12 Athletics, Sprints, Hurdles, High Jump, Long Jump, Triple Jump, Distance Running

Gian Luigi Canata, Valentina Casale, Antonella Ferrario, Enrico Ferranti Calderoni, Giacomo Zanon, and Franco Bidoglio

12.1 Introduction

Athletics, also known as track and field, is a group of sport events including running, jumping, and throwing. Track and field athletics was included in the first modern Olympic Games in 1896, and currently can be classified into four main categories [1]:

- Track events, including sprints (100, 200, and 400 m), middle-distance running (800 and 1500 m), long-distance running (5000 and 10,000 m), hurdling (100 m for women, 110 m for men and 400 m for both), relays (4 × 100 and 4 × 400 m), and 3000 m steeplechase.
- Field events, including long jump, triple jump, high jump, pole vault, shot put and discus, javelin and hammer throw.
- Road events, including marathon, 20-km race walk for women, 20- and 50-km race walks for men.
- Combined events, including heptathlon for women and decathlon for men.

Disciplines like sprint, hurdles, and jumps have a high incidence of acute, traumatic events (e.g., hamstring or calf injuries in the 100 m), while sports like middle- or long-distance running typically predispose to overuse injuries such as bone stress fractures and tendinopathy [2–5]. The risk of injury depends on different biomechanics and technical movements, as well as the implements used, the training workload and the duration of practice [6].

Although each discipline is characterized by different physical, mechanical, technical, and psychological demands, in fact, the practice of track and field carries the risk of injury during both competing and training [5, 7–15].

Despite differences, in fact, all track and field disciplines highly involve the musculoskeletal system, composed by muscle, tendon, bone, cartilage, ligament, and soft tissue. When repeated mechanical loading exceeds the remodeling capability of the structures under stress, together with insufficient recovery and undertrained conditions, an overuse injury may develop [16].

Running disciplines require long periods of repetitive stress on musculoskeletal system, resulting in a high rate of overuse injuries. The field events are characterized by the generation of maximum force in a short time lapse instead,

G. L. Canata (✉) · V. Casale
Centre of Sports Traumatology, Koelliker Hospital, Torino, TO, Italy
e-mail: studio@ortosport.it

A. Ferrario · F. Bidoglio
Interdisciplinary Research Center in Biology and Sports Medicine, Università degli Studi di Pavia, Pavia, PV, Italy

E. F. Calderoni · G. Zanon
IRCCS Policlinico San Matteo, Pavia, PV, Italy

S. Rocha Piedade et al. (eds.), *Specific Sports-Related Injuries*,
https://doi.org/10.1007/978-3-030-66321-6_12

with maximal muscle contractions causing high stress [2].

Factors such as athlete's growth and maturation process, anatomical characteristics, muscle-tendon imbalance, history of prior injury, menstrual dysfunction, and psychological aspects should also be taken into account as intrinsic factors. Training workload, competition schedule, resting time, sports-specific characteristics, training environment, and equipment influence as extrinsic factors the development of such injuries [17]. In pole vault, there is also a relative risk of serious head and cervical injuries [18].

12.2 Injury Epidemiology

During elite Athletic Championships, the overall incidence is nearly 130 injuries per 1000 registered athletes [12, 19–21].

Patellar tendinopathy, Achilles tendinopathy, the medial tibial stress syndrome (MTSS), hamstring strains, plantar fasciitis, stress fractures of metatarsal bones, and the tibia and ankle sprains have been reported as the most frequently diagnosed injuries during track and field events [7, 15, 22–27].

It is widely assumed that overuse injuries represent the majority of all injuries in track and field, and they usually affect the lower extremities with rates from 60% to 100% [2, 5, 9, 14, 15, 28, 29].

Musculo-tendinous injuries are usually correlated with explosive events such as sprints and jumps, mostly due to indirect forces on the muscle-tendon junction, which is well-known as a weak point [6].

Thigh strain is the most frequent diagnosis, especially hamstring strain [12, 22]. Several factors play a role in occurrence of such injuries, like hamstring mechanics during the sprint phase [30], strength imbalances [31], flexibility, fatigue, age, ethnicity, and the severity of previous injuries [13, 32].

Other main injuries during such events are lower leg strains, ankle sprains, and trunk muscle cramps, most frequently caused by overuse [8, 11, 12, 19, 22]. Lower back injuries are common as well, especially among sprinters, jumpers, and throwers [6, 10]. This can be explained considering that all track and field disciplines require a good back and abdomen sheathing to effectively transmit the force to the lower extremities [6].

Young athletes have been reported to be at higher injury risks than adults [33], especially in middle- and long-distance running [9]. This particularly concerns the adolescent athletes. The musculoskeletal system of a growing athlete, in fact, is more vulnerable to specific injuries, such as epiphyseal traumatic injuries or apophysis overuse injuries [34–36]. Nevertheless, still very little is known about sports injury and complaint profiles of adolescent elite athletes [37].

During an athletic season, only a small percentage of injuries can be classified as traumatic [5, 9]. Considering the overall incidence, the relationship between rate and training loads seems to be directly proportional [9, 15, 38].

Furthermore, it has been reported that a higher rate of injuries occurs during training (60–91%) than during competition (9–30%) [2, 4, 10, 39]. Most of the season time, in fact, is spent in training rather than competition [10, 39].

During athletic championships, athletes competing in disciplines like combined events, steeplechase, and middle- and long-distance running are at higher risk of developing overuse injuries above all [11, 12, 19, 22]. The rate of in-competition injuries has been reported as up to three times higher than the rate of training disorders [22]. During championships, in fact, athletes spend less time in training than during season [28]. Furthermore, during competition the maximum effort required can facilitate the development of injuries, reducing the awareness of a potential disorder at an early stage as well [22].

12.3 Track Disciplines

12.3.1 Sprint

Sprinting requires a huge muscle mass for an explosive lower extremity activity (Fig. 12.1). As a result, the most frequently reported injuries involve the lower limb, in particular hamstring

Fig. 12.1 Sprint finish line

and rectus femoris strains [5, 8–10, 15, 18], as well as Achilles tendon ruptures [9] and/or back injuries [10].

Hamstring injuries are very common among sprinters, especially involving the biceps femoris [40] and are more frequent in males than female athletes [12].

It has been suggested that during both the late swing phase [41] and the early phase of sprinting [42] hamstrings are more prone to develop injury.

Referring to indirect muscle injuries, the eccentric contraction plays a key role in the pathogenesis of muscle strains. Mechanical factors based on overstretching can lead to sarcomeres fibers disruption, vessels lesion, cytoskeletal proteins, and sarcoplasmic reticulum damages [43, 44]. Fast contraction muscle fibers, as well as bi-poliarticular muscles and musculo-tendinous junctions can be considered as the most susceptible to injuries structures [45].

Achilles tendinopathy is usually correlated with explosive events such as sprints, hurdles, and jumps, but it may develop among middle- and long-distance runners too [2, 28]. It can be considered as the most common overuse injury occurring among sprinters and hurdlers [6]. It has been highlighted how an appropriate loading and adaptation may increase cross-sectional are and tensile strength of the tendons. Conversely, immobilization and inappropriate adaptation may cause tendon degeneration and the development of tendinopathy. Tissue adaptive changes, either physiological or pathological, are in fact influenced by the response of the peripheral nervous system and its messengers to external forces such as mechanical loading to the tendon [46]. Biomechanical causes of the development of Achilles tendinopathy may be intrinsic (such as avascularity, malalignment, hyperpronation, imbalance of the agonist–antagonist muscle action, poor running style, insufficient warm-up and stretching before sports, age and eccentric loading of the Achilles tendon with a dorsiflexed foot) or extrinsic (ground surfaces, excessive increase in sports activity, repetitive mechanical loadings, or old footgear by changing alignment) [47].

When the inflammation involves the peritendinous sheaths without any pathological changes in the tendon itself, the term *Achilles peritendinopathy* is more appropriate [48, 49].

12.3.2 Hurdles

Hurdlers and steeplechasers are frequently injured by the obstacles they must jump over [18]. Steeplechasers, as well as middle- and long-distance runners, show higher risk of injury compared to other disciplines. Despite these, events require lower intensity of exercise, the time spent in training and/or in competition is longer, causing a higher risk of developing overuse injuries [12].

Among both male and female hurdlers, most injuries are located in the thigh (especially as muscle strains), while hip and groin disorders especially affect males, and knee injuries mostly concern females [7].

Focusing on groin pain, it usually develops in sports requiring a combination of sudden and sharp movements involving the hip adductor and the abdominal musculature [50–52]. The main risk factors include adductor muscle weakness, greater hip adductor to abductor strength ratio, sport specificity of training, and the amount of pre-season sport-specific training [53]. Torsion and traction at the insertion of the involved muscle groups can cause functional overuse and repeated microtraumas [54]. The insertional tendinopathy of the adductors and rectus abdominis are the most frequent causes of groin [50].

As mentioned above, Achilles tendinopathy is a common injury above runners, including hurdlers [6]. Risk factors may be intrinsic (such as forefoot or varus deformity, *pes cavus*, leg length discrepancy, limited mobility of the subtalar joint) and extrinsic (excessive overload training, excessive eccentric loading, hard surfaces, poor shock absorption) [55–57].

Activities requiring explosive acceleration, sudden changes in direction, jumping and sprinting predispose to such an injury [58–60].

Considering the insertional Achilles tendinopathy, in particular, muscle-tendon stiffness fatigue-induced or contracture/imbalance of gastrocnemius, soleus, and anterior tibialis muscles increase the stress on the insertional zone of the tendon [58].

12.3.3 Distance Running

Middle- and long-distance runners are usually leaner, have greater endurance requirements, and are more likely to suffer from chronic injuries then athletes participating in other disciplines [3] (Fig. 12.2).

The most frequently diagnosed disorders during long-distance events are in fact patellofemoral syndrome (PFS), medial tibial stress syndrome (MTSS), Achilles tendinopathy, iliotibial band friction syndrome, plantar fasciitis and stress fractures of the metatarsal bones, the sesamoid bone, and the tibia [6, 24, 29, 61, 62] (Figs. 12.3 and 12.4). Less common disorders are ankle sprains, hamstring muscle injury and tendinopathy, gastrocnemius muscle injury, trochanteric bursitis, low back pain, tibial posterior and hip

Fig. 12.2 Three thousand meter steeplechase

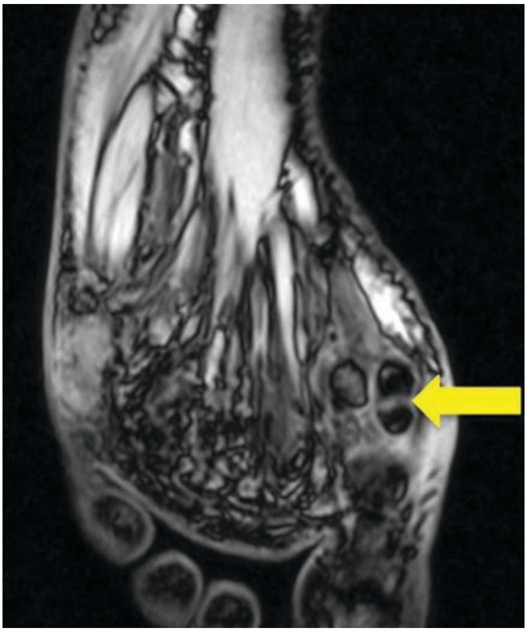

Fig. 12.3 MRI showing a sesamoid stress fracture (yellow arrow)

Fig. 12.4 MRI showing a tibial stress fracture (yellow arrow)

adductor tendinopathy, infrapatellar bursitis, and knee sprain [24].

The overall incidence of injuries may vary from 6.8 to 59 injuries per 1000 h of exposure to running [24]. This large variation is due to differences in the definition of injury, as well as study populations, type of run, and follow-up periods [63].

Acute injuries are rare among these disciplines, mainly consisting of muscle injuries, sprains, or skin lesions [64]. Eighty percent of running disorders are overuse injuries instead, mostly involving the lower extremity and the knee in particular [29].

The MTSS has been reported as the most frequently diagnosed musculoskeletal injury among middle- and long-distance runners [24]. The main pathomechanical process is related to repetitive contraction of the posterior tibial, soleus, and/or flexor digitorum longus muscles during both the landing and the propulsion phases of running. This repetitive process can generate excessive stress on the tibia, resulting in the development of inflammation at the insertion of the periosteal [65–68]. Another cause of MTSS is an inadequate capacity of bone remodeling, due to the repetitive and constant stress on the tibia after both muscle contraction and vertical ground reaction during the landing phase [66, 69]. Furthermore, several risk factors for the development of MTSS have been recently proposed: female sex, high weight, high navicular drop, previous running injuries, and great hip external rotation with the flexed hip are some examples [70].

12.4 Field Disciplines

12.4.1 Jumps

Jumping events require a running approach, thus the most frequent jumping-related injuries are usually seen among runners too [5].

Among the field events in athletics, horizontal jumps (long and triple jump), and vertical jumps (high jump and pole vault) involve the production of maximum force in a short period of time (Fig. 12.5).

The resulting maximal muscle contractions cause high stress on several body districts. Disciplines involving plyometrics, such as jumping and landing, are in fact frequently associated with musculoskeletal injuries of different locations and types [7, 71].

Most of the disorders affect the lower extremities, in particular the thigh region [5, 8–10]. The knee, the ankle and the hip joints are frequently involved too [7].

Patellar tendinopathy, also called the jumper's knee, typically affects athletes involved in repetitive jumps and with a high explosive strength required [72] (Fig. 12.6). The ground reaction force in a long jump take-off, in fact, can correspond up to ten times the body weight [73], and the resulting forces through the extensor tendons are proportional to the ground reaction force. Therefore, a correlation between the loading pattern of the knee extensors and the prevalence of jumper's knee may be considered [74].

The main risk factors for the development of patello-femoral pain (PFP) may be classified as anatomical (such as enhanced femoral anteversion, trochlear dysplasia, patella alta and baja, excessive foot pronation) and biomechanical (muscle tightness or weakness, generalized joint laxity, and gait abnormalities) [72, 75].

Pole vault can be considered as the highest risk jump event [13]. It also represents the track and field discipline with the highest risk of mortality, mainly due to the landing phase directly onto the head or neck [18]. Head injuries, spinal fractures, brain stem injuries, and pneumothorax are some examples of possible traumatic events experienced by pole vaulters [76]. Because of such potential injuries, it is imperative for the medical personnel stationed by the vault field to be highly versed in acute traumatic head and neck injury management [3].

Fig. 12.5 High jump

12.5 Prevention

Several approaches do exist to effectively prevent track and field injuries [6].

One strategy focuses on the specific characteristics and risk factors of the most common injuries: the better you know the problem, the better you can manage it.

Considering hamstring strain as one of the most frequent injuries among track and field athletes, for example, factors such as hamstring mechanics during sprinting, strength imbalances, athlete's flexibility, effort, age or ethnicity, and severity of previous disorders play an important role in developing such an injury [30–32, 77].

Ankle sprains development and gravity are influenced by the severity of previous injuries, ankle proprioceptive deficits, altered neuromuscular control, postural instability, and strength deficiency as well [78–80].

Fig. 12.6 MRI showing patellar insertional tendinopathy (yellow arrow)

Another prevention strategy focuses on the track and field disciplines with higher injury risks, such as combined events, middle- and long-distance running, pole vault, and hurdles [4, 11, 12, 14, 19, 81, 82]. Thoroughly knowing the biomechanics and metabolic needs of these disciplines may help preventing the related most common injuries [6, 12].

Above all the existing strategies, promptly treating acute injuries, reducing overtraining risks, improving strengthening and recovery schemes, and managing the first episode of injury with the appropriate treatment and rehabilitation can be considered as the milestones for an effective prevention [5, 6, 12].

Also the technical knowledge of the discipline an athlete practices is paramount for preventing injuries. This can be explained when considering the higher incidence of injuries during combined events. Besides the more intensive training load required to master several different disciplines, it should be considered that the athlete might not be as experienced and prepared in each sport as athletes competing in a single one [22].

Conclusions

Athletics has a great historical background and is one of the most fascinating individual sports coupling competition with a constant research of self-improvement. Top-level activity carries a significant risk of acute traumatic lesions or overuse injuries. The relationship between rate of injuries and training loads seems to be directly proportional.

Young athletes are at higher injury risks than adults, especially in middle- and long-distance running. The musculoskeletal system of a growing athlete is more vulnerable to specific injuries, and careful training and well-planned competition programs are mandatory.

Sprint and hurdles show a higher risk of hamstring and rectus femoris strains, as well as Achilles tendon ruptures. Long-distance events are more prone to anterior knee pain, medial tibial stress syndrome, Achilles tendinopathy, iliotibial band friction syndrome, plantar fasciitis, and stress fractures. Anterior knee pain and patellar tendinopathy affect more frequently jumpers. Pole vault can be considered as the highest risk jump event being the track and field discipline with the highest risk of mortality, mainly due to the landing phase directly onto the head or neck. Careful selection of the athlete and training in an appropriate environment are the best prevention strategies, as well as a prompt and accurate management of acute or overuse injuries is the best way to safely resume competition at the same or hopefully even higher level.

References

1. Rauh MJ, Macera C. Athletics. In: Epidemiology of injury in Olympic sports. Hoboken, NJ: Wiley; 2009. p. 26–48.
2. Zemper ED. Track and field injuries. Med Sport Sci. 2005;48:138–51.
3. Thing J, Scheer V. Track and field. In: Sports-related fractures, dislocations and trauma. Advanced on- and off-field management. Cham: Springer Nature; 2020. p. 955–8.
4. Edouard P, Morel N. Suivi prospectif des blessures en athlétisme. Étude pilote sur deux clubs durant une saison. Sci Sports. 2010;25:272–6.
5. Bennell KL, Crossley K. Musculoskeletal injuries in track and field: incidence, distribution and risk factors. Aust J Sci Med Sport. 1996;28:69–75.
6. Edouard P, Alonso J-M. Epidemiology of track and field injuries. New Stud Athletics. 2013;28:85–92.
7. Edouard P, Navarro L, Branco P, Gremeaux V, Timpka T, Junge A. Injury frequency and characteristics (location, type, cause and severity) differed significantly among athletics ('track and field') disciplines during 14 international championships (2007–2018): implications for medical service planning. Br J Sports Med. 2020;54:159–67.
8. Jacobsson J, Timpka T, Kowalski J, Nilsson S, Ekberg J, Renström P. Prevalence of musculoskeletal injuries in Swedish elite track and field athletes. Am J Sports Med. 2012;40:163–9.
9. Jacobsson J, Timpka T, Kowalski J, Nilsson S, Ekberg J, Dahlström Ö, et al. Injury patterns in Swedish elite athletics: annual incidence, injury types and risk factors. Br J Sports Med. 2013;47:941–52.
10. D'Souza D. Track and field athletics injuries—a one-year survey. Br J Sports Med. 1994;28:197–202.
11. Alonso JM, Junge A, Renström P, Engebretsen L, Mountjoy M, Dvorak J. Sports injuries surveillance during the 2007 IAAF World Athletics Championships. Clin J Sport Med. 2009;19:26–32.
12. Alonso J-M, Edouard P, Fischetto G, Adams B, Depiesse F, Mountjoy M. Determination of future prevention strategies in elite track and field: analysis of Daegu 2011 IAAF Championships injuries and illnesses surveillance. Br J Sports Med. 2012;46:505–14.
13. Opar D, Drezner J, Shield A, Williams M, Webner D, Sennett B, et al. Acute injuries in track and field athletes: a 3-year observational study at the Penn Relays Carnival with epidemiology and medical coverage implications. Am J Sports Med. 2015;43:816–22.
14. Watson MD, DiMartino PP. Incidence of injuries in high school track and field athletes and its relation to performance ability. Am J Sports Med. 1987;15:251–4.
15. Lysholm J, Wiklander J. Injuries in runners. Am J Sports Med. 1987;15:168–71.
16. Aicale R, Tarantino D, Maffulli N. Overuse injuries in sport: a comprehensive overview. J Orthop Surg. 2018;13:309.
17. Farpour-Lambert N. Adolescent athletes. In: Injury and health risk management in sports. A guide to decision making. Cham: Springer Nature; 2020. p. 7–16.
18. Pendergraph B, Ko B, Zamora J, Bass E. Medical coverage for track and field events. Curr Sports Med Rep. 2005;4:150–3.
19. Alonso J-M, Tscholl PM, Engebretsen L, Mountjoy M, Dvorak J, Junge A. Occurrence of injuries and illnesses during the 2009 IAAF World Athletics Championships. Br J Sports Med. 2010;44:1100–5.
20. Soligard T, Steffen K, Palmer D, Alonso JM, Bahr R, Lopes AD, et al. Sports injury and illness incidence in the Rio de Janeiro 2016 Olympic Summer Games: a prospective study of 11274 athletes from 207 countries. Br J Sports Med. 2017;51:1265–71.
21. Soligard T, Palmer D, Steffen K, Lopes AD, Grant M-E, Kim D, et al. Sports injury and illness incidence in the PyeongChang 2018 Olympic Winter Games: a prospective study of 2914 athletes from 92 countries. Br J Sports Med. 2019;53:1085–92.
22. Feddermann-Demont N, Junge A, Edouard P, Branco P, Alonso J-M. Injuries in 13 international Athletics championships between 2007–2012. Br J Sports Med. 2014;48:513–22.
23. Edouard P, Branco P, Alonso J-M. Muscle injury is the principal injury type and hamstring muscle injury is

the first injury diagnosis during top-level international athletics championships between 2007 and 2015. Br J Sports Med. 2016;50:619–30.
24. Lopes AD, Hespanhol Júnior LC, Yeung SS, Costa LOP. What are the main running-related musculoskeletal injuries? A systematic review. Sports Med Auckl NZ. 2012;42:891–905.
25. Pollock N, Dijkstra P, Calder J, Chakraverty R. Plantaris injuries in elite UK track and field athletes over a 4-year period: a retrospective cohort study. Knee Surg Sports Traumatol Arthrosc. 2016;24:2287–92.
26. Figueroa D, Figueroa F, Calvo R. Patellar tendinopathy: diagnosis and treatment. J Am Acad Orthop Surg. 2016;24:e184–92.
27. Zwerver J, Bredeweg SW, van den Akker-Scheek I. Prevalence of Jumper's knee among nonelite athletes from different sports: a cross-sectional survey. Am J Sports Med. 2011;39:1984–8.
28. Ahuja A, Ghosh AK. Pre-Asiad '82 injuries in elite Indian athletes. Br J Sports Med. 1985;19:24–6.
29. van Gent RN, Siem D, van Middelkoop M, van Os AG, Bierma-Zeinstra SMA, Koes BW. Incidence and determinants of lower extremity running injuries in long distance runners: a systematic review. Br J Sports Med. 2007;41:469–80; discussion 480.
30. Schache AG, Dorn TW, Blanch PD, Brown NAT, Pandy MG. Mechanics of the human hamstring muscles during sprinting. Med Sci Sports Exerc. 2012;44:647–58.
31. Yeung SS, Suen AMY, Yeung EW. A prospective cohort study of hamstring injuries in competitive sprinters: preseason muscle imbalance as a possible risk factor. Br J Sports Med. 2009;43:589–94.
32. Malliaropoulos N, Isinkaye T, Tsitas K, Maffulli N. Reinjury after acute posterior thigh muscle injuries in elite track and field athletes. Am J Sports Med. 2011;39:304–10.
33. Carragher P, Rankin A, Edouard P. A one-season prospective study of illnesses acute and overuse injuries in elite youth and junior track and field athletes. Hurdling Chall 2019 IAAF World Championships. Front Media SA. 2020;86–97.
34. Caine D, DiFiori J, Maffulli N. Physeal injuries in children's and youth sports: reasons for concern? Br J Sports Med. 2006;40:749–60.
35. Engebretsen L, Steffen K, Bahr R, Broderick C, Dvorak J, Janarv P-M, et al. The International Olympic Committee Consensus statement on age determination in high-level young athletes. Br J Sports Med. 2010;44:476–84.
36. Launay F. Sports-related overuse injuries in children. Orthop Traumatol Surg Res. 2015;101:S139–47.
37. Steffen K, Engebretsen L. More data needed on injury risk among young elite athletes. Br J Sports Med. 2010;44:485–9.
38. Lundberg Zachrisson A, Ivarsson A, Desai P, Karlsson J, Grau S. Athlete availability and incidence of overuse injuries over an athletics season in a cohort of elite Swedish athletics athletes - a prospective study. Inj Epidemiol. 2020;7:16.
39. Edouard P, Morel N, Serra JM, Pruvost J, Oullion R, Depiesse F. Prevention of musculoskeletal injuries in track and field. Review of epidemiological data. Sci Sports. 2011;26:307–15.
40. Malliaropoulos N, Papacostas E, Kiritsi O, Papalada A, Gougoulias N, Maffulli N. Posterior thigh muscle injuries in elite track and field athletes. Am J Sports Med. 2010;38:1813–9.
41. Chumanov ES, Schache AG, Heiderscheit BC, Thelen DG. Hamstrings are most susceptible to injury during the late swing phase of sprinting. Br J Sports Med. 2012;46:90.
42. Orchard JW. Hamstrings are most susceptible to injury during the early stance phase of sprinting. Br J Sports Med. 2012;46:88–9.
43. Morgan DL, Allen DG. Early events in stretch-induced muscle damage. J Appl Physiol. 1999;87:2007–15.
44. Proske U, Morgan DL. Muscle damage from eccentric exercise: mechanism, mechanical signs, adaptation and clinical applications. J Physiol. 2001;537:333–45.
45. Potvin JR. Effects of muscle kinematics on surface EMG amplitude and frequency during fatiguing dynamic contractions. J Appl Physiol. 1997;82:144–51.
46. Ackermann PW, Longo UG, Maffulli N. Aetiology of tendinopathy of the Achilles tendon: mechano-neuro-biological interactions. In: Achilles tendinopathy: current concepts. London: DJO Publications; 2010. p. 15–23.
47. Rosso C, Valderrabano J. Biomechanics of the Achilles tendon. In: Achilles tendinopathy: current concepts. London: DJO Publications; 2010. p. 25–34.
48. Canata GL, Casale V. Endoscopic Achilles tenolysis. In: EFOST surgical techniques in sports medicine foot and ankle surgery. London: JP Medical Limited; 2015. p. 95–100.
49. van Dijk CN, van Sterkenburg MN, Wiegerinck JI, Karlsson J, Maffulli N. Terminology for Achilles tendon related disorders. Knee Surg Sports Traumatol Arthrosc. 2011;19:835–41.
50. Valent A, Frizziero A, Bressan S, Zanella E, Giannotti E, Masiero S. Insertional tendinopathy of the adductors and rectus abdominis in athletes: a review. Muscles Ligaments Tendons J. 2012;2:142–8.
51. Ellsworth AA, Zoland MP, Tyler TF. Athletic pubalgia and associated rehabilitation. Int J Sports Phys Ther. 2014;9:774–84.
52. Paajanen H, Ristolainen L, Turunen H, Kujala UM. Prevalence and etiological factors of sport-related groin injuries in top-level soccer compared to non-contact sports. Arch Orthop Trauma Surg. 2011;131:261–6.
53. Maffey L, Emery C. What are the risk factors for groin strain injury in sport? A systematic review of the literature. Sports Med Auckl NZ. 2007;37:881–94.
54. Estwanik JJ, Sloane B, Rosenberg MA. Groin strain and other possible causes of groin pain. Phys Sportsmed. 1990;18:54–65.

55. Chimenti RL, Cychosz CC, Hall MM, Phisitkul P. Current concepts review update: insertional Achilles tendinopathy. Foot Ankle Int. 2017;38:1160–9.
56. Tuite DJ, Renström PA, O'Brien M. The aging tendon. Scand J Med Sci Sports. 1997;7:72–7.
57. Li H-Y, Hua Y-H. Achilles tendinopathy: current concepts about the basic science and clinical treatments. Biomed Res Int. 2016;2016:6492597.
58. Jacxsens M, Weisskopf L, Valderrabano V, Rosso C. Achilles tendon. In: Foot and ankle sports orthopaedics. New York: Springer; 2017. p. 187–99.
59. Järvinen TAH, Kannus P, Maffulli N, Khan KM. Achilles tendon disorders: etiology and epidemiology. Foot Ankle Clin. 2005;10:255–66.
60. Möller A, Astron M, Westlin N. Increasing incidence of Achilles tendon rupture. Acta Orthop Scand. 1996;67:479–81.
61. Wen DY. Risk factors for overuse injuries in runners. Curr Sports Med Rep. 2007;6:307–13.
62. Taunton JE, Ryan MB, Clement DB, McKenzie DC, Lloyd-Smith DR, Zumbo BD. A retrospective case-control analysis of 2002 running injuries. Br J Sports Med. 2002;36:95–101.
63. Hoeberigs JH. Factors related to the incidence of running injuries. A review. Sports Med Auckl NZ. 1992;13:408–22.
64. van der Worp MP, ten Haaf DSM, van Cingel R, de Wijer A, Nijhuis-van der Sanden MWG, Staal JB. Injuries in runners; a systematic review on risk factors and sex differences. PLoS One. 2015;10:e0114937.
65. Beck BR, Osternig LR. Medial tibial stress syndrome. The location of muscles in the leg in relation to symptoms. J Bone Joint Surg Am. 1994;76:1057–61.
66. Craig DI. Medial tibial stress syndrome: evidence-based prevention. J Athl Train. 2008;43:316–8.
67. Michael RH, Holder LE. The soleus syndrome. A cause of medial tibial stress (shin splints). Am J Sports Med. 1985;13:87–94.
68. Moen MH, Tol JL, Weir A, Steunebrink M, De Winter TC. Medial tibial stress syndrome: a critical review. Sports Med Auckl NZ. 2009;39:523–46.
69. Mubarak SJ, Gould RN, Lee YF, Schmidt DA, Hargens AR. The medial tibial stress syndrome. A cause of shin splints. Am J Sports Med. 1982;10:201–5.
70. Reinking MF, Austin TM, Richter RR, Krieger MM. Medial tibial stress syndrome in active individuals: a systematic review and meta-analysis of risk factors. Sports Health. 2017;9:252–61.
71. Canata GL, Pulici L, Pavei G, Casale V. Jumping sports. In: Injury and health risk management in sports. A guide to decision making. Cham: Springer Nature; 2020. p. 503–8.
72. Visnes H, Aandahl HÅ, Bahr R. Jumper's knee paradox—jumping ability is a risk factor for developing jumper's knee: a 5-year prospective study. Br J Sports Med. 2013;47:503–7.
73. McNitt-Gray JL. Musculoskeletal loading during landing. In: The encyclopedia of sports medicine. Oxford: Blackwell Scientific; 2000. p. 523–49.
74. Lian OB, Engebretsen L, Bahr R. Prevalence of jumper's knee among elite athletes from different sports: a cross-sectional study. Am J Sports Med. 2005;33:561–7.
75. Davis IS, Powers CM. Patellofemoral pain syndrome: proximal, distal, and local factors, an international retreat, April 30–May 2, 2009, Fells Point, Baltimore, MD. J Orthop Sports Phys Ther. 2010;40:A1–16.
76. Boden BP, Boden MG, Peter RG, Mueller FO, Johnson JE. Catastrophic injuries in pole vaulters: a prospective 9-year follow-up study. Am J Sports Med. 2012;40:1488–94.
77. Opar DA, Williams MD, Shield AJ. Hamstring strain injuries: factors that lead to injury and re-injury. Sports Med Auckl NZ. 2012;42:209–26.
78. Malliaropoulos N, Ntessalen M, Papacostas E, Longo UG, Maffulli N. Reinjury after acute lateral ankle sprains in elite track and field athletes. Am J Sports Med. 2009;37:1755–61.
79. Holmes A, Delahunt E. Treatment of common deficits associated with chronic ankle instability. Sports Med Auckl NZ. 2009;39:207–24.
80. Edouard P, Chatard J-C, Fourchet F, Collado H, Degache F, Leclair A, et al. Invertor and evertor strength in track and field athletes with functional ankle instability. Isokinet Exerc Sci. 2011;19:91–6.
81. Edouard P, Samozino P, Escudier G, Baldini A, Morin J-B. Injuries in youth and National Combined Events Championships. Int J Sports Med. 2012;33:824–8.
82. Rebella GS, Edwards JO, Greene JJ, Husen MT, Brousseau DC. A prospective study of injury patterns in high school pole vaulters. Am J Sports Med. 2008;36:913–20.