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CHAPTER 19: INJURY PREVENTION AND REHABILITATION

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Abstract

Injury risk screening and management in women's football must be based around incidence data and understanding match demands. Current screening and prevention programmes are based on relatively limited data in women's football compared to data on men. However, despite this, appropriate and effective screening and risk management programmes have been proposed for women footballers. Movement screening is an effective way to help players understand how they move and how they can move more effectively. Significant reductions in injury incidence rates and likely reduced injury burden have been demonstrated in injury prevention programmes . Injury risk management programmes are, however, only effective if they are adopted, implemented and maintained by clubs, coaches and players. Implementing programmes at an early stage in a player's training journey ensures that preventive measures seamlessly integrate into their weekly training routine. Appropriate

rehabilitation strategies need to consider the high re-injury rates in women and that resource is required to make sure players are fit to return to sport. Other issues specific to women around perceptions of social support also need consideration.

Introduction

There has been a rapid growth in women's football and thus there is greater need to develop injury screening, risk prevention strategies and rehabilitation modalities. All of these are key factors in ensuring the health and wellbeing of players, enhancing their performance and sustaining the long-term success of the sport across all levels of participation. Injury epidemiology has been described in Chapter 17 of this book, and the information from these studies form the foundation of screening, prevention and rehabilitation models in women's football. Data from the current chapter highlight the importance of injury risk screening and prevention, given the severity and burden of anterior-cruciate ligament (ACL) injuries in women players. Such injuries are associated with increased risk of end-stage osteoarthritis resulting in total knee arthroplasties (Khan et al., 2019), considerable financial contributions per injury to gain a quality-adjusted life (Eggerding et al., 2022) and psychological barriers that may affect recovery, return to sport and an increased risk of sustaining a subsequent injury (Ardern et al., 2016). Likewise, match demands in women's football (see Chapter 6) are important to understand, in terms of preparing players for the demands of the game, which must be considered alongside injury risk-management strategies. Understanding and exploring loading and accumulated fatigue, in terms of injury risk, are paramount in the prevention strategy, but data on players from the women's game are severely lacking. By implementing comprehensive injury prevention measures, teams and players can mitigate the risk of injuries and ensure a sustainable and thriving future for women's football. Recent advances in using machine learning and artificial intelligence to predict injury risk have provided greater insight into the possible mechanisms associated with injury risk in women's football (Nassis et al., 2022). As part of the Van Mechelen et al. injury model (1992), the first stage of understanding injury, and subsequently trying to reduce incidence, is understanding the surveillance and risk data. Only then can appropriate screening, prevention and rehabilitation strategies be developed that are designed for players in women's football. The aims of this chapter are to describe appropriate injury risk screening strategies, review the efficacy of prevention programmes and outline rehabilitation processes for women's football.

Screening strategies for injury risk

Sport-related injuries in women's football have complex, multifactorial causes and occur frequently, with significant negative consequences on players' health and career development, both in the short and long term (McKay & Mellalieu, 2021). Through numerous systematic reviews and meta-analyses, it has been demonstrated that the likelihood of these injuries occurring in the women's game can be minimised through injury prevention programmes (IPPs) if routinely implemented during training sessions (Crossley et al., 2020; Lemes et al., 2021). These IPPs typically target evidence-based modifiable risk factors for lower extremity injuries including high-risk biomechanical movement strategies (e.g., excessive dynamic knee valgus motion at landing and cutting) and neuromuscular deficits (e.g., muscle weakness and poor dynamic joint stability).

For exercise-based interventions to be highly effective in mitigating modifiable risk factors of injury, they must meet specific requirements, including a design tailored to the specific characteristics and needs of each player and their context (Olivares-Jabalera et al., 2021). Therefore, the initial step for practitioners in designing individualised IPPs is the careful selection and application of assessment tests targeting the key modifiable risk factors associated with the most burdensome injuries in women's football, i.e., muscle strains of the hamstring and quadriceps, ankle sprains and ACL tears (Robles-Palazón, Cejudo, et al., 2021). Moreover, the information gathered from testing in healthy players can greatly assist in decision making regarding a safe return to competition following rehabilitation post-injury.

Systematic analysis of video in women's football has established identifiable patterns in non-contact soft-tissue injuries among players (Aiello et al., 2023; Lucarno et al., 2021). As a result, an effective test battery for assessing football-related neuromuscular capacities and movement mechanics should include jump, sprint and changes-of-direction tests. These tests have demonstrated valid, reliable and independent kinetic and kinematic measures, providing rich data with minimal testing in players. Given the time and resource constraints commonly encountered in applied environments, it is recommended to incorporate tests that are portable, cost-effective and technically simple to administer, to enable the assessment of players within a short timeframe. Therefore, it is paramount that an evidence-based approach to testing the key neuromuscular parameters and biomechanical movement patterns involved in the occurrence mechanisms of the most burdensome women's football injuries is implemented. We discuss two such screening frameworks below.

The 'Stop and Go' programme

The Stop & Go programme was designed based on the research in women's and girls' football of the "Locomotor System and Sports" (University of Murcia) and the "Move Well Be Strong" (https://www.movewellbestrong.net/) research groups. The programme consists of three blocks of field-based tests that allow the assessment in applied scenarios of several factors related to the incidence of injuries in football:

1. Personal or individual factors (e.g., age, sex, maturation status, history of previous injuries).
2. Psychological factors related to emotional wellbeing and sports performance (e.g., sleep quality and quantity, anxiety and stress, emotional regulation and cognitive functioning).
3. Factors related to physical performance, neuromuscular capacity and motor competence.

For this chapter, we will focus solely on the third block of tests, which includes vertical and horizontal jump tests, maximal speed running assessment and postural assessment. For more information on the other blocks, please refer to Robles-Palazón, Cejudo, et al. (2021).

Jumping assessment

Jump landings have consistently been identified as primary movement patterns associated with some of the most burdensome knee and ankle injuries in women's football (Lucarno et al., 2021). Given that neuromuscular strategies and lower extremity biomechanics adopted during jumps and landings are task-specific (Taylor et al., 2016), a range of different jump methodologies have been proposed. The proposed jump assessment protocol encompasses six vertical and two horizontal jump tests to provide a comprehensive evaluation of players' physical performance, landing mechanics and neuromuscular capacity during this primary motor skill (Table 19.1) (Flanagan & Comyns, 2008; Lloyd et al., 2009; Myer et al., 2008).

In the Drop Vertical Jump (DVJ) (typically from 30 cm) and Countermovement Jump (CMJ) tests, simultaneous assessment of some kinetic (Bishop et al., 2021) and kinematic measures can by conducted using two force platforms (for calculating bilateral differences in kinetic measures) and three two-dimensional cameras positioned in the frontal and sagittal planes. The captured images from the DVJ and CMJ tests are subsequently analysed using software packages (e.g., Kinovea, Quintic, ImageJ and Dartfish), which allow kinematic analysis in a plane that is perpendicular to the camera (Robles-Palazón et al., Ruiz-Perez, et al., 2021; Ruiz-Perez et al., 2021). In the absence of force platforms, cost-effective alternatives, such as the "My Jump" app, are available to assess jumping performance (Balsalobre-Fernández et al., 2015).

The qualitative information extracted (ligament dominance, quadriceps dominance, leg dominance, trunk dominance, feedforward mechanisms, deficits and neuromuscular fatigue [Font-Vanmeerhaeghe et al. 2017]) from the Tuck Jump Assessment (TJA) regarding players' neuromuscular capacity could be enriched with kinematic assessment of each landing performed during the 10-s test, following the same methodology as described above for DVJ and CMJ (Robles-Palazón, Ruiz-Perez, et al., 2021). Additionally, the 20 submaximal, bilateral hop test, as described by Lloyd et al. (2009), allows relative leg stiffness, normalised to the player's body mass, to be calculated (Dalleau et al. (2004). Finally, the five-maximum hop test (Flanagan & Comyns, 2008), and the modified reactive strength index (McMahon et al., 2022) allow stretch-shortening-cycle capability to be determined.

Table 19.1. Jump tests included in the Stop & Go programme (https://www.stopandgosport.com/) and the measures extracted from them. All measures must be taken in the dominant and non-dominant legs.

	Vertical jump tests	
Jump protocol	**Neuromuscular capacity**	**Landing mechanic**
Drop vertical jump	Peak landing force (first and second landing). Modified reactive strength index.	Frontal plane projection angle.

	Ratio of peak landing force to peak take-off force. Asymmetries (%). Jump height.	Hip, knee and ankle flexion angles at initial contact and peak flexion and their respective ranges of motion.
Countermovement jump	Peak landing force. Modified reactive strength index. Time to take off. Jump momentum. Countermovement jump depth Leg stiffness. Asymmetries (%). Jump height.	
Tuck jump	Ligament dominance (yes/no). Quadriceps dominance (yes/no). Leg dominance (yes/no). Trunk dominance (yes/no). Neuromuscular fatigue (yes/no). Feedforward mechanism deficits (yes/no).	
20 submaximal vertical hops	Leg stiffness.	
Five maximum vertical hops	Modified reactive strength index.	
Horizontal jump tests		
Bilateral broad jump	Distance reached.	

Single hop (horizontal) test	Distance reached. Asymmetries (%).

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It is advisable to perform three to five valid attempts of the DVJ and CMJ tests and select the one with the highest jump height for subsequent kinetic and kinematic analyses to ensure accurate measurements and a true representativeness of the players' neuromuscular capability. For the vertical hop tests, two to three valid attempts should be performed, and those with the greatest relative leg stiffness and modified reactive strength index values selected. However, due to the physical demands of the TJA, only one valid attempt is recommended to avoid fatigue-related responses. In the horizontal jump tests, only the distance reached is recorded, which must be normalised with respect to the players' leg length. For the single hop test (Munro & Herrington, 2011), the differences between the distances reached by the dominant and non-dominant leg are also calculated.

Sprint assessment

The Stop & Go programme incorporates two sprint tests: a) A 30-m straight-line sprint test (Lahti et al., 2020) and b) a 90º change-of-direction test (Aparicio-Sarmiento et al., 2020). These two tests aim to assess the physical performance, neuromuscular function and mechanics of sprinting (including acceleration, maximal speed and deceleration).

In the straight-line sprint test, the time recorded at 5, 10, 15, 20, 25 and 30 m using timing gates is incorporated into the spreadsheet designed by Samozino et al. (2016), to calculate the players' mechanical capacity to generate force during maximum speed running (Table 19.2).

Concurrently, the players' sprint mechanics (sagittal plane) are assessed to record hip, knee and ankle flexion angles (Lathi et al., 2020). An alternative, cost-effective and reliable option for those who do not have access to timing gates is to video the 30-m sprint and analyse data using the "My Sprint" app (Romero-Franco et al., 2017).

The change-of-direction test (modified by Aparicio-Sarmiento et al., 2022) allows determination of both qualitative (using the cutting movement assessment score) and quantitative (Weir et al., 2019) assessment of players' change-of-direction mechanics. The time taken by participants to complete the change-of-direction test is also recorded using timing gates as a measure of performance.

Table 19.2. Maximum speed running tests included in the Stop & Go programme and the measures extracted from them.

Maximum speed running	Neuromuscular capacity	Landing mechanic
30-m sprint	Time (physical performance): 5-, 10-, 15-, 20-, 25- and 30-m split times. Force-velocity profile measures: Theoretical maximal force, maximal ratio of forces, mean ratio of forces at 10 m, maximal power and velocity.	Early acceleration and upright sprint (maximal) kinematic measures in the toe-off and touchdown phases: Centre of mass distance (m/body length), hip angle (ipsilateral and contralateral legs), trunk

		angle and step length (m/body length).
90º change of direction	Time (physical performance): 5- and 10-m split times.	Initial and final (weight acceptance phase) contact time, trunk and knee flexion angles and ranges of motion of both the penultimate and final footsteps of each change of direction (left and right). Frontal plane projection angle and trunk inclination angle and ranges of motion of the final footstep.

Postural assessment

The shortened version of the postural fitness test battery includes a series of tests aimed at assessing neuromuscular constructs, such as dynamic and static trunk stability, trunk muscle endurance, maximal isometric strength of the hip muscles and range of motion of the lower extremity. Specifically, postural assessment should include the rotary stability and trunk stability push-up tests (Cook et al., 2006), for assessing the dynamic stability of the trunk musculature during a combined upper and lower extremity motion and a closed-chain upper body movement.

For the trunk muscle endurance assessment, the flexion rotation trunk test (Brotons-Gil et al., 2013) is proposed, while the protocol described by Ruiz-Pérez et al. (2021) is preferred for assessing isometric hip abduction and adduction strength. The players' results for each hip abduction and adduction isometric strength measurement are normalised to body mass and tibia length (isometric strength [N] × tibial length [m] ÷ body mass [kg]) (Cejudo et al., 2021). Finally, the maximum passive range of motion for hip flexion and extension with the knee extended, hip abduction, knee flexion and ankle dorsiflexion with the knee extended is evaluated using the methodology and instrumentation described by Cejudo et al. (2020).

Considerations for the implementation of screening in applied environments

In applied contexts, where there is a need to assess several players within the same training session, it is proposed to carry out the tests using a circuit approach to optimise the time available. Normally the circuit consists of six stations, requiring approximately six to eight experienced testers (Figure 19.1), which needs consideration if resource is limited. Each station includes one or several tests to maximise the time spent screening players.

<Figure 19.1 here>

Prevention strategies

Given the benefits of screening athletes for injury risk, it is imperative that effective injury prevention strategies are put in place. Over the last three decades, mitigation of injury risk has seen the implementation of validated IPPs with the vast majority designed specifically to address ACL injury in girls and women (De Ste Croix et al., 2018; Walden et al., 2012).

With the demands of football including high-intensity running (made up of rapid accelerations and decelerations), changes in direction (see Chapter 6) and contact through tackling, the adoption of evidence-based IPPs reduces incidence and severity of injuries (Crossley et al. 2020). These programmes typically consist of a combination of strength and conditioning exercises, flexibility training, balance and proprioception drills and education of coaches and players on how to best mitigate injury risk. A criteria-driven approach should be used (see figure 19.2) to support the player on their developmental journey to reduce injury risk.

<Insert Figure 19.2 here>

Strength and conditioning training

Strength and conditioning training has been shown to significantly reduce injury risk in footballers (Crossley et al. 2020). De Ste Croix et al. (2018) implemented an injury prevention programme consisting of strength, plyometric and balance exercises in girls aged 13–17 years. It was reported that markers of injury risk (knee valgus, leg stiffness and peak knee adduction moment) were all improved with the programme. Further, it was identified that there were significant beneficial effects of such training for those players who were identified as high risk through screening, as opposed to those classified as low risk. This finding highlights the importance of incorporating strength and conditioning exercises tailored to women's football in IPPs.

Flexibility training

Flexibility training plays a crucial role in injury prevention by improving joint range of motion and muscle extensibility (Ayala et al. 2012). Most evidence focuses on the implications of dynamic stretching embedded in IPPs such as the FIFA 11+ on lower-extremity range of motion, measured through either joint angular change (e.g., passive knee extension, passive dorsiflexion or the modified Thomas test (Matsuo et al., 2019; Curry et al., 2009; Pamboris et al., 2019) or through posterior-chain flexibility tests such as the sit-and-reach test (Ayala et al., 2012). The implementation of comprehensive IPPs, including flexibility training, in elite women football players demonstrated reductions in the incidence of injuries by 27% (Crossley et al., 2020). These findings underscore the significance of flexibility training in reducing the risk of specific injuries in women's football.

Balance and proprioception training

Balance and proprioception training are vital in enhancing neuromuscular control and preventing injuries, particularly in lower limb joints (Crossley et al., 2020). Steffen et al. (2008) investigated the effectiveness of balance training in elite girls' football (13–18 years), with players who undertook the training exhibiting a 35% reduction in the incidence of ankle sprains compared to that of the control group. Moreover, a multitude of researchers have integrated various forms of balance training into their IPPs, highlighting the significance of including exercises focused on balance and proprioception in injury prevention initiatives for girls' and women's football (Foss et al., 2018; Emery& Meeuwisse 2010; Söderman et al., 2000).

Injury prevention education

Educating athletes and coaches on injury prevention techniques and promoting injury awareness is essential. However, there is an ongoing concern regarding the uptake and maintenance of such programmes (Emery et al. 2007), which may be attributed to coach knowledge, understanding and attitude towards such interventions. Coaches often lack access to the knowledge and skills that are required to teach the exercises or to correct faulty technique. Recently it has reported that a coach education workshop can be effective in improving adherence to IPPs when there is a practical element for coaches to undertake and appreciate what quality movement is (De Ste Croix et al., 2020). Empowering coaches and athletes with this training may help overcome barriers to adherence, to achieve sustained injury reduction in the football players.

Sports science and data analysis

The integration of sports science and data analysis has provided valuable insights into injury prevention in women's football. In their 2021 study, Xiao et al. employed global positioning systems' technology to monitor training loads and assess injury risk in football players. The results of their research revealed a link between high training loads spanning two, three and four weeks and an elevated risk of injury. This study demonstrates the significance of data-informed decision-making and load-management strategies in minimising injury risk, which is a growth area in the development of sport science support in women's football (Costa et al. 2022).

Rehabilitation for football players

Given the previously noted greater injury incidence rates in women's football, inevitably the rehabilitation process needs to be effective in terms of return to play. In a recent report into gender inequality in football, it was suggested that the disparity in resource between men's and women's football places the woman player at a potential disadvantage in this process (Philippou et al., 2022), but, to date, this assumption is largely anecdotal, with little data to support such claims. There is no suggestion that rehabilitation programmes should be fundamentally different across the men's and the women's game (Cerulli et al., 2002), however linking back to the injury prevention elements, women may wish to focus on specific types of training within the rehabilitation process. Cerulli et al. (2002) suggest that rehabilitation processes after ACL injury in women athletes should focus on neuromuscular capability, plyometrics, postural balance, biomechanics of movement and functional agility, all within a sport-specific context. As with prevention programmes, it is important that rehabilitation strategies are specific for women and focused on their biology, anatomy, physiology and movement competency, as well as access that they have to resources. In a study exploring hip and core strengthening on patellofemoral pain syndrome, an eight-week programme in women players reduced pain, reduced knee abduction and improved neuromuscular control (Earl et al., 2011). This finding is supported by López -Valenciano et al. (2017), who stressed that players' rehabilitation should include exercises for strength and mobility of the hip abductors and core stability (especially in the frontal plane).

The key to a successful rehabilitation process is compliance (Johnson, 1997) and many researchers have examined the psychosocial elements of successful return to play in women athletes, probably due to the high burden associated with serious injuries. Those women footballers (n = 43) who are most successful in their rehabilitation demonstrate autonomous motivation that results in rehabilitation adherence (Johnson, 1997), as well as high levels of self-confidence and mindfulness (Mosewich et al., 2014). It has been identified that those less successful in the rehabilitation process are younger women, with limited injury experience, negative emotions and with perceived isolation (Forsdyke et al., 2016), noting that there is a gender bias with little data on women compared to men (Forsdyke et al., 2016)

Return to play post injury

Given the greater propensity of players in women's football to suffer serious injuries, the rehabilitation process can often be long, and it might be perceived that players will not be able to return to pre-injury levels of performance. However, most data indicate good return-to-play outcomes for football players with most returning to the same pre-injury levels (Webster et al., 2021), often back to the highest level of competition. This positive outcome is evident in a recent case study by Taberner et al. (2020), who used the "control-chaos continuum" as a framework for return to play for an elite player, which resulted in a return to above pre-injury training load demands and who achieved her goal of representing her country at the World Cup.

Nordahl et al. (2014) found that the main characteristics of women skiers who did not return to sport post-ACL injury were young women with no previous experience of injury and who demonstrated risk and fear of re-injury. However, Johnson et al. (2016) found women footballers displayed resilient behaviours during ACL rehabilitation and were more successful if they had rich interactions with significant others, strong belief in one's own actions and ability to set clear goals.

Re-injury rates in women's football

Around one in four women who have returned to play following an ACL injury will go onto either re-injure the same or other ACL, and this is around 23% higher than it is in men (Wong et al. 2023). Faude et al. (2006) reported that 26.3% of German professional players went on to have a second ACL injury. Webster (2021) noted that data regarding level of performance after return to play are severely lacking in women's sport. There are limited data, but based on data from one study, it has been shown that hamstring eccentric training after hamstring injury in women players resulted in no re-injuries 12 months after return to play (Tyler et al., 2017).

Psychosocial aspects in return to play post injury

Many researchers have explored the psychosocial aspects needed for successful return to play in women's sport, and a range of mechanisms have been identified. These mechanisms include motivation, goal setting, social support and managing internal and external pressures (Hildingsson et al., 2018). One of the mechanisms that most often appears in the literature is the effectiveness of social support mechanisms in the rehabilitation process for players, and this might be due to the reduced formal support that players get in women's club settings (Hildingsson et al., 2018). Forsdyke et al. (2022) noted that increasing positive perceptions of social support is important in preparing players to be more psychologically ready to return to sport. Managing emotions, anxiety regarding performance and re-injury fears, alongside building confidence and sound social-support mechanisms appear essential if productive rehabilitation outcomes are desired in women's football. For those interested in this area, the reader is guided to the extensive work of Forsdyke and colleagues (2016, 2022).

Practitioners' perspective

With the practitioner as the front line of screening, prevention and rehabilitation work, it is important that any continuation and carry over of improved kinematics needs to transfer into sports performance (i.e., when they are stressed and under fatigue), and this needs to be reinforced by the technical coaches and other support staff, so there is not a disconnect between strength and conditioning/physiotherapy practices and technical training. This disconnect highlights the need for technical coaches to be educated in how their players should be moving, so they can also reinforce good movement patterns and manage training load when required. Thus, technical coaches need to work with the multidisciplinary team to identify sports-specific technical models to both minimise injury and maximise effectiveness in football. Movement screening (Tables 19.1 and 19.2) is an efficient way to get to know "new players" and identify training needs quickly, but players need to be motivated to perform at their best in movement screens, so player education may also be needed. Movement screening can be effective as a player education tool by raising awareness of their own movement competency. However, it is important that any data are presented to athletes in a clear and impactful way.

Technical coaches should have a good idea of what strategies they can use in a warm-up that effectively improves movement competency (e.g., mobility drills improve range of motion) for each player that may form part of the individualised warm-up but should be developed using objective movement screening data (refer to the section on prevention strategies). Given that we often find clubs that are resource poor in the women's game, it is important that coach and player education is effective in reducing injury risk. Keeping prevention training fun and engaging is important for player compliance and subsequently minimising risk.

Summary

In this chapter, we have highlighted the growing popularity of women's football and the need for injury screening, risk prevention and rehabilitation strategies to ensure athletes' wellbeing and long-term success in the sport. Non-contact ACL injury incidence is higher in women than it is in men, causing personal, societal and economic burdens. Screening strategies for injury risk are crucial, including strength and conditioning training, flexibility training, balance and proprioception exercises and education on injury prevention. Rehabilitation for players in women's football should focus on neuromuscular capability, plyometrics, postural balance and functional agility. Successful return to play relies on compliance, psychosocial support and managing emotions and anxiety, and appropriate goal setting.

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