Training Load and Injury Risk

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Contents

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67.1 Introduction

Football is a dynamic and physically demanding sport, has an intermittent character, and switches between short high-intensity phases with or without ball such as sprints, jumps, and side-cutting movements and low-intensity phases, such as tactical built-up and game interruptions. To be able to participate on the highest level, players will have to withstand the continuously increasing high athletic demands.

Due to increases in game speed, numbers of matches, and athleticism, the musculoskeletal system has a high demand and therefore a potential high risk of injuries. In an analysis of the national statutory accident insurance company, the first national football league in Germany showed a distribution of 38.3% match injuries and 61.7% training session injuries in the season 2014/2015 [1]. Comparing the distribution of sustained injuries for each month of the season, injuries during training sessions occurred to a higher number during the classic preseason times in July and January in which players have a higher training exposition than in other months,

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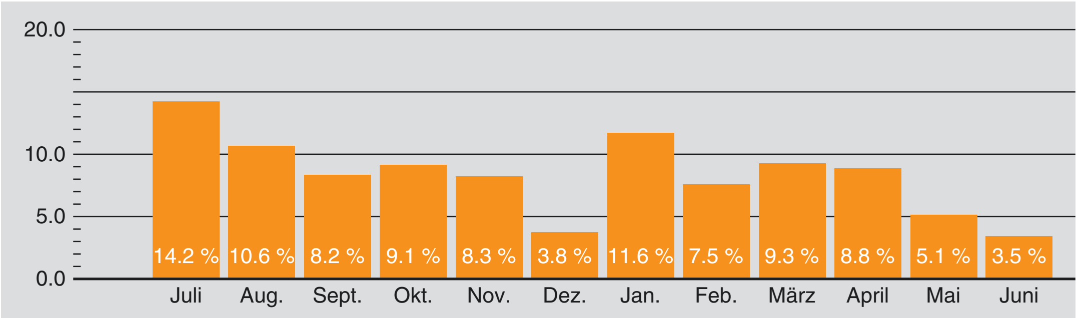

Fig. 67.1 Distribution of training session injuries for each month in the season 2014/2015 in the highest two national football leagues in Germany. Injuries during training sessions occurred to a higher number during the classic preseason times in July and January, from Verwaltungsberufsgenossenschaft-Sportreport 2016 [1]

but evidence is yet inconclusive if increased training volume and increased training intensity may play a role. This chapter will help to provide available evidence to show data connecting football training load and injury risk in elite football players. Injury aetiology models have evolved over the previous two decades highlighting multiple factors which contribute to injury of athletes. These models include internal risk factors, exposure to external risk factors, and an inciting event, wherein biomechanical breakdown and injury occurs (Fig. 67.1).

67.2 Internal and External Risk Factors for ACL Injury

Injury is not a circumstance of destiny. A multifactorial influence of internal and external risk factors modifies the injury risk in a certain unique situation. In the following some of these risk factors will be described in detail. For further information, Chap. 19 will highlight further modifying risk factors.

67.2.1 Internal Risk Factors for ACL Injury

Over 40 million women play football today [2]. Considering the total number of both genders, the incidence of ACL injury is two to three times higher compared to male football [3–5]. Generally, women have a higher incidence in team sports compared to males [3, 6]. Certain differences between men and women as a cause for anterior cruciate ligament injuries have already been established. Women have more often noncontact ACL injuries than male football players. In men, cruciate ligament tears occur more often in their shooting leg compared to the standing leg in women [7]. During an ACL disruption, the bodyweight is shifted over the injured body side, especially in women. Hewett presents different causes on why women have a higher rate of cruciate ligament tears [8]. “Ligament dominance” refers to a neuromuscular imbalance that ends in a knee valgus collapse in certain movements, for example, landing after a jump. Muscles cannot cushion the impact sufficiently enough, and joints and ligaments therefore need to absorb higher-energy peaks.

After a jump, women tend to land in a more extended knee position than males [8]. The dominant muscle for the stabilization of the knee joint while landing is the quadriceps muscle. Its activation results in an extended knee position while landing and to a strain of the ACL through an anterior shift of the tibia. An imbalance between the quadriceps muscle and its antagonist, the hamstring muscles, has been called “quadriceps dominance.” A further risk factor for anterior cruciate ligament tears is “leg dominance.” Here, muscle power and muscle control present a higher side-to-side difference in females [9]. Athletes that do not possess a sufficient sense of positioning of the body trunk in a three-dimensional space and have need of greater corrective movements are assumed to have a predisposition for an ACL tear [9]. “Trunk dominance” suggests that males typically exhibit greater control of the trunk in performance situations. Rapid growth in pubescence may be a possible trigger for trunk control decrements.

Most injuries of the anterior cruciate ligament occur in young age. Injuries are sustained especially in phases of alterations of anthropometric composition, and resulting biomechanical alteration of lever arms is often not sufficiently stabilized by the musculoskeletal system. This occurs most often during growth spurt. Hormonal changes may also have a great impact on players during a whole season, especially in women. Estrogen levels play an important role and influence muscles and ligaments, which are more loose in women [10]. This fact tends to result in one of the major reasons for injuries of the lower extremity in female football [2, 11, 12].

Another important risk factor for an ACL tear are previous ACL tears or knee injuries [3–5, 13]. An ACL tear of one side is an increased risk for an ACL injury of the other side. Previous knee injuries lead to a persistent disturbance of proprioception. Eighty percent of football players with ACL tears showed a previous injury in a short period before the incident. Most of these injuries were minor injuries, such as muscle injuries on the thigh, ankle injuries, or even blisters on heel or toes. These disturbing factors lead to a disbalance in the coordination of the musculature in the lower extremity [8] and thereby to a vulnerability of the anterior cruciate ligament.

Different sports are characterized by a multitude of highly specific, stereotypical patterns of movement. When the movements are performed at sufficient magnitudes for a long period of time, these sport-specific motor stimuli evoke specific responses in which certain biological structures undergo adaptations that enable the athlete to adequately “process” the loads. These sport-specific adaptions affect bones, ligaments, and musculoskeletal and myofascial structures and are characterized in all sports by an asymmetrical distribution of loads between the right and left sides of the athlete’s body (e.g., football with normally dominant kicking and standing leg). Generally the adaptations heighten the quality of the sport-specific movement patterns and thus have a positive effect on the athlete’s performance in that particular sport. On the other hand, many of these adaptations cause changes in muscular loads and can sometimes lead to the overuse or unphysiologic loading of certain musculoskeletal structures and in so far could create an additional risk factor, exceeding the stress tolerance of the structures and resulting in injury [14, 15].

Further risk factors include an adequate fitness of the players, fluctuations in weight, and psychological aspects such as match experience, motivation, or performance pressure.

67.2.2 External Risk Factors for ACL Injury

Artificial turf is a typical example for scientific studies being able to assess initially assumed risk factors as harmless. It could be shown that artificial turf of the third and fourth generation that possesses a FIFA license does not increase the risk of injury in football players [16]. Despite these results, the utilization of artificial turf for matches is still controversely discussed in European amateur and professional football. This may be influenced by possible negative results of switching between artificial and natural turf. For this reason, players are supposed to perform their training session on the respective surface their upcoming match will be played.

The data for the influence of football shoes and shoe profile on ACL tears is not yet conclusive. The different interactions between surface of the turf and shoe make influences on injury mechanisms theoretically possible. Yet no scientific study could show connections between different shoe brands or shoe cleats and ACL injury. For example, long cleats do not increase the likelihood of ACL injury [17]. Sport scientists and sport brand manufacturers are very active in the analysis of possible risk factors and optimization of shoe design to reduce the likelihood of injury.

Environmental conditions may influence the likelihood of injury as dry weather increased the rate of ACL injury [18]. But data is yet inconclusive as most data has been published from the Australian Football League.

67.3 Phases with Increased Risk of ACL Injury

Specific phases of a football season or football career are assumed to have an increased risk of ACL injury. The preseason period and the first match days of a new season have an increased risk of ACL injury in amateur and professional football. The series of summer break with loss of fitness, muscle force, and coordination and sudden physical overexertion at the beginning of the new season are assumed to let this time window appear more prone to ACL injuries. In phases of neuromuscular fatigue during preseason, the players have a decreased proprioception which results in increased load of the joints of the lower extremities. Countermovements from full sprint, rotational, or valgus movements may then result in overload of the knee joint and subsequent ACL tear.

The transition from junior football to senior football also appears to present a dangerous age phase. Söderman et al. found an increased risk for ACL tears in female junior football players participating in senior football [19]. The same could be established for male adolescents by our own data (not published). This topic is especially important for permits for junior players that want to play in professional senior football. No scientific data has been established, but young players should be treated with caution to enable neuromuscular adaption and sufficient regeneration.

The increase of physical load in a football player may arise if a player changes its football team, especially if this new team plays in a more professional and demanding level, for example, in a higher-performing league. A promotion of a team into a higher league also increases the demands of the player. Krutsch could show that implementing a new professional third national football league increases the rate of ACL and PCL tears in this league in the first season [20]. The same could be shown in handball, where after restructuring the second league two-division system into one single national second league, Luig et al. (submitted) showed an increase of injury incidence in the second national division to almost the same level of the first national division within the first two seasons.

67.4 Training Load

In addition to the interplay of risk factors or inciting time phase, every athletic injury is sustained while athletes are exposed to training and competition workloads. Match workloads are due to the competitive demands of the sport, while training workloads are applied to athletes with the goal of inducing positive physiological changes and maximizing performance. The various biological adaptations induced by (appropriate) training increase athletes' capacity to accept and withstand load and may thus provide protection from injuries.

67.4.1 External and Internal Training Load

An external training load refers to any external stimulus applied to the athlete, whereas the individual biological response to this external load is called internal load [21, 22]. In football, the former refers to the quality, quantity, organization, and content of physical exercises prescribed by the coach, and the latter is of physiological and psychological nature.

67.4.2 Biological Response

The external load stimulates a biological response and eventually adaptation of the human body's systems. The stimulus for training-induced adaptations is the actual physiological stress, i.e., the internal load, imposed on the football players by the external load [23, 24]. Training results in temporary decrements in physical performance and induces fatigue [25]. These decrements are typically derived from increased muscle damage, impairment of the immune system, imbalances in anabolic-catabolic homeostasis, alteration in mood, and reduction in neuromuscular function [26–32]. Gender differences have not much taken into consideration yet since, for example, estrogens have been shown to protect against reactive oxygen species [33].

The resultant fatigue after a training load can take up to 4–5 days to return to baseline values after the respective training. This fatigue follows a supercompensation phase, whereby the body adapts to increase the specific capabilities affected by the initial stressor [34]. In sports that have frequent training and competition, such as football, fatigue may accumulate over time [35].

Periodization was developed with the aim of manipulating these adaptive processes and effects. Football athletes and coaches push their training to the limits by means of volume and intensity to maximize their performance. The aim of load management is to optimally configure training, competition, and other loads to maximize adaptation and performance with a minimal risk of injury [36]. Load management therefore comprises the appropriate prescription, monitoring, and adjustment of external and internal loads. But limited information exists on the training dose-response relationship in elite football athletes (Fig. 67.2).

67.5 Monitoring Training Load

Warm-up or training programs are created by the football coach in amateur and professional football and present good and simple influencing tools with which the rate for ACL tears can be reduced [11, 38]. Coaches therefore have a decisive share of the responsibility to reduce and prevent injuries. A direct connection between any certain training program and an increase of ACL tears has not been shown, but it is recommended to select exercises for the warm-up and training in such a manner to not only succeed in matches but to prevent injuries. The relationship between training programs and health outcomes can be discussed by monitoring the training load and injury. Assessment of football training load involves measuring external and internal loads, where tools to measure the former can be general or football specific and, for the latter, objective or subjective (Fig. 67.3).

67.5.1 Monitoring External Training Load

To gain an understanding of external training load, a number of tools and technologies are available to athletes, coaches, and medical staff [21]. Measuring single exercises such as lifted weight or distance covered in a certain time may help to

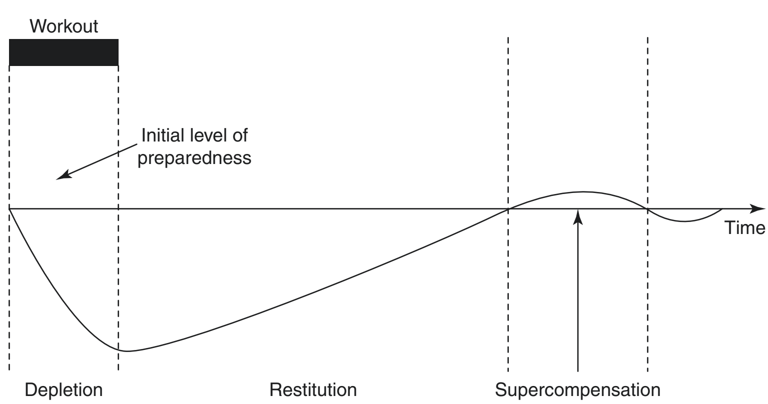

Fig. 67.2 Time course of the restoration process and athlete's preparedness after a workout according to the supercompensation theory. After any given sufficient training stimulus, an athlete's preparedness first declines, then recovers, and is followed by a supercompensation phase, from Zatsiorsky [37]

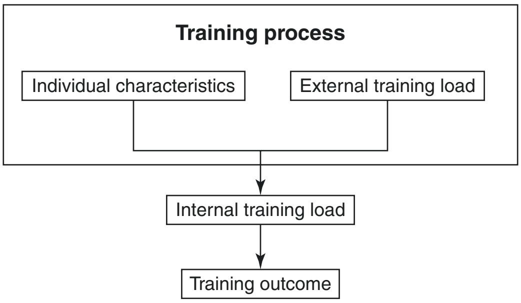

Fig. 67.3 Training outcome is the consequence of internal training load determined by (1) individual characteristics and (2) quality, quantity, and organization of external training load, adapted from Impellizzeri [39]

quantify power output. Training can be recorded to provide information on a number of parameters, including power, speed, and accelerations. Time-motion analysis, such as global positioning system (GPS) tracking, and movement pattern analysis via digital video are popular measuring tools. The reliability of GPS for monitoring movement is influenced by factors such as sample rate, velocity, and duration and type of task. From the available literature, it appears that the higher the velocity of movement, the lower the GPS reliability [40]. Measures of neuromuscular function such as jump tests (squat jump, drop jump), sprint performance, and isokinetic and isoinertial dynamometry are often utilized in team sports due to the simplicity and minimal amount of fatigue induced [41]. To perform, for instance, a drop jump, the athlete drops off a box, hits the ground, and immediately jumps vertically as high as possible at ground contact [42]. Equipment requirements may include contact mats, portable or non-portable force platforms, and rotatory encoders [21]. Common variables from jump tests include mean power, peak velocity, peak force, jump height, flight time, contact time, and rate of force development [41, 43, 44].

67.5.2 Monitoring Internal Training Load

The use of rating of perceived exertion (RPE) is based on the notion that an athlete can monitor their physiological stress during exercise as well as retrospectively provide information regarding their perceived effort post training or competition [21]. The most commonly used scale is introduced by Gunnar Borg and rates exertion on a scale of 6–20. The range is to follow the general heart rate of a healthy young adult by multiplying by 10. For instance, a perceived exertion of 14 would be expected to coincide with a heart rate of roughly 120 beats per minute. Evidence suggests that RPE correlates with heart rate during steady-state exercise and high-intensity interval cycling training, but not as well during short-duration high-intensity soccer drills [45]. RPE is therefore often combined with other variables to provide additional insights into the internal load experienced by the athlete.

Foster developed the “session rating of perceived exertion” method of quantifying a training load unit, which involves multiplying the athlete’s RPE on a 1–10 scale by the duration of the session in minutes [46, 47]. This simple method has been shown to be valid and reliable, with individual correlations between session RPE and summated heart rate (HR) zone scores. Subsequent research in football training has identified individual correlations between RPE and HR zones [48]. The session RPE method was developed to eliminate the need to utilize HR monitors or other methods of assessing exercise intensity. While the session RPE method may be simple, valid, and reliable, the addition of heart rate monitoring may aid in understanding some of the variance that it does not explain [21].

The use of heart rate monitoring during exercise is based on the linear relationship between the heart rate and the rate of oxygen consumption during steady-state exercise [49]. Percentage of maximum heart rate can be used to monitor intensity; heart rate recovery is the rate at which heart rate declines at the cessation of exercise and is suggested to improve with increased training status [50]. Daily variation in heart rate makes individual responses and interpretation difficult and controlling factors such as hydration, environment, and medication important.

Training impulse (TRIMP) is a term coined by Eric Banister to describe the exercise dose as a single number with an integration of time, intensity, and relative weighting of the intensity of the exercise [51]. The mean heart rate is weighted according to the relationship between heart rate and blood lactate as observed during incremental exercise and then multiplied by the session duration. The modeling conducted has focused on endurance training and is limited for use in intermittent sports such as football, mainly because the use of mean heart rate may not reflect the fluctuations that occur during intermittent exercise.

Psychomotor speed tests are often computerized tests and assess reaction time and rapid visual information processing tasks. Overtrained athletes regularly report symptoms such as concentration problems, cognitive complaints, and memory problems [52].

Research in the area of biochemical, hormonal, and immunological assessment is limited, and no definitive marker to monitor internal load, measure fatigue, and minimize excess fatigue has been identified as markers have high inter- and intraindividual difference and are dependent on multiple other factors, such as temperature, hydration, environment, diet, and prescribed exercise. The most popular measure is blood lactate concentration due to the simplicity of sample collection and analysis and is sensitive to changes in exercise intensity and duration [53].

Monitoring sleep quality and quantity can be useful for early detection of performance and health decrements. Athletes can use diaries to indicate hours of sleep and perceived sleep quality. Actigraphy, wristwatch devices utilizing accelerometry, may provide more detailed information, such as bedtime, wake time, sleep onset latency, wake during sleep, sleep efficiency, and sleep routines [21].

67.5.3 Monitoring Athletes

Monitoring athletes may help provide essential data to understand the athlete's response to a prescribed training program, with the goal of minimizing fatigue and injury and examining the effectiveness. Monitoring is incorporated differently, depending on the familiarity of athletes and staff with each monitoring tool, but it appears self-reported measures and sport-specific performance assessment are most commonly used. A recent systematic review on internal load monitoring concluded that subjective measures were more sensitive and consistent than objective measures in determining acute and chronic changes in athlete well-being in response to load [54]. However, the nature of load monitoring required varies greatly between team sport and individual sport athletes. Monitoring in team sports is more challenging due to the diverse range of training activities and number of players. Athletes usually train in groups which leads to the situation that the intensity of the training will not be similar to all the athletes. Players respond differently to given stimuli, and the load required for optimal adaptation therefore differs from one athlete to another. Team sports like football, in which inter-individual differences exist, makes prescription of training exercises extremely difficult. Interindividual adjustments to training therefore have to be taken into account. This emphasizes the importance of monitoring the individual athlete, rather than the team as an average, as it may help to ensure the prescribed load by the coach has been applied. Players have to be monitored directly, as the coach's perceptions of the training intensity and the athlete evaluation of the training load might not always be the same. Heinsoo et al. could demonstrate differences between the perception of training intensity in adolescent cross-country skiers and coaches with a 10-point intensity scale. Further, the measurement of cognitive performance and "cognitive load" that influences decision making is important and poses many challenges for accurate assessment.

67.6 Training Load and Injury Risk

In football, players may participate in 50–80 games during a season. In many European top leagues, top teams compete in two games per week during several periods within a season [55]. During these congested periods, players have only 3–4 days of recovery between successive international and national games, which may be insufficient to restore normal homeostasis [27, 56]. Without sufficient regeneration after a match, players will begin their next match with a certain amount of fatigue with the potential of causing performance impairment and injuries in the short and long term [57–59].

67.6.1 Absolute Training Load and Injury Risk

The majority of studies on the relationship between training load and injury risk in team sport have used assessment of absolute load, irrespective of the present or past rate of load application. Absolute training load is the total of all training sessions performed within a specified period, such as a single day or 1 week. Both low and very high acute training loads have been associated with increased risk of injury in Australian football, rugby union, and football [60–65].

Owen monitored maximal heart rate of 23 elite-level professional football players over two consecutive seasons and found significant correlations between training volume and injury incidence [66]. Further analysis revealed how players achieving more time in zones of maximal heart rate of >90% increased the odds of sustaining a match injury but did not for sustaining a training injury. The studies associating low absolute loads with an increased risk of injury suggest the finding the players are not prepared enough for the training and match volume and intensity.

Gabbet proposed the idea of a player's threshold, i.e., the amount of training load that could be sustained before an injury occurred [64]. He suggested this threshold decreased during the season, potentially as players became fatigued when compared to preseason thresholds. In this sense, low acute training loads may be beneficial for players, as some studies indicate. At present knowledge, moderate-to-high workloads can protect best against injury [67].

Fact Box
- High absolute training loads are associated with greater injury risk.
- Moderate-to-high workloads can protect best against injury.

67.6.2 Relative Training Load and Injury Risk

Series completed in cricket, rugby league, and Australian football have shown that if an athlete's training and playing load for a given week (acute load) spikes above the chronic load over the past 4 weeks in average, they are more likely to be injured [68]. The findings demonstrate a strong predictive relationship between acute-chronic load ratio and injury likelihood. In the elite team setting, quantifying the loads the athlete's staff is expecting may help in the return-to-play decision (Fig. 67.4).

Training loads can be achieved in multiple different ways. Volume, intensity, frequency, and training content are unlikely to carry all the identical injury risk. Further research has to elaborate which type of high training load may be an important predictor of injury or injury protecting factor.

Fact Box
- The ratio of acute to chronic training load is a better predictor of injury than acute or chronic loads in isolation.
- To minimize the risk of injury, do not exceed weekly load increases dramatically.

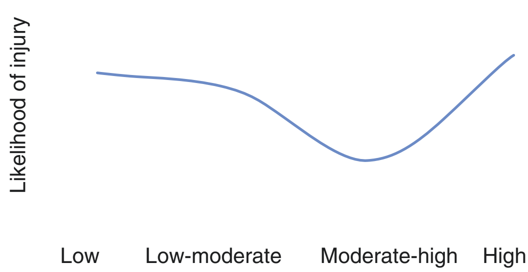

Fig. 67.4 Acute-chronic workload ratio and likelihood of subsequent injury from studies of three different sports. The data indicates that if an athlete's training and playing load for a given week (acute load) spikes above the chronic load over the past 4 weeks in average, they are more likely to be injured, adapted from Blanch P, Gabbett TJ [68]

67.6.3 Training Load and Match Injury Risk

No evidence has yet been established to show a link between training content and injury risk in matches in football. For amateur players, little evidence exist to prove this question as data acquirement has been shown difficult with non-professional players. Further research may answer these questions with the help of databases, for example, national and international ACL injury registers.

Take-Home Message
There is limited evidence at present on training load and injury risk in football. High absolute training loads are associated with greater injury risk while moderate-to-high workloads can protect best against injury at current knowledge. Here, the ratio of acute to chronic training load is a better predictor of injury than acute or chronic loads in isolation. Therefore, to minimize the risk of injury, weekly load should not increase dramatically. More research in the future has to elaborate and identify risk factors associated with training load.

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