EQOL Journal (2019) 11(2): 55-63

REVIEW ARTICLE

Injuries in elite athletes

Nikola Radulović [1] ✉ • Ilona Mihajlović [1] • Milan Šolaja [1] • Ratko Pavlović [2]

Received: 13th June, 2019
Accepted: 4th October, 2019

DOI: 10.31382/eqol.191207

Abstract
The purpose of this research was to review current research findings related to injuries in elite athletes. For the needs of the paper, professional and scientific literature was analyzed from prestigious scientific journals. The types of athletic injuries that occur are dependent on the athletic discipline. The most commonly injured sites in athletes are the front and back muscles of the thigh and in the ankle joint. The results of this study have indicated that the causes of most injuries are due to overstraining and overload syndrome. These causes often arise from training procedures that have been implemented inadequately and usually relate to the volume and intensity of training without the application of injury prevention techniques.

Keywords injuries • athletes • frequency.

Introduction

Professional sport involves exposing the body to great effort and strain, often resulting in a range of sports injuries, which in turn can have a huge impact on athletes' performances in competitions, which can have additional impact on athletes' self-esteem (Bojanić, Nedeljković, Šakan, Mitić, Milovanović, Drid, 2019). Many athletes do not recover completely after injury, which leads to repeated trauma in the affected area and can lead to a more serious injury. These injuries can be of many different types and need to be rehabilitated in the correct time frame to avoid additional complications and longer absence from the sports field. Different sports involve different mechanisms and types of injury, while age, sex and other requirements, depending on whether it is a professional, amateur or recreational sport, directly affect the prevalence of injuries (Maffulli, Longo, Gougoulias, Loppini, Denaro, 2010).

In athletic running disciplines, the process of training and competition involves constant periods of stress on the musculoskeletal system that is repetitive. The consequences of this load, which primarily involves the foot as the beginning of the kinetic chain and the action of forces that are several times greater than the body's weight, are athletes' injuries.

Throwing and jumping disciplines involve the creation of maximum force in a short period of time and in these disciplines injury results from stress caused by maximum muscular contractions (Tyflidis, Kipreos, Tripolitsioti, Stergioulas, 2012). The Australian authors who investigated the frequency, distribution and types of muscle-bone injuries, indicate that athletes belong to a high-risk group of sportspeople who are prone to injuries in the musculoskeletal system (Bennell and Crossley, 1996).

Athletic injuries vary in their degree of damage and, depending on this, can cause different periods of absence from the sports field, including training and competitive events. The incidence of injuries during international athletic competitions is 10% to 14% of the total number of athletes in the world championships (Alonso, Edouard, Fischetto, Adams, Depiesse, Mountjoy, 2012). Due to the la-

✉ nikolaradulovicfsfv@gmail.com

[1] University of Novi Sad, Faculty of Sport and Physical Education, Novi Sad, Serbia

[2] University of East Sarajevo, Faculty of Physical Education and Sports, East Sarajevo, Bosnia and Herzegovina

rge number of disciplines and participants in athletics when comparisons are made with collective sports, injury research in athletes is much more demanding. It is possibly the reason why fewer studies have been conducted in this area and the data is rather scarce. However, over the last ten years the largest world athletic competitions have been used to monitor the number, type and cause of injuries, as well as the injury mechanism. This tracking is intensified by certain systems and databases (Jacobsson, Timpka, Ekberg, Kowalski, Nilsson, Renström, 2010).

Monitoring the frequency and types of injuries, as well as the risk factors for their emergence, is very important for modelling an adequate preventive strategy in order to reduce the high number of injuries that occur in international athletic competitions (Alonso, Edouard, Fischetto, Adams, Depiesse, Mountjoy, 2012) and improving the quality of the results and increasing the number of healthy elite athletes. The most common cause of injury in athletics, as stated by numerous authors (D'Souza, 1994; Bennell and Crossley, 1996; Alonso, Junge, Renström, Engebretsen, Mountjoy, Dvorak, 2009; Alonso, Tscholl, Engebretsen et al., 2010; Alonso, Edouard, Fischetto et al., 2012) is overstraining and overload syndrome. This syndrome is caused by constant micro traumas over a certain period of time. Reducing the training load can lead to the regeneration of damaged tissue to the previous structural and functional level, if applied in the acute phase of the injury. Later, when injuries become chronic, there is a lack of tissue regeneration (Jacobsson, Timpka, Kowalski et al., 2012). An athlete with a chronic type injury does not have the ability to continuously advance their sporting form and results and this is often the cause of those athletes retiring from active sports. The seasonal variations in the competition schedule may influence the prevalence of injuries on the field (Rekus, Simaškitė, Šakalys, 2016). The aim of this study is to analyse the frequency of elite athletes' injuries that have occurred in the past 20 years.

Method

The descriptive method was used for the development of this paper, which was supported by theoretical analysis and generalization. Primary and secondary sources were combined including local and foreign professional and scientific literature, expert papers, search of Internet domains and electronic journals. During the search into research carried out by local and foreign authors, the following databases were used: PubMed, Medline, Google scholar, DOAJ, KOBSON, Crossref and HINARI. Newspapers in medicine, sports medicine and sports sciences were searched using the words “injuries”, “frequency”, “female athletes” and “male athletes”.

Lower limb injuries

The training and competitive process in athletic running disciplines involves long periods of repetitive stress on the musculoskeletal system, with a foot impact of 1000 to 1200 times per mile registered (Taunton, McKenzie and Clement, 1988), and the recorded action of this force is two to three times greater than the weight of the body (Cavanagh and Lafortune, 1980). As a result of these stresses that are placed on the locomotor system of athletes, the system becomes overused and injuries reoccur most often in the lower limbs. Injuries to the lower limbs are common in athletics and the site of the injury depends on the particular athletic discipline. Marathon runners most often injure their feet, middle- and long-distance runners often injure their shins, while athletes involved in throwing events tend to receive injuries to the upper limbs (Feddermann-Demont, Junge, Edouard, Branco, Alonso, 2014).

According to a number of studies, the most common injuries that athletes encounter are injuries to the muscles in the back and front of the thigh and ankles (Alonso, Jacobsson,Timpka, Ronsen et al., 2015; Alonso, Junge, Renström et al., 2009; Fong, Hong, Chan, Yung, Chan, 2007; Freckleton and Pizzari, 2013; Alonso, Edouard, Fischetto et al., 2012; Malliaropoulos, Papacostas, Kiritsi et al., 2010; Šolaja et al., 2013; Junge, Engebretsen, Mountjoy, Alonso, Renström et al., 2009).

Injuries to back thigh muscles

Some of the most frequent injuries that occur in athletes and footballers are injuries to the muscles in the back of the thigh (Reurink, Tol and de Vos, 2014). Injuries of this type are common in sports that include sprinting, acceleration, deceleration, jumping and rapid changes in direction of movement which can often lead to repeated injuries (Freckleton and Pizzari, 2013). The rate of re-injuries in the muscles at the back of the thigh is high and two of the most common reasons are the lack of an adequate rehabilitation programme and / or premature involvement in the training process after injury (Malliaropoulos, 2012). The function of the muscles in the back of the thigh is complex and depending on the position of the leg and in what relation it is to the

surface, the muscles of this region have different functions. They can serve as hip extensors, knee flexors and external rotors of the hip and knee (Malliaropoulos, 2012). Injuries are usually sustained during sprinting and the region of the injury is mainly on the long head of the biceps femoris muscle and usually involves the proximal muscle-tendon junction (AskLingo, Malliaropoulos, Karlsson, 2012).

In sprinting disciplines, the rapid change in the contraction of the muscles in the back of the thigh from the agonist phase to the antagonist phase is considered to be the moment when the greatest possibility of injuries is present. Loads during running are different for each muscle of the back of the thigh; however, the two-headed thigh muscle (biceps femoris) is most exposed to stretching forces (Chumanov, Heiderscheit, Thelen, 2011). The most common cause of muscle injury to the back of the thigh is the overstretch syndrome (Alonso, Edouard, Fischettoisar, 2012; Alonso, Jacobsson, Timpka, Ronsen et al., 2015). The data from the 13th World Athletics Championships 2011 in Daegu (South Korea) show that the most common place of injury is the thigh (n = 67; 26.9%) where 58 cases of injuries were in hamstring muscles (23.3% in relation to total number of analysed injuries). The analysis shows that the most frequently diagnosed injury was stretching of the hamstring muscles (n = 39; 15.7%) (Alonso, Edouard, Fischetto et al., 2012). Among the elite athletes of Serbia, in the Olympic period from 2008 to 2012, 174 injuries were registered. Of the total number of injuries, the most injured part of the body were the lower limbs - 90.8% (n = 158) and from this total 56.9% (n = 99) were in the thigh region, with the highest figure for injuries being in the muscles of the back of the thigh, recorded in 61 cases (30, 05%). The most frequent diagnosis was stretching of the hamstring muscles (n = 37; 21.3%) (Šolaja, A., Šolaja M., Milankov, 2013). Similar results are found at the last World Championships in Moscow (Russia, 2013), where the thigh is the most frequently injured region (33.3% of the total number of injuries), while the most frequently diagnosed was stretching of the hamstring muscles (20.3% of the total number of injuries). Athletes who participated in this competition reported 32 (16.5% of the total number of injuries) injuries to the thigh two months before the competition (Alonso, Jacobsson, Timpka, Ronsen et al., 2015). In the literature available there is no consensus on the time needed to return to the sports field after an injury to the muscles in the back of the thigh, but the criteria for recovery after an injury of this type is very variable. There is also no consensus on the impact of the congested competition schedule on player health (Valle, Mechó, Prune, Pedret, Isern, Monllau, Rodas, 2018).

Greek authors state that the most commonly injured muscle in athletes are the two-headed muscle located at the back of the thigh (m. biceps femoris) (Malliaropoulos, Papacostas, Kiritsi et al., 2010), while the other group of authors define that 1st and 2nd degree stretching injuries of the thigh muscles tend to return and that athletes often have a problem with the recurrence of the injury in the same region (Malliaropoulos, Isinkaye, Tsitas, Maffulli, 2011). Australian authors have reported that stress fractures (21%) is the most common injury in athletes, with injuries of the muscles in the back of the thigh being the second most common (14%) (Bennell and Crossley, 1996). Hamstring injuries are most common in the sport disciplines of sprinting, hurdles and jumping events and makes up one third to one half of the injuries in this group of athletes and takes up to three quarters of the rehabilitation time (Fredericson, Moore, Guillet, Beaulieu, 2005).

It is evident in the literature (Rekus, Simaškaitė, Šakalys, 2016; Alonso, Edouard, Fischetto, Adams, Depiesse, Mountjoy, 2012; Chumanov, Heiderscheit, Thelen, 2011; Malliaropoulos, Papacostas, Kiritsi et al., 2010; Malliaropoulos, Isinkaye, Tsitas, Maffulli, 2011; Schache, Kim, Morgan, Pandy, 2010; Opar, Williams, Shield, 2012; Schache, Dorn, Blanch, Brown, Pandy, 2012; Yeung, Suen, Yeung, 2009; Šolaja et al., 2013) that muscle injuries to the back of the thigh are the most commonly reported by athletes.

A classic mild muscle rupture in this area usually requires three weeks of therapy, while severe forms of injuries can lead to the athlete never returning to the sports field (Kujala, Orava, Jarvinen, 1997). After six weeks the condition of the muscles at the back of the thigh should be checked with an MRI scan, thus giving accurate data that is relevant in the prediction required for the return of athletes to the training process (Askling, Tengvar, Saartok, Thorstensson, 2007).

Ankle Joint Injuries

During sports activities involving the ankle joint or its structures, high forces act and 25% of all athletes' injuries are attributed to injuries to the ankle joint. Also, repeated injuries occur in 70% of cases due to the action generated during movement in combination with the residual joint (Vesović-Potić and Manojlović-Opačić, 2011). Injuries of the anterior ligament complex of the ankle are most

commonly caused by running on uneven surfaces and during impact landing usually from an unstable position. Then the entire body movement moves to the anterior talofibular ligament (lig. talofibularis anterior) and can cause strains, partial rupture or total tearing. In the analysis of 70 sport disciplines that have been the subject of a study, athletics appears in 24 sport disciplines, where the most common injury is that of the ankle joint (Fong, Hong, Chan, Yung, Chan, 2007). Among athletes who have frequent jumps in their events, such as high jump and long jump, an increased incidence of this injury has been observed. In the event of an ankle injury, the most common is a grade 2 sprain (Moderate). These types of injuries are more common among professional athletes than those who participate in amateur sports (Marjanović, 2011). During the World Championship in Daegu (South Korea, 2011), 6% of ankle joint injuries were recorded in relation to the total number of injuries. According to the figures, these types of injuries were the third most common, while injuries to the back of the thigh and lower leg injuries occupied the first two places (Alonso, Edouard, Fischetto et al., 2012). At the 2008 Beijing Olympics, the highest number of injuries recorded was ankle injuries, most common being stretching of the ligaments in the ankle (Junge, Engebretsen, Mountjoy, Alonso, Renström et al., 2009). In their research with elite Serbian athletes, Šolaja et al. registered 24 (13.79%) injuries to the ankle in four years, second only to the most common injuries occurring in the back of the thigh. At the World Championship in Moscow (2013), ankle injuries accounted for 2.1% of the total number of injuries in that competition. However, participants in this competition reported 19 (9.8%) injuries to the ankle joint two months before the World Championship (Alonso, Jacobsson, Timpka, Ronsen et al., 2015). Greek and Spanish authors concluded that there was a statistically significantly higher incidence of injuries to the back side of the thigh in elite athletes who had also experienced earlier injuries to the ankle ligaments (Malliaropoulos, Bikos, Mecca, Vasileios, Valle, Lohrer, Maffulli, Padhiar, 2018).

Table 1. Locations of main (severe) injury before the competition and the location of the first injury during the 13th World Athletics Championships in Moscow (Alonso, Jacobsson, Timpka, Ronsen et al., 2015).

Total	Injuries before competition			Injuries during competition		
	Total N	F N (%)	M N (%)	Total N	F N (%)	M N (%)
	194	92	102	48	18	30
Face/head	10 (5,1)	3 (3,2)	7 (6,8)	0 (0)	0 (0)	0 (0)
Neck/spine	23 (11,1)	7 (7,6)	16 (15,7)	1 (2,1)	1 (5,6)	0 (0)
Torso (excluding spine)	18 (9,2)	10 (10,9)	8 (7,8)	2 (4,2)	1 (5,6)	1 (3,3)
Shoulder	3 (1,5)	2 (2,2)	1 (1,0)	1 (2,1)	0 (0)	1 (3,3)
Arm/hand excluding shoulders)	4 (2,0)	3 (3,3)	1 (1,0)	3 (6,3)	2 (11,1)	1 (3,3)
Hip/groin	21 (10,8)	10 (10,9)	11 (10,8)	0 (0)	0 (0)	0 (0)
Thigh	32 (16,5)	15 (16,3)	17 (16,7)	17 (35,4)	6 (33,3)	11 (36,7)
Knee	24 (12,4)	10 (10,9)	14 (13,7)	3 (6,3)	0 (0)	3 (10,0)
Lower leg	24 (12,4)	14 (15,2)	10 (9,8)	9 (18,8)	3 (16,7)	6 (20,0)
Achilles tendon	0 (0)	0 (0)	0 (0)	4 (8,3)	1 (5,6)	3 (10,0)
Ankle	19 (9,8)	10 (8,8)	9 (8,8)	1 (2,1)	0 (0)	1 (3,3)
Foot	16 (8,4)	8 (7,8)	8 (7,8)	7 (14,6)	4 (22,2)	3 (10,0)

For this calculation one injury prior to the competition and the first injury suffered during the athletic competition were noted. Information was lacking for 10 athletes, 6 females and 4 males, on injuries before the competition and data on the first injury during the competition by an athlete. This data is excluded from the analysis. The value of the arithmetic mean for upper leg injuries before the competition was 6.0 (3.5), for knee injuries 4.9 (4.3), for lower leg 4.7 (3.4), for injuries of the neck/spine 5.2 (3.9), for hip/groin 5.9 and for injuries of the ankle 5.9 (3.0) (Table 1).

Injuries to Muscles in the Front of the Thigh

The maximum speed of running is based on certain motor skills. These abilities primarily relate to the frenetic movement and the explosive power of the muscles of the lower extremity extensions (Tončev,

2001). Front thigh muscles actively engage with maximum stress in running and jumping and because of this they are often injured. The cause of injuries to this muscular region is often an inadequate amount of training intensity and accordingly leads to constant overstretch and muscle load (Tončev, 2001). The cause of this type of injury, which is manifested by swelling and muscle pain in the front of the thigh, may include, among other things, pelvic injuries, such as an avulsion fracture of the ischial tuberosity (spina iliaca anterior inferior). Such injuries require an operative treatment to enable the full recovery of the athlete. In the rehabilitation process, systematic muscle strengthening is necessary because after the operation, isokinetic muscle testing shows weakness of the extensor musculature in the leg operated on (Milankov, Harhaji, Gojković, Drapšin, 2011). A rupture of the tendon of the four-headed muscle (m. quadriceps femoris) is an example of a severe front thigh muscle injury also, caused by a high percentage of degenerative changes in the tendon itself. Possible risk factors that underline these degenerative changes are of a different nature: long-term immobilisation, metabolic diseases, jumper's knee and steroid abuse (Ristić, Maljanović, Popov, Harhaji, Milankov, 2013). At the World Athletics Championships in Osaka, 2007 (Japan), a high number of injuries to the lower limbs were recorded (80%), with the most common diagnosis being muscle strain in the front thigh (16%) (Alonso, Junge, Renström, Engebretsen, Mountjoy, Dvorak, 2009). These results were repeated two years later at the World Athletics Championships in Berlin (Germany) in 2009, where the highest number of injuries were localized in the muscles of the front area of the thigh - 37 (13.8%) (Alonso, Tscholl, Engebretsen, Mountjoy, Dvorak, Junge, 2010). In the analysis of injuries which included all sports at the Beijing Olympics (2008), the most frequent diagnosis was the partial rupture of the front thigh muscles (Junge, Engebretsen, Mountjoy, Alonso, Renström et al., 2009). At the next most important world-class competition, the London Olympics (2012), out of a total of 38 muscle strains, 24 strains in the front thigh muscles were recorded, which occurred mainly in athletic disciplines (Engebretsen, Soligard, Steffen, Alonso, Aubry et al., 2013). In the Olympic period (2008 to 2012), 22 (12, 63%) of injuries to the muscles in the front of the thigh were registered in Serbian athletes, of which 19 were strains and 3 ruptures (Šolaja A., Šolaja M., Milankov, 2013). Based on data from the 13th World Athletics Championships - in open and closed terrain, from 2007 to 2012, there were 1470 injuries. The most common diagnosis was muscle strains of the front thigh (28.2%) (Feddermann-Demont, Junge, Edouard, Branco, Alonso, 2014).

In athletics, injuries to the lower limbs are characteristic and the greatest number of injuries is diagnosed in those athletic disciplines where during the whole year the primary load is focused on the lower extremities during the training and competition process, such as in sprints (Rekus, Simaškaitė, Šakalys, 2016). Injuries to the muscles of the inner thigh, the hip flexor muscle, knee, lower leg, Achilles tendon and the feet belong in specific athletic injury groups (Šolaja et al., 2013). They are common and their appearance is registered in major international competitions (D'Souza, 1994; Bennell and Crossley, 1996; Zemper, 2005; Fallon, 1996; Tyflidis, Kipreos, Tripolitsioti, Stergioulas, 2012; Alonso, Edouard, Fischetto, Adams, Depiesse, Mountjoy, 2012; Alonso, Junge, Renström, Engebretsen, Mountjoy, Dvorak, 2009; Alonso, Tscholl, Engebretsen, Mountjoy, Dvorak, Junge, 2010; Jacobsson, Timpka, Kowalski, Nilsson, Ekberg, Renström, 2012; Junge, Engebretsen, Mountjoy, Alonso, Renström et al., 2009, Engebretsen, Soligard, Steffen, Alonso, Aubry et al., 2013; Edouard, Morin, Pruvost, Kerspern, 2011; Rekus, Simaškaitė, Šakalys, 2016).

Injuries to Upper Limbs and Torso

Injuries to the upper limbs are characteristic of the athletic throwing disciplines (Rekus, Simaškaitė, Šakalys, 2016). The lower back - lumbar area around the spine has the greatest load during these types of sports activities. Different activities that are present in the athletic training process, such as weight lifting in power training and the throwing of projectiles such as: javelin, discus, shot put and hammer, the constant torsion and compression of the spine seen during jumping and running can all be the causative agent of acute or chronic back pain. Problems occurring in the lumbar area of athletes who deal with throwing, jumping and sprinting are defined as discogenic, back muscle injuries, combined injuries, etc. (Malliaropoulos, Bikos, Tsitas, Papadopoulou, 2011). Upper limb injuries are characteristic in throwing disciplines. During the throwing of the projectile, a multiple load is observed in the shoulder joint, which is conditioned by the weight of the projectile and the speed of movement. On the one hand, the shoulder must have sufficient flexibility to allow for excessive external rotation during movement, but on the other hand it has to be stable enough to prevent symptomatic shoulder subluxation (Wilk, Obma,

Simpson, Cain, Dugas, Andrews, 2009). Lithuanian researchers who investigated injuries in their top-ranking track and field athletes found that all of the injuries to the upper limbs (12%) were in athletes involved with throwing events (Rekus, Simaškaitė, Šakalys, 2016). If we are talking about a young person, the risk of a re-emergence of shoulder subluxation is larger. If the person is between 20 and 30 years of age, the recurrence rate is 50%, while for those younger than 20 years this figure increases to 80% (Milankov, 2010). The prevention of repeated shoulder subluxation involves applying an appropriate treatment after the first injury. In this way, the possibility of a recurrence of shoulder subluxation is reduced. If there is instability of the shoulder joint in one direction, an open minimal invasive surgical treatment of the instability of the shoulder joint is recommended. This treatment is reliable and, especially in younger athletes, gives good clinical results (Ninković, Harhaji, Stanković, Savić, Milankov, 2008).

In a study involving 174 top athletes, back injuries amounted to 14.4% of the total number of injuries (De Souza, 1994). In a study by authors from Australia (Bennell and Crossley, 1996), torso injuries, which included back, pelvic and hip injuries, were represented with 13% of the total number of injuries and ranked fourth. The highest number of injuries was recorded in the location of the lower limbs, as follows: the muscle of the front thigh (21.5%), knee (16.2%) and foot (14.6%). In a four-year study involving French decathletes (from 1994 to 1998), most injuries were localised in the back (9%), while lower limb injuries were the most common (77%) (Edouard, Morin, Pruvost, Kerspern, 2011). It was also noted that marathon runners had a high percentage of back injuries - 6% of the total number of injuries, while lower limb injuries had the highest percentage (90%) (Fallon, 1996).

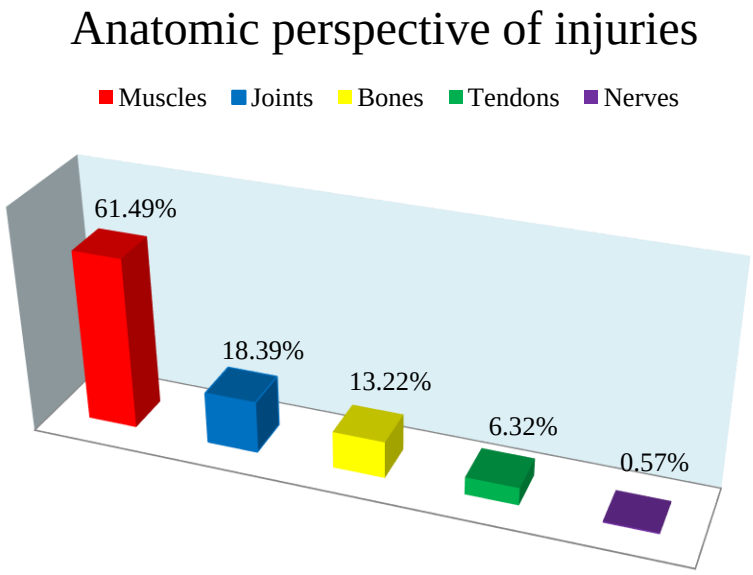

Figure 1. Showing the frequency of injury from the anatomical aspect of elite Serbian athletes in the Olympic period from 2008 to 2012 (according to A. Šolaja, M. Šolaja, Milankov, 2013)

In analyzing data received at the World Athletics Championships in Berlin (Germany), 2009, 236 injuries were recorded, with 13% being torso injuries (Alonso, Tscholl, Engebretsen, Mountjoy, Dvorak, Junge, 2010). In four years 19 (10.92%) injuries to the torso and upper limbs were recorded in elite Serbian athletes (Šolaja et al., 2013). While taking part in the World Championships in Moscow, 2013, 14 torso and upper limb injuries occurred. Here the authors included neck and spine in the injuries of the torso (Alonso, Jacobsson, Timpka, Ronsen et al., 2015).

The study, which included 64 injuries, found that 1.5% of the total number of injuries included upper limbs and injuries to the chest (Fallon, 1996). In all studies that dealt with this problem, the highest percentage of athletic injuries were recorded in the lower limbs (64-87%), while the probable residual percentage refers to upper limbs (Zemper, 2005).

Conclusion

The type of athletic injuries that occur depends most often on the particular athletic discipline. The most frequently injured sites in athletes are the back and front of the thigh and in the ankle joint. The causes of most athletic injuries are described in literature as a result of overstrain and overload syndrome. Inappropriate volume and intensity applied during the training process without the use of specific exercises for the goal of preventing athletes' injuries, results in injuries in athletes. In order to reduce the number of injuries and increase the number of healthy athletes who are then able to achieve top performances in competitions, constant education of athletic coaches is needed along with the cooperation of athletic clubs and selected top sports doctors.

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How to cite this article:

APA: Radulović, N., Mihajlović, I., Šolaja, M., & Pavlović, R. (2019). Injuries in top-class athletes. *Exercise and Quality of Life, 11*(2), 55-63. doi:10.31382/eqol.191207

MLA: Radulović, Nikola, et al. "Injuries in top-class athletes." *Exercise and Quality of Life* 11.2 (2019): 55-63.

Chicago: Radulović, Nikola, Ilona Mihajlović, Milan Šolaja, and Ratko Pavlović. "Injuries in top-class athletes." *Exercise and Quality of Life* 11, no. 2 (2019): 55-63.