervous or emotional disorders), as well as previous injuries [177,184,185,186].

Finch (2006) [187] classifies risk factors as modifiable and non-modifiable. The identification of modifiable risk factors linked to running injuries serves as a foundation for the development of interventions aimed at preventing such injuries. On the other hand, non-modifiable risk factors play a crucial role in risk stratification and targeted prevention efforts [188].

Several studies have confirmed that prior injuries pose a risk for subsequent running injuries. Additionally, most of the studies included in the analysis did not establish any association between gender and running injuries [189]. The lack of individualization of physical activities, especially during the growth period, different conditions can appear, which must be treated by specific recovery methods. [190].

Participating in the activity of running has the potential to result in various types of injuries, specifically affecting the knees, ankles, and feet. Running-related injuries have the potential to impact a significant proportion, approximately 83%, of both amateur and competitive runners, therefore potentially compromising their quality of life either temporarily or permanently [186,191,192,193]. Research on individuals engaged in long-distance running, specifically those who ran distances exceeding 5 km during each training session, revealed varying rates of knee injuries ranging from 7.2% to 50%. Similarly, leg injuries were reported at frequencies between 9% and 32.2%, while injuries to the lower legs occurred at rates ranging from 5.7% to 39.3%. Thigh injuries were observed in the range of 3.4% to 38.1%, while ankle injuries were reported at frequencies of 3.9% to 16.6%. Finally, hip injuries were documented at rates between 3.3% and 11.5% [186].

The majority of running-related disorders, specifically around 70%-80%, can be attributed to overuse injuries. These injuries primarily affect the anatomical regions of the knee, ankle/foot, and shank [194,195]. According to Francis et al. (2019) [195], patellofemoral pain syndrome has been identified as the prevailing overuse injury, whereas [196] has highlighted medial tibial stress syndrome as the predominant musculoskeletal injury associated with running. Several studies have presented conflicting findings regarding the prevalence of acute running injuries. While certain studies have indicated that such injuries are infrequent, others have suggested that they are quite prevalent, primarily manifesting as ankle sprains and muscle injuries, specifically strains in the quadriceps and hamstring muscles [197,198,199].

According to Kemler et al. (2018) and other sources, a significant majority (80%) of injuries related to running can be attributed to overuse. These injuries occur as a consequence of an imbalance between the connective tissue's capacity to endure stress and the biomechanical load imposed by running. Research has indicated that female runners exhibit a higher vulnerability to stress fractures when engaging in prolonged running activities, in comparison to their male counterparts. The elevated occurrence of this phenomenon can be ascribed to decreased levels of bone mineral density due to hormonal influences. The influence of variables such as running surface, age, and stretching techniques on the development of running injuries appears to be negligible [200,201].

In a retrospective analysis conducted by Clement et al. (1981) [202], it was found that leg length discrepancy, inadequate hamstring flexibility, and limited back flexibility were identified as potential risk factors associated with the onset of nonspecific back pain among individuals engaged in running activities.

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