# Injury Prevention and Performance Enhancement in Sub-elite Football Players.

## Cumulative Dissertation

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## Author

Mojtaba Asgari


## Supervisors

Professor. Dr. Thomas Jaitner
Professor. Dr. PT. Martin Hägglund

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# Preface

Football has always been more than just a sport to me. It has been a lifelong passion, a source of inspiration, and, at times, a journey marked by both triumphs and setbacks. As a former professional player whose career was cut short by injuries at a very young age, I have experienced firsthand the physical and emotional toll that injuries can have on athletes. This personal experience ignited my desire to bridge the gap between injury prevention research and its practical application in football, ensuring that future generations of young talents can develop and compete in a safer and more performance-oriented environment.

This dissertation represents years of dedication, research, and collaboration, culminating in the development of the Football+, a scientifically grounded, football-specific warm-up program designed to reduce injury risk while enhancing athletic performance. Through rigorous investigation and a strong commitment to applied sports science, I sought to address the challenges associated with traditional injury prevention programs by integrating evidence-based methods with real-world applicability. The journey was not always easy, but it was filled with invaluable learning experiences, professional growth, and, most importantly, the unwavering support of those who believed in this mission.

The following pages reflect not only an academic pursuit but also a vision that aims to reshape the way injury prevention is perceived and implemented in football. None of this would have been possible without the support of my colleagues, friends, and family, to whom I extend my deepest gratitude.

## Gratitude

*"The only reason I asked you to join my group was that I wanted you to become a good scientist"*, *Thomas told me six years ago!!*

Well, I'm not sure how successful I was in fulfilling that mission, but I do know that you, Thomas, were the game-changer in both my personal life and scientific career. At the very least, I can confidently say that I feel like a better person now. From the bottom of my heart, I want to express my deepest gratitude, respect, and warmest regards to the best Doktorvater, Professor. Dr. Thomas Jaitner. Sometimes, it's hard to put deep emotions into words, and I don't want to make this too long or boring, so I'll keep it simple: Thank you for everything! It has been a great pleasure and a true honor to be a member of your group.

Next, my sincere thanks go to Professor Martin Hägglund, a highly respected and leading expert in the field. I had the privilege of working with you and learning extensively from your expertise. Martin, thank you for joining me on this journey and for your patience, support, and invaluable contributions; it has been truly appreciated.

I would also like to extend my gratitude to Dr. Mario Bizzini for his professional and friendly cooperation over these years. There's no need for a long introduction; your incredible career in both science and practice speaks for itself. It was an absolute privilege to have the opportunity to work with you. Thank you very much, Mario.

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A special appreciation goes to Dominik and Kevin, my office mates for the past five years. Guys, I can't explain how amazing you are. What I could say, though, is that Kevin is one of the few basketball players who could actually do something with his feet. respect Alter!

By the way, Dominik! Remember that my InBody scores were always better than yours, even though you spent more time on the treadmill! Maybe it's time to cut back on the chocolate and cheese, my friend. Beyond all this, our office was always an open space for great discussions, laughter, and good conversations. I learned from you, and I'm grateful to have had such kind, supportive, and inspiring colleagues by my side.

As this journey comes to an end, I would like to express my gratitude to all professors and colleagues at the Institute for Sport and Sport Science (IFSS) for making it the best place to work. Always supportive, always ready to help, always warm and welcoming; I couldn't have asked for a better environment.

A special thank you to Borussia Dortmund (BVB09), and particularly the Women's Football Department, for your invaluable and constructive collaboration, as well as your commitment to advancing knowledge in women's football. Without your support, this innovative and practical project would not have been possible.

***Your Moji***
***May 2026***

# Contents

**Summary** ..... 1

**1. Introduction and theoretical background** ..... 3

1.1. Football population ..... 4

1.2. Women's football: a rapidly growing global trend ..... 4

1.3. Challenges and underrepresentation in women's football ..... 5

**2. Injuries in football** ..... 6

2.1. Injury incidence rates (IIRs) in football ..... 7

2.2. IIRs in women's football ..... 7

2.3. The short- and long-term consequences of injuries in football ..... 8

2.4. Injury risk factors ..... 9

**3. Prevention of injuries** ..... 11

3.1. Contemporary approaches to football injury prevention ..... 12

3.2. Conceptual models for injury prevention studies ..... 12

3.3. Efficacy of injury prevention programs ..... 13

3.4. Current state and challenges: role of compliance ..... 15

**4. Research problem and literature review** ..... 17

4.1. Problem definition ..... 18

4.2. Publication one. ..... 20

**5. Introducing the Football+ program** ..... 30

5.1. A comprehensive warm-up program for injury prevention and performance enhancement ..... 31

5.2. Development rationale of the Football+ ..... 31

5.3. Structure and components of the Football+ ..... 32

5.4. Research aims and hypothesis ..... 33

**6. Empirical evaluation of the Football+ program: Effects on injury risk factors and motor performance** ..... 35

6.1. Publication 2. ..... 36

6.2. Publication 3. ..... 49

6.3. Publication 4. ..... 57

**7. Discussion** ..... 64

**8. Practical implications** ..... 69

8.1. For coaches, trainers, and players ..... 70

8.2. For clubs and associations ..... 70

8.3. For policymakers and governing bodies ..... 71

8.4. Limitations ..... 71

**9. Future research**.....73
9.1. Clinical studies.....74
9.2. Large-scale RCTs.....74
9.3. Longitudinal studies on compliance and adherence.....74
9.4. Broader population studies.....75
9.5. Integration with performance science.....75
9.6. Program optimization and personalization.....75
9.7. Socioeconomic and public health Impact.....75
**10. Conclusion**.....76
**References**.....80
**11. Appendices**.....87

# Summary

This dissertation addressed a major challenge in football injury prevention (IP) research: the limited real-world implementation of established injury prevention programs (IPPs), despite their proven efficacy in reducing injury incidence, with a particular focus on the FIFA 11+ (the 11+), the most extensively studied IPP in football. Further, the project specifically focused on female football players, a population characterized by a high injury burden and an increased risk of severe knee injuries, while remaining underrepresented in IP research.

The first phase of the dissertation consisted of a systematic review evaluating the effects of the 11+ on motor performance and biomechanical measures. The findings demonstrated that, although the 11+ effectively improves certain biomechanical parameters associated with injury risk, its effects on motor performance are inconsistent and generally limited, particularly with respect to technical skills and acute performance enhancement. These findings suggested that traditional IPPs may insufficiently address the performance demands of football, limiting their applicability, and highlighted the need for a more performance-oriented approach.

Based on these findings, a novel football-specific warm-up program, the Football+, was developed in collaboration with Borussia Dortmund (BVB09). The Football+ was designed as a dual-purpose intervention integrating established IP principles with performance-enhancing training components, based on the premise that an effective warm-up should not only reduce injury risk but also optimize performance. The program combines football-specific movements, neuromuscular exercises, small-sided games, plyometric drills, and agility-based tasks within a progressive and practically applicable warm-up structure.

The effects of the Football+ on motor performance, biomechanical risk factors, and landing technique in previously injured players were subsequently evaluated across three experimental studies in line with the conceptual models for IP. The first experimental study investigated the acute effects of the Football+ on motor performance. Compared with the 11+, the Football+ significantly improved sprinting, agility, and dribbling performance, indicating its suitability as a warm-up routine capable of enhancing immediate performance readiness.

The second experimental study examined the effects of three months of supervised training with the Football+ on biomechanical risk factors and motor performance in comparison with the 11+ and traditional warm-up routines. The findings demonstrated improvements in knee kinematics and kinetics associated with lower-limb injury risk, while simultaneously enhancing motor performance outcomes following application of the Football+ program. These results indicated that integrating performance-oriented components into IPPs does not compromise their preventive efficacy, while also increasing their applicability as a time-efficient warm-up strategy aimed at reducing injury risk and enhancing motor performance.

The third experimental study focused on landing mechanics in players with and without a history of severe lower-limb injury. The findings revealed that four months of supervised training with both the Football+ and 11+ improves landing technique and movement quality, particularly in previously injured players, with the Football+ demonstrating greater efficacy. These outcomes suggest the potential value of the Football+ as a secondary prevention tool for athletes at elevated risk of reinjury.

Taken together, the findings of this dissertation emphasize that IP and performance enhancement should not be viewed as competing objectives, but rather as complementary components of an effective warm-up strategy. The Football+ showed strong potential to bridge the gap between scientific evidence and real-world implementation by combining IP, neuromuscular training, and sport-specific performance enhancement within a single framework. From a scientific perspective, this dissertation supports a shift toward more integrated, ecologically valid, and performance-oriented approaches in football IP research and practice.

# 1. Introduction and theoretical background

## 1.1. Football population

Football is the most popular sport worldwide and fascinates people across all ages and cultures. In 2006, there were approximately 265 million active players globally, reflecting a 10% increase from 242 million in 2000 (Junge et al., 2011). However, since FIFA's[1] last global survey, the "Big Count," in 2006, updated global statistics have remained unavailable. Nevertheless, estimates suggest that more than 300 million people currently play football across 211 countries, representing an increase of nearly 13% since 2006. In Germany, the DFB[2] also reports steady growth. In 2006, the DFB had 6,351,078 registered players; this number increased to 7,364,775 in 2023, marking a 16% rise over 17 years. This makes the DFB the largest football association in the world.

## 1.2. Women's football: a rapidly growing global trend

The 2012 London Olympics marked a historic milestone for women in sport and was named the "Year of the Woman," with every participating nation including female athletes, a powerful symbol of progress (Grappendorf, 2013). Women's football, in particular, has experienced extraordinary growth, expanding from just two international competitions in 1971 to more than 500 by 2010 (Geertsema et al., 2021; Sugimoto, Howell, Tocci, & Meehan III, 2018). Of the 265 million active players reported in 2006, around 26 million were female. This corresponded to an increase of 23% (approximately 6 million players) in women's football compared with 2000 (Kunz, 2007).

While fewer than 600,000 female players were registered worldwide in the late 1990s, today, more than 30 million registered female players across 176 countries are actively engaged in recreational and organized football, reflecting a 14% increase since 2006 (Del Coso, Herrero, & Salinero, 2018; Geertsema et al., 2021) and accounting for 10 percent of the world's football population. In Germany alone, the DFB recorded more than 1.17 million female players in 2023, almost 1.5% more than in 2022, reinforcing its status as the world's largest women's football association.

[1] Fédération Internationale de Football Association

[2] Deutsche Fußball-Bund

Additionally, a 72% increase in qualified female match officials between 2016 and 2020 further reflects a global shift in attitudes toward women's role in football (Wesam Saleh A Al Attar et al., 2021).

## 1.3. Challenges and underrepresentation in women's football

However, despite the rising prominence of women's football, they are dealing with substantial, multidimensional challenges, including low socioeconomic support due to poor commercial and sponsorship opportunities, particularly at amateur level. Further, although female players are 4 to 8 times more likely to sustain knee injuries than their male counterparts, with distinct consequences, research on this population remains significantly underdeveloped across disciplines and lags far behind research on male players (Kirkendall & Krustrup).

# 2. Injuries in football

## 2.1. Injury incidence rates (IIRs) in football

Despite its popularity, football is one of the highest-risk Olympic sports, characterized by high physical demands and its full-contact nature (Engebretsen et al., 2013). Injury surveillance studies over the past 15 years report alarmingly high IIRs in amateur male and female players, with 5.70 and 10.9 injuries per 1,000 training hours and 14.43 and 55.5 injuries per 1,000 match hours, respectively (Babwah, 2014; Ekstrand, Hägglund, & Fuller, 2011; Faude, Junge, Kindermann, & Dvorak, 2005; Hartmut, Becker, Walther, & Hess, 2010; Horan et al., 2022b; Ibikunle, Efobi, Nwankwo, & Ani, 2019; Jacobson & Tegner, 2007; Jon Larruskain, Jose A Lekue, Nerea Diaz, Adrian Odriozola, & Susana M Gil, 2018; Robles-Palazón, López-Valenciano, Croix, et al., 2022; Robles-Palazón, López-Valenciano, De Ste Croix, et al., 2022; Tegnander, Olsen, Moholdt, Engebretsen, & Bahr, 2008), compared with other competitive sports.

Similarly, Quintana-Cepedal et al. (2024) reported an IIR of 12.76 injuries per 1,000 match hours in female players (Quintana-Cepedal et al., 2024), while Larruskain et al. (2018) found an even higher IIR of 29.86 per 1,000 match hours in male players (J. Larruskain, J. A. Lekue, N. Diaz, A. Odriozola, & S. M. Gil, 2018). Reports also indicate consistently high IIRs across various age groups (Faude, Rößler, & Junge, 2013), with the knee, ankle, and hip being the most frequently affected regions affected (Babwah, 2014; Ekstrand et al., 2011; Faude et al., 2005; Hartmut et al., 2010; Horan et al., 2022b; Ibikunle et al., 2019; Jacobson & Tegner, 2007; Jon Larruskain et al., 2018; Robles-Palazón, López-Valenciano, Croix, et al., 2022; Tegnander et al., 2008), emphasizing the need for effective preventive measures.

## 2.2. IIRs in women's football

Alongside this growth, a concerning trend emerges from injury surveillance studies conducted in women's football leagues across Europe, the Americas, Asia, and Africa, reporting IIRs ranging from 12.5 to 55.5 and from 1.4 to 10.9 per 1,000 hours of match and training exposure, respectively, with the knee, ankle, and hip being the most frequently affected (Babwah, 2014; Ekstrand et al., 2011; Faude et al., 2005; Hartmut et al., 2010; Horan et al., 2022a, 2022b; Ibikunle et al., 2019; Jacobson & Tegner, 2007; Jon Larruskain et al., 2018; Robles-Palazón, López-Valenciano, Croix, et al., 2022; Tegnander et al., 2008). Horan et al. (2022) showed that elite-level Irish female players sustain, on average, 0.69 injuries per season, equating to 15 time-loss injuries per season for a squad of 22 players (Horan et al.,

2022a). The UEFA Women's Elite Club Injury Study, covering four consecutive seasons from 2018 to 2022, reported an injury incidence of 6.7 per 1,000 hours and a nearly fourfold higher incidence during match play than during training. This study also emphasized that thigh muscle injuries were the most frequent injury type, whereas anterior cruciate ligament (ACL) injuries had the highest burden (38.0 days lost per 1,000 hours) (Hallén et al., 2024).

These statistics underscore a critical issue: female players, across all levels of play, may sustain IIRs and injury severities comparable to, or even greater than, those of their male counterparts (Jon Larruskain et al., 2018; Robles-Palazón, López-Valenciano, Croix, et al., 2022). Bloch et al. (2025) reported that female players not only demonstrate a higher risk of ACL injury, but also tend to experience delayed surgical treatment and prolonged time-loss compared with male players. (Bloch, Krutsch, Klein, Achenbach, & Reinsberger, 2025). These findings highlight the urgent need for targeted IPPs that specifically address lower-extremity injuries. However, despite the rising prominence of women's football and its distinct injury profile, research on this population remains significantly underdeveloped across disciplines and continues to lag behind research on male players (Kirkendall & Krustrup).

## 2.3. The short- and long-term consequences of injuries in football

Football-related injuries have serious consequences, including functional impairments, training and match absences, reduced performance levels, early dropout of young talents, increased healthcare and rehabilitation costs, substantial socioeconomic burdens, early retirement, and a heightened risk of osteoarthritis (Dvorak, Junge, Derman, & Schwellnus, 2011; Everhart et al., 2018; Junge et al., 2011; Valderrabano, Hintermann, Horisberger, & Fung, 2006; Wright, 2009). Additionally, injuries affect team success by reducing player availability and creating tactical and strategic disadvantages. Studies also confirm a direct link between IIRs and team performance, with lower injury rates correlating with higher league rankings and greater competitive success (Eirale, Tol, Farooq, Smiley, & Chalabi, 2013; Ekstrand, Spreco, Bengtsson, & Bahr, 2021).

From a financial perspective, injury burden represents a substantial economic challenge in football. For instance, in the English Premier League, each team is estimated to lose approximately £45 million per season due to injury-related underperformance (Eliakim, Morgulev, Lidor, & Meckel, 2020). Similarly, a recent study on the German Bundesliga

reported considerable indirect financial losses associated with injury-related performance decline, amounting to approximately €24.2 million per season in the first division and €9.8 million in the second division when monetised through lost ranking positions and associated revenues. The same study further demonstrated that, in the first division, an average of 1.62 unavailable players per matchday is associated with a one-position drop in the final league ranking, while in the second division, 0.71 unavailable players per matchday correspond to a similar decline (Dallmeyer, Steinfeldt, Hübers, Pietzonka, & Breuer, 2025).

Further, VBG[3] reports highlight that football exhibits the highest injury burden among professional team sports in Germany, with an average absence of approximately 31 days per player per season. Importantly, these reports emphasize that even small increases in injury incidence can lead to disproportionately large financial consequences (VBG, 2021). Taken together, these findings underline that injury prevention (IP) is not solely a medical concern but also an economically critical factor in modern football.

## 2.4. Injury risk factors

Over the past five decades, substantial progress has been made in understanding the multifactorial nature of football injuries and in our understanding of the factors contributing to football injuries. Since Ekstrand et al. (1983) conducted the first major IP study (Ekstrand, Gillquist, & Liljedahl, 1983), numerous investigations have identified key biomechanical, physiological, psychological, neurological, and motor-behavior factors contributing to football injuries (Bathe, Fennen, Heering, Greif, & Dubbeldam, 2023; Geertsema et al., 2021; Hewett et al., 2005; Sugimoto et al., 2018). These findings have deepened our understanding of injury causes, mechanisms, and etiology and have formed the foundation for contemporary IP approaches and strategies.

Contemporary injury etiology models, particularly the multifactorial model proposed by Bahr and Krosshaug (2005), suggest that sports injuries result from a complex interaction between intrinsic and extrinsic risk factors in the presence of a specific inciting event. According to this model, injury occurrence is not caused by a single factor, but rather by the interaction of multiple contributing elements that collectively increase injury susceptibility.

[3] German Social Accident Insurance

Intrinsic risk factors refer to athlete-related characteristics and may include biomechanical, neuromuscular, physiological, anatomical, psychological, and motor-control deficits. Extrinsic risk factors involve external influences such as playing surface, footwear, weather conditions, training load, match congestion, and contact with opponents. While both categories contribute to injury risk, the present dissertation primarily focuses on intrinsic and especially modifiable factors that can be targeted through physical training and injury prevention programs (IPPs).

Injury risk factors can further be categorized as modifiable and non-modifiable. Non-modifiable factors include age, sex, previous injury history, anatomical alignment, and genetic predisposition. Among these, previous injury is considered one of the strongest predictors of future injury. Female players are at an elevated risk of severe knee injuries, particularly ACL injuries, due to a combination of anatomical, hormonal, neuromuscular, and biomechanical characteristics, with later surgical care and longer time loss compared to men (Bloch et al., 2025). However, although non-modifiable factors may increase injury susceptibility, they cannot be directly altered through training interventions.

In contrast, modifiable risk factors represent the primary target of contemporary IP strategies and are therefore of particular relevance to this dissertation. These include deficits in neuromuscular control, impaired landing mechanics, reduced balance and proprioception, muscle weakness, asymmetrical movement patterns, decreased core stability, and altered lower-extremity biomechanics during high-risk tasks such as cutting, jumping, and landing (Hewett et al., 2005; Sugimoto et al., 2018). Excessive knee valgus, insufficient knee flexion, poor trunk control, and inadequate hip and ankle stabilization have repeatedly been associated with increased ACL and lower-limb injury risk.

# 3. Prevention of injuries

## 3.1. Contemporary approaches to football injury prevention

Importantly, many of these modifiable risk factors can be addressed through appropriately designed IPPs. Contemporary IP strategies, therefore, commonly incorporate neuromuscular, balance, plyometric, agility, strength, and landing-control exercises aimed at improving movement quality and reducing biomechanical stress during football-specific actions. Programs such as the FIFA 11+ (the 11+) have demonstrated that such interventions can reduce injury incidence by positively influencing these underlying mechanisms. Hence, IP has gained considerable attention over the past two decades within the sports science community and among governing bodies.

Protecting athletes' health has become a key objective of the International Olympic Committee (IOC) ("IOC mission "). The IOC has accredited 11 research centres for the prevention of injuries and illness worldwide. Additionally, FIFA has implemented various initiatives to mitigate injury risks, including the establishment of the FIFA Medical Assessment and Research Center (F-MARC, 2000-2016) and the FIFA Medical Center of Excellence (FMCE, 2014-present), both of which have played a crucial role in advancing football-related medical research and IP efforts. In this regard, a landmark 18-year prospective cohort study from the UEFA Elite Club Injury Study covering the period from 2001 to 2021 confirmed that overall IIRs decreased in men's professional football and that player availability for training and match play increased, indicating substantial progress at the professional level (Ekstrand et al., 2021). However, during the same period, hamstring injuries increased significantly and now comprise 24 percent of all injuries in male professional players (Ekstrand et al., 2023), underscoring the need for targeted preventive strategies.

## 3.2. Conceptual models for injury prevention studies

Several models and frameworks have been introduced to guide IP research (van Mechelen et al. 1992 (Van Mechelen, Hlobil, & Kemper, 1992); Finch et al. 2006 (Finch, 2006) and to improve understanding of injury aetiology (Meeuwisse et al. 2007 (Meeuwisse, Tyreman, Hagel, & Emery, 2007); Windt and Gabbett 2017 (Windt & Gabbett, 2017). The most widely cited IP model is the "sequence of prevention" proposed by van Mechelen et al. (1992). Building on earlier public health approaches developed by the World Health Organization, this

model consists of four key steps: (1) establishing the extent of the injury problem, (2) identifying the key risk factors and mechanisms of injury, (3) introducing preventive strategies to mitigate injury risk, and (4) evaluating the effectiveness of preventive strategies by repeating Step 1.

Finch (2006) introduced an extension of the van Mechelen model called the Translating Research into Injury Prevention Practice (TRIPP) framework. Compared with the sequence of prevention, this model includes two additional steps and emphasizes the key role of implementation factors in achieving real-world IP success (Finch, 2006): (i) potential modification of interventions to account for the implementation context and (ii) assessment of factors associated with the real-world introduction and application of safety measures, together with the development of implementation strategies to support the rollout of interventions.

Following development of the FC Barcelona Muscle Injury Guide, O'Brien et al. (2018) introduced the Team-sport Injury Prevention (TIP) cycle, a simplified and continuous three-phase model comprising: (1) (Re)evaluate, (2) identify, and (3) intervene. This model emphasizes a dynamic, iterative approach to IP, allowing ongoing assessment and adaptation based on real-world feedback (O'Brien, Finch, Pruna, & McCall, 2019). Although the applicability and relevance of each model are context dependent, most existing frameworks have been designed primarily for IP research. A common theme across all models, however, is the need to understand and assess the effects of IPPs on injury risk factors and injury incidence (Finch, 2006; O'Brien et al., 2019; Van Mechelen et al., 1992).

## 3.3. Efficacy of injury prevention programs

In response to phases three and four of the conceptual models for IP, several IPPs have been developed and investigated in different research settings. Numerous high-quality randomized controlled trials (RCTs) have demonstrated the efficacy of these programs in reducing football-related injuries by 36% to 75% across various populations and playing levels. Most IPPs are structured as neuromuscular warm-up programs and typically combine exercises targeting balance, proprioception, strength, core stability, plyometrics, agility, running mechanics, and landing technique. These interventions aim to modify deficits in neuromuscular control, impaired movement mechanics, poor landing strategies, dynamic

knee valgus, asymmetrical movement patterns, and insufficient trunk and hip stabilization. Through repeated exposure to controlled and football-specific movement tasks, IPPs seek to improve movement quality and reduce biomechanical stress during high-risk actions such as cutting, decelerating, jumping, and landing.

Among these, the 11+ program stands out as the most widely implemented program (Emery et al., 2022; Soligard et al., 2008; Kathrin Steffen et al., 2013). The 11+ has been extensively studied in more than 30 countries across five continents and in both male and female players aged 10 to 36 years, making it the most thoroughly researched IPP to date (Asgari, Nazari, Bizzini, & Jaitner, 2022). Given its scientific validation and widespread adoption, this dissertation considers the 11+ as the primary reference program for IPPs.

Beyond the 11+, several structured IPPs have been developed and implemented to address specific injury risks. These include, but are not limited to, the knee ligament injury prevention program (Pfeiffer, Shea, Roberts, Grandstrand, & Bond, 2006), the knee injury prevention program (KIPP) (LaBella et al., 2011), the Knee Control Program (KCP) (Lindblom, Sonesson, Torvaldsson, Waldén, & Hägglund, 2023b) and its extended edition (Lindblom, Sonesson, Torvaldsson, Waldén, & Hägglund, 2023a), Prevent Injury and Enhance Performance (PEP)(Mandelbaum et al., 2005), the Funball program (Obërtinca et al., 2024), the HarmoKnee program (Kiani, Hellquist, Ahlqvist, Gedeborg, & Byberg, 2010), and the F-MARC IP family, including the 11 (K. Steffen, Myklebust, Olsen, Holme, & Bahr, 2008), the 11+ Kids (Rössler, Donath, Bizzini, & Faude, 2016), the 11+ Shoulder (Ejnisman et al., 2016) for upper-body IP, and the 11+ Referees (Wesam Saleh A Al Attar et al., 2021).

Collectively, these programs have demonstrated the potential to improve neuromuscular control, enhance movement mechanics, and reduce injury incidence across different football populations (Obërtinca et al., 2024; Soligard et al., 2008; Zarei et al., 2020). By reducing IIRs, these programs help optimize player availability, minimize the financial burden associated with medical care, and improve overall team performance, thereby providing substantial benefits to all stakeholders, including players, coaches, clubs, healthcare providers, and public health systems.

## 3.4. Current state and challenges: role of compliance

Building on previous research, the evidence strongly supports the notion that scientific efforts have contributed to reducing injury risks in football players. However, recent epidemiological and observational studies challenge the view that the problem has been sufficiently addressed and reinforce earlier findings that IIRs in football, particularly among youth players, remain high (Beck, Lawrence, Nordin, DeFor, & Tompkins, 2017; Robles-Palazón, López-Valenciano, De Ste Croix, et al., 2022). Additionally, synthesizing epidemiological findings from the past 20 years underscores that the incidence and severity of injuries among football players across different playing levels and age groups remain alarmingly high (Hägglund, Waldén, & Ekstrand, 2009; Junge, Chomiak, & Dvorak, 2000). Subsequent research highlights low compliance and fidelity, limited buy-in, and poor adherence to IPPs in the real football world, which may partly explain the persistent high IIRs in football (Wesam Saleh A. Al Attar et al., 2017; O'Brien, Young, & Finch, 2017).

For instance, the 11+ has been shown to reduce overall, hamstring, groin, and knee injuries by 40%, 66%, 48%, and 46% (W. S. A. Al Attar, 2022a, 2022b, 2022c; Wesam Saleh A Al Attar, Soomro, Pappas, Sinclair, & Sanders, 2016; Bizzini & Dvorak, 2015; Thorborg et al., 2017), respectively. However, in 2018, only 42.6% of German amateur-level coaches were familiar with the program, and just 32.1% reported partial implementation(Wilke, Niederer, Vogt, & Banzer, 2018). Similarly, O'Brien et al. (2017) reported low adoption rates in Australia, with 12% and 28% implementation of the 11+ and its modified variations (O'Brien et al., 2017), while Al Attar et al. (2017) reported less than 40% usage in Saudi Arabia (Wesam Saleh A. Al Attar et al., 2017). These statistics indicate that even strong evidence for IP alone may not be sufficient to promote widespread adoption of IPPs.

This discrepancy between scientific efficacy and real-world implementation highlights a fundamental translational challenge in contemporary sports medicine. While many IPPs demonstrate strong effects under controlled experimental conditions, their practical effectiveness ultimately depends on long-term adoption, contextual suitability, player acceptance, and sustained compliance in everyday football environments. Consequently, IP research increasingly emphasizes not only whether interventions work under ideal

conditions, but also whether they can be realistically integrated into the practical and performance-related demands of football.

# 4. Research problem and literature review

## 4.1. Problem definition

The incidence and severity of injuries among football players, particularly in youth and amateur populations, remain high despite extensive scientific efforts and preventive initiatives implemented over the past two decades. Lower-extremity injuries, especially those involving the knee and ankle joints, represent a major concern due to their high prevalence, prolonged recovery periods, increased reinjury risk, and potential long-term health consequences. Notably, although evidence suggests that female football players may sustain injuries at rates comparable to or even exceeding those observed in male players and may experience more severe injury outcomes, they continue to receive disproportionately less scientific attention and fewer targeted intervention strategies. Consequently, further research focusing specifically on female football players remains necessary.

Beyond their medical implications, football-related injuries also impose considerable performance and economic burdens. Recent evidence demonstrates that injury-related player unavailability is directly associated with reduced team performance and substantial financial losses at the professional level. These findings further emphasize that IP is not solely a medical concern, but also an important factor for performance optimization and economic sustainability in modern football.

In response to this challenge, several IPPs have been developed and scientifically validated. Among these, the 11+ is considered the most extensively studied and widely implemented IPP in football. Numerous RCTs have demonstrated that the 11+ and similar IPPs can substantially reduce injury incidence by targeting modifiable intrinsic risk factors such as impaired neuromuscular control, altered landing mechanics, reduced balance and proprioception, muscle weakness, and dysfunctional movement patterns.

Despite the proven efficacy of IPPs, their real-world implementation remains limited. Existing literature consistently identifies low compliance and suboptimal adherence as major barriers to successful implementation. Several studies have investigated the underlying causes of this issue and reported multiple practical barriers, including prolonged program duration, lack of time during training sessions, low player enjoyment and engagement, limited player motivation, concerns regarding specific exercises, and insufficient alignment with football-

specific goals and training demands (Åkerlund, Sonesson, Lindblom, Waldén, & Hägglund, 2023; Donaldson et al., 2019). Consequently, bridging the gap between scientific evidence and practical application remains one of the major unresolved challenges in football IP research.

Another potentially important explanation for this implementation problem relates to concerns regarding the effects of IPPs on motor performance. As the final preparatory stage before high-intensity physical activity, warm-up routines are generally expected not only to reduce injury risk but also to optimize performance readiness. However, several studies found the 11+ as insufficiently football-specific and potentially ineffective for enhancing performance, which may negatively influence motivation, acceptability, and long-term adherence barriers (Arundale et al., 2018; Ayala et al., 2017; Daneshjoo, Mokhtar, Rahnama, & Yusof, 2013; Dunsky, Barzilay, & Fox, 2017; Ghareeb, McLaine, Wojcik, & Boyd, 2017; Zarei et al., 2018).

To establish a scientific foundation for the subsequent phases of this dissertation, it was therefore necessary to critically evaluate whether these concerns regarding performance enhancement are supported by empirical evidence. Given that the 11+ represents the most extensively studied IPP in football, a systematic review was conducted to synthesize the available literature regarding its effects on motor performance measures. This step was considered essential for identifying the strengths and limitations of existing IPPs and for determining whether insufficient performance enhancement may contribute to the compliance and implementation challenges observed in practical football settings. The findings of this review subsequently served as the scientific basis for the development of a novel football-specific warm-up program designed to better integrate IP and performance enhancement.

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Review

# Effects of the FIFA 11+ program on performance, biomechanical measures, and physiological responses: A systematic review

Mojtaba Asgari [a,*], Bahareh Nazari [b], Mario Bizzini [c], Thomas Jaitner [a]

[a] *Institute for Sport and Sports Science, TU Dortmund University, Dortmund 44221, Germany*
[b] *Faculty of Physical Education and Sports Science, University of Tehran, Kish Island branch, Kish Island 79416, Iran*
[c] *Human Performance Lab, Schulthess Clinic Lengghalde, Zürich 8008, Switzerland*

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**Abstract**

*Background*: The side effects of the FIFA 11+ program on performance have not been generally reviewed. The objective of this study was to synthesize the literature on the effects of the 11+ on players' performance.

*Methods*: Five online databases (PubMed, Scopus, ScienceDirect, Springer, and Google Scholar) were searched (from April 2006 to March 2022) using predefined keywords and sub-keywords. The potential references were primarily recorded through Endnote and imported to Covidence. Out of the 123 references screened by 2 blinded researchers through the software, 59 full texts were assessed for eligibility, 33 of which were ultimately included. The quality of the studies and the risk of bias were then assessed. Study ID, title, place, aim, design, start/end dates, population description, study criteria, statistical analysis, and outcomes were extracted.

*Results*: Studies were conducted on male and female players aged 10–32 years old. The quality of the studies was moderate to high, and except for unclear bias for blinding outcome assessment, the risk of bias for all domains was low. Long-term application of the 11+ improved most biomechanical measures and physiological responses except for lower extremity stability, ankle evertors time latency, ankle dorsiflexion, and proprioception. Conversely, the 11+ showed acute negative effects on physical performance compared to dynamic warm-ups and non-significant effects on technical abilities.

*Conclusion*: Mid-to-long-term implementation of the 11+ improved the majority of biomechanical and a couple of physical measures but showed no effects on technical skills. Precaution must be observed for using the 11+ before competitions, as it could acutely decrease physical/technical performance. Given the contradictory nature of the literature, further studies should evaluate the short-to-mid-term effects of the 11+. Further studies are required to address ankle responses to the 11+ intervention.

**Keywords:** Football; Futsal; Injury prevention; Systematic review

## 1. Introduction

The FIFA Medical Assessment and Research Centre launched the 11+ program (2006) to merge injury risk-reducing exercises into a warm-up protocol aiming to mitigate football-related injuries, particularly in sub-elite and amateur players. The available literature strongly supports that except for lower effects on ankle and groin injuries,[1–3] the 11+ has successfully reached the aim for which it was introduced.[4–8] Hence, it is labeled an evidence-based and well-structured warm-up program, receiving much attention from sports scientists. Given the advantages it entails in injury prevention, the researchers have consistently recommended the 11+ to be applied as a part of daily routine training. However, how this program can be delivered into the football world has remained a challenging question.[2,9] In other words, the persuasion of coaches, trainers, and players to accept and follow the 11+ has not been entirely successful up to this point.[10] Some barriers include but are not limited to complaints about prolonged duration, lack of time at training, lack of player enjoyment and engagement, concerns regarding some of the training (namely, Part 2), and lack of a link to football-related goals.[11]

Another potential reason for such disinclination would be concerns regarding the effects of the 11+ on performance improvement, biomechanical measures, and physiological

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* Corresponding author.
*E-mail address:* mojtaba.asgari@tu-dortmund.de (M. Asgari).

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responses, which appear to interact strongly with the pre-identified barriers.[12–17] Heterogeneous studies in various designs, representing different age ranges, genders, playing levels, and often including low numbers of participants and different follow-up periods have investigated the 11+ on a variety of performance, biomechanical, and physiological measures (Fig. 1).

Regarding performance parameters, for example, Zarei et al.[15] stated that applying the 11+ over a football season enhances agility, vertical jump, and countermovement jump among amateur U16 players. Conversely, Impellizzeri et al.[18] failed to find the same results after performing the program for 9 weeks among amateur players aged 21–25 years old. Arede et al.[19] reported a significant improvement in sprinting among child players after they performed the program for 6 weeks, while Trajković et al.[20] showed that short-term application of the 11+ may not improve sprinting among child players. It becomes more challenging when we consider that Ayala et al.[12] recently demonstrated that the 11+ might acutely decrease performance parameters such as sprinting when compared to a dynamic warm-up program. Reis et al.[21] found that the 11+ improves dribbling skill among amateur futsal players, whereas Daneshjoo et al.[22] observed that the 11+ produces no impact on the dribbling skill of youth elite football players.

Regarding biomechanical measures, for instance, Daneshjoo et al.[16] reported that the 11+ do not significantly improve the concentric quadriceps strength of elite players and that improvements in hamstring muscles appeared only in the dominant leg. In contrast, Ghareeb et al.[17] showed a significant improvement in the strength peak torque of the quadriceps and hamstrings in both dominant and non-dominant legs among amateur players after performing the 11+ program.

This lack of clarity regarding the side effects of the 11+ alongside the barriers mentioned above has resulted in low compliance and poor implementation of the program,[10,23] which has even decreased over time. Although compliance and implementation rate have shown a strong correlation to the success of each injury prevention program and team success,[9] O'Brien et al.[10] reported that the 11+ was only applied in 12% of the training sessions. Thus, trainers have suggested modifying, rescheduling, or applying the 11+ in conjunction with other exercises to be more challenging, to have variation, progression, and individualization, and to be linked to football-specific demands[10,24,25] or to be done outside of the training sessions.[26]

Finally, yet importantly, the follow-up period required for successfully implementing the 11+ has remained challenging and needs to be addressed. Although the terms "immediate", "short-term", "mid-term", and "long-term" have been clearly defined in the field of orthopedics,[27] they have remained undefined in sports science. Hence, they have been arbitrarily used in the studies, and recommendations on the adequate follow-up duration for the 11+ differ from 1 study to another.

Taken together, whether the 11+ increases performance and, if so, for how long it should be implemented are questions that remain to be addressed, especially since they may potentially influence the compliance and implementation rate of the program. Although the injury prevention side of the 11+ has been appropriately reviewed,[2,5,28] to the authors' knowledge, no systematic review has generally evaluated the impacts of the 11+ on players' performance. Therefore, this study aimed to scrutinize the available literature on the 11+ in order to address the effects of the original 11+ program on physical performance and technical abilities, physiological responses, and biomechanical measures among football and futsal players. We assume that a synthesis of the available literature will adequately address concerns regarding the performance side of the program.

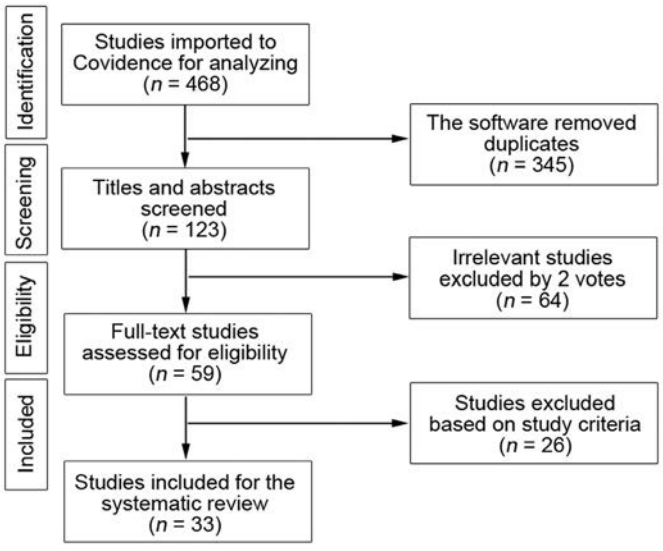



Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow chart.

## 2. Methods

### 2.1. Registration and search protocol

This systematic review was aligned with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[29,30] It was preregistered in PROSPERO (CRD42021283100) and carried out using Covidence (extraction 2, Cochrane, Melbourne, Australia), a well-established platform for conducting systematic reviews and meta-analyses.[31] Two blinded members (MA and BN) of the research group systematically and independently searched the PubMed, Scopus, ScienceDirect, Springer, and Google Scholar databases for the period from April 2006 (year of introduction of the 11+) to March 2022. For instance, the following strategy was used to search PubMed: ("11+" OR "the 11+", OR "the 11+ warm-up" OR "the 11+ programme" OR "FIFA injury prevention programme" OR "FIFA11+") AND ("football" OR "soccer" OR "futsal") AND ("performance" OR "biomechanics" OR "skill", OR "EMG" OR "force" OR "kinetic" OR "kinematic" OR "agility" OR "sprint" OR "jump" OR "dribbling speed" OR "pass" OR "heading", OR "change of direction" OR "balance" OR "stability" OR "flexibility", OR "muscle strength", OR "proprioception", OR "muscle activity" OR "power" OR "endurance" OR "functional test"). A manual crossover search of the eligible references was further performed (November and December 2021) to ensure a complete census of literature on the 11+.

### 2.2. Literature search and screening

Five pre-identified keywords (the FIFA11+, 11+ warm-up, the 11+ program, the 11+, and FIFA injury prevention programme) were used in conjunction with the following sub-keywords to discover potentially relevant references: football, soccer, futsal, performance, fitness biomechanics, physical/technical performance, Electromyography (EMG), force, kinetic, kinematic, torque, moment, agility, sprint, jump, dribbling speed, pass, heading, acceleration, change of direction, balance, stability, flexibility, muscle strength, power, endurance, proprioception, and muscle activity. Each researcher provided 5 libraries per Endnote (EndNote X9; Clarivate™, Boston, MA, USA), where the potential references from each database were imported separately. The libraries were then exported to Covidence for further assessments. The software recognized duplicates and merged them into 1 study using study IDs. Additionally, systematic reviews and meta-analyses and papers without full-text access, such as conference papers, current opinions, and letters to editors, were determined to be irrelevant references and were filtered out based on 2 "exclude" votes given by 2 blinded reviewers (MA and BN); the rest were considered for primary assessment.

### 2.3. Study criteria

Studies were included if they (a) investigated the 11+ on all performance and biomechanical parameters as well as on physiological responses regardless of the playing level, gender, age, and population description, (b) had a prospective design involving a test battery for assessing performance, biomechanics, and physiological responses, and (c) were published in English. Twofold studies investigating injury and performance were only included if they prospectively assessed and reported performance, biomechanical, or physiological parameters. The studies were excluded if they assessed any other similar programs, such as the 11, FIFA11+kids, FIFA11+referees, and FIFA11+shoulder injury prevention.

In this study, we arbitrarily defined the follow-up periods as (0 to $<1$ week = acute/immediate, 1 week to $\leq 6$ weeks = short-term, $>6$ weeks to $\leq 10$ weeks = mid-term, and $>10$ weeks = long-term).

### 2.4. Study selection and data collection

Of the 468 primary potential references recorded in our search, the software found 345 duplicates and integrated them. Further, 2 blinded reviewers (MA and BN) screened the titles and abstracts of the 123 potential references through Covidence and voted them separately. Studies with 2 "include" votes were considered for eligibility assessment, and those with 2 "exclude" votes were excluded. If a conflict arose, the related study was referred to the lead researcher (TJ) for the final decision. Out of the 123 titles and abstracts screened, 59 full texts were reviewed in detail for eligibility, 33 of which were ultimately included in the systematic review.[12–22,26,32–52] The main reasons for exclusion during this step were not implementing the 11+ to investigate its effects on the performance measures or implementing other interventions, such as FIFA11+kids. The following data were extracted by adjusting the software template: study ID, title, lead author, the country in which the study was conducted, aim, study design, start/end dates, possible conflict of interest, inclusion/exclusion criteria, methods of recruitment of participants, population description, statistical analysis, and results. They were then exported to a Microsoft Excel 2016 (Microsoft Corp., Redmond, WA, USA) spreadsheet.

### 2.5. Quality of studies, applicability risk of bias

To assess such measures, we adapted the related template on Covidence based on the guidelines of Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2), a recommended tool for assessing the methodological quality, risk of bias, and applicability of the studies.[53] Two blinded research group members (MA and BN) reviewed the studies independently and scored them separately. When conflicts occurred, the relevant study was double-checked by the lead researcher (TJ). Overall, the quality of the studies was identified to be moderate to high given that nearly half of them (15 studies) had randomized controlled-trial designs[15,18,26,32–42,50] and the rest had either prospective cohort or non-randomized experimental designs.[12–14,16,17,19–22,43–49,51] However, most of the studies revealed a lack of ability to recruit enough samples. Indeed, this is not the case for clinical trials but should be considered in further field-based studies. Reviewers' judgments regarding the risk of bias revealed that except for an indefinite amount of bias for allocation concealment and blinding outcome assessment, the risk of bias for all domains was low.

## 3. Results

Table 1 presents a comprehensive and detailed summary of the included studies. The experiments were carried out in 15 countries and 4 continents, recruiting female and male players ranging from 10 to 32 years. These statistics reaffirm that the 11+ has been investigated worldwide. Better adherence to the program was associated with a higher impact on performance.[42] The vast majority of studies (22 studies) evaluated adult amateur players,[12–15,17,18,21,26,32–36,38,39,41,43–45,47–49] but no study was conducted in professional football. Eleven studies were conducted with youth players, 8 of which included children,[13,19,20,40,42,46,50,52] and the rest[16,22,37] evaluated adolescent/youth elite players. Twenty-five studies were conducted with male players;[13,15–22,26,33–41,43–48] one had a mixed sample,[12] and 7 studies were conducted with female players,[14,32,40,42,49,50,52] indicating that female players have not been adequately studied with respect to the 11+. Overall, the 11+ appeared to be more beneficial for performance enhancement when applied in the mid-to-long term. On the other hand, 2 studies reported acute negative effects of the 11+ on physical and technical abilities.[12,48] Contradictory results were reported regarding the short-term effects of the 11+ on players' performance.

Table 1
Summary of 11+ studies.

| Study | Country | Age (year) | Sample | Playing level | Duration | Design | Results |
|---|---|---|---|---|---|---|---|
| Akbari et al. (2020)[37] | Iran | 16–18 | 24 male players | Youth elite | 8 weeks | RCT | The usefulness of the 11+ for reducing biomechanical risk factors associated with non-contact anterior cruciate ligament (ACL) injuries was observed. Players with higher risk profiles would benefit more than those with lower risk profiles. |
| Arede et al. (2022)[19] | Portugal | 11–12 | 36 male players | Kids | 6 weeks | Cohort study | Practitioners should select the 11+ to improve inter-limb asymmetries and 0–20 sprint time and 180-degree change of direction. |
| Arsenis et al. (2020)[33] | Greece | 19–20 | 32 male players | Amateur | 8 weeks | RCT | The 11+ was effective in increasing balance, concentric strength of the hamstrings, and conventional muscle ratio. |
| Arundale et al. (2018)[14] | USA | 18–20 | 68 female players | Amateur | 2 football seasons | NRES | They 11+may require some modifications to impact landing biomechanics and potentially risky movement patterns, particularly when used in collegiate women. |
| Ayala et al. (2017)[12] | Spain | 18–22 | 12 men and 10 women players | Amateur | Acute | Crossover and counterbalanced study | Neither 11+ nor the Harmoknee routines appear superior to the dynamic warm-up routines currently performed by most football players before training sessions and matches. |
| Bizzini et al. (2013)[45] | Italy | 23–25 | 20 male players | Amateur | Acute | Within-subject pre–post design | The 11+ can be considered an appropriate warm-up and may acutely improve sprinting and agility. |
| Brito et al. (2010)[44] | Portugal | 18–22 | 20 male players | Amateur | 10 weeks | NRES | The 11+ appears to be adequate and effective for football training and conditioning due to improved strength and muscle balance around the knee joint. |
| Cloak et al. (2014)[48] | UK | 20–21 | 74 male players | Amateur | Acute | Cohort study | Adding an acute bout of whole-body vibration post-FIFA 11+ warm-up produces a neuromuscular response leading to an improvement in reactive strength index but has no impact on agility. |
| Daneshjoo et al. (2013)[16] | Iran | 17–20 | 36 male players | Youth elite | 8 weeks | NRES | The 11+ increased hamstring concentric strength in the dominant leg and did not improve concentric quadriceps strength significantly. |
| Daneshjoo et al. (2013)[22] | Iran | 17–20 | 36 male players | Elite | 8 weeks | NRES | Neither the 11+ nor HarmoKnee improved players' performance in the speed test (10 m with and without a ball) and 20 m single sprint between pre to post time points. |
| Dix et al. (2021)[49] | USA | 18–20 | 46 female players | Amateur | 12 weeks | NRES | Clinically meaningful decreases in knee valgus collapse may indicate a beneficial biomechanical effect of the 11+. Application of the 11+ may lower ACL injury risk by reducing valgus collapse during a 90˚ cut. |
| Dunsky et al. (2017)[13] | Israel | 12–13 | 20 male players | Kids | 6 weeks | NRES | No differences were found in kicking accuracy following the intervention for both groups. However, static and dynamic balance improved significantly among the 11+ group with significant interaction with the control group. |
| Fard et al. (2022)[51] | Iran | 14–15 | 30 male players | Amateur | 8 weeks | NRES | The 11+ injury prevention program may improve static postural stability in the anterior–posterior and medial–lateral directions and dynamic postural stability in the anterior–posterior and medial–lateral directions. |
| Baeza et al. (2017)[46] | Chile | U14 | 22 male players | Kids | 6 weeks | NRES | The 11+ did not produce significant improvements in players' fundamental movements. It is not effective at acutely improving the fundamental movement patterns of male footballers. |

(*continued on next page*)

Table 1 (Continued)

| Study | Country | Age (year) | Sample | Playing level | Duration | Design | Results |
|---|---|---|---|---|---|---|---|
| Ghareeb et al. (2017)[17] | USA | 15−17 | 34 male players | Amateur | 6 weeks | NRES | Isokinetic strength peak torque increased at 60-degree in the quadriceps and hamstrings in dominant and non-dominant legs in NWP and hamstrings in the 11+. At 180 degree, the 11+ showed improvements across all muscle groups. |
| Hwang et al. (2019)[38] | Republic of Korea | 20 | 20 youth male players | Amateur | 12 weeks | RCT | The 11+ improved 30 m sprint, coordination, and arrowhead agility records with better functional movement, such as the deep squat, hurdle step, and rotary stability. |
| Impellizzeri et al. (2013)[18] | Italy | 21−25 | 20 male players | Amateur | 9 weeks | RCT | Significant differences in favor of the 11+ were found in time-to-stabilization, core stability, flexors eccentric, and concentric strength. The net effects for jump, sprint, and agility were not significant. |
| Lopes et al. (2019)[39] | Portugal | 18 | 61 male futsal players | Amateur | 10 weeks | RCT | Performing the 11+ for 10 weeks may not improve balance and proprioception, and that improvement in balance and proprioception would persist 10 weeks after the intervention. |
| Lopes et al. (2020)[34] | Portugal | 22−31 | 71 male futsal players | Amateur | 10 weeks | RCT | In the long term, the gains in hamstrings eccentric strength were significantly higher in the 11+ group. No significant enhancements were found in strength and muscle latency time immediately after the 11+. |
| Pardos-Mainer et al. (2019)[50] | Spain | 12−13 | 36 female players | Kids | 10 weeks | RCT | The 11+ improved the CMJ, 3-step jump, agility, star excursion balance test (SEBT), and muscle asymmetries. However, it produced no impact on DJ, YBT, Ankle dorsiflexion, or change of direction. |
| Nakase et al. (2013)[43] | Japan | 26−33 | 10 healthy men | Amateur | Acute | Clinical trial | The FDG accumulation within the abdominal rectus, gluteus medius, and minimus were significantly higher in the 11+ group than in the control group. |
| Navarro-Santana et al. (2020)[35] | Spain | 22−25 | 36 male players | Amateur | 6 weeks | RCT | The IAI provided better results on the vertical jump height measured with countermovement jump and on the proprioceptive precision compared to the 11+ program. |
| Parsons et al. (2019)[40] | Canada | 10−11 | 47 female players | Kids | 5 months | RCT | The 11+ had no impact on LESS or Y balance test scores, T test time, or vertical jump height but showed a significant effect on static plank hold time and demonstrated a medium effect size compared to the control group. |
| Rahlf et al. (2020)[36] | Germany | 14−19 | 104 youth male players | Amateur | 10 months | RCT | Beneficial effects found for hamstring and ankle flexibility after the 20 min the 11+ as compared to the 10 min program. Improvements in static balance, vertical jump performance, and hip flexibility were not significant. |
| Rey et al. (2018)[41] | Spain | 22−27 | 23 amateur male players | Amateur | 6 weeks | RCT | Post-training changes in FMS scores were not different between the 11+ and control groups. The 11+ may not produce additional improvements in the quality of fundamental movement patterns. |
| Reis et al. (2013)[21] | Portugal | U16 | 36 adolescent male futsal players | Amateur | 12 weeks | Cohort study | Youth futsal players performing the 11+ improved strength, sprinting, agility, jumping, balance, and skill abilities. |
| Steffen et al. (2013)[42] | Canada | 13−18 | 226 female players | Kids | 4 months | RCT | The 11+ could improve dynamic and functional balance performance. Better functional balance was observed for players who highly adhered to the prescribed exercises compared to those with less adherence. |

(*continued on next page*)

Table 1 (Continued)

| Study | Country | Age (year) | Sample | Playing level | Duration | Design | Results |
|---|---|---|---|---|---|---|---|
| Takata et al. (2016)[47] | Japan | 26–32 | 11 recreational males players | Amateur | 4 weeks | NRES | Increased glucose uptake occurred in the sartorius, semimembranosus, biceps femoris, and hallux muscles, following performance of the 11+ program. |
| Thompson et al. (2017)[52] | USA | 11 | 51 female players | Kids | 7 weeks | Controlled laboratory study | The 11+ reduced peak knee valgus moment during the double leg jump task and unanticipated cutting compared with the control group. but had no impact on single jump and pre-planned cutting movements. |
| Trajković et al. (2020)[20] | Serbia | 10–12 | 36 children male players | Kids | 4 weeks | Cohort study | Implementation of 11+ for 4 weeks appeared to be sufficient to elicit significant improvements in some (Illinois test, sit and reach, and standing long jump) but not all (20 m sprint time and $VO_{2max}$) measures. |
| Veith et al. (2021)[26] | Australia | 13–16 | 65 adolescent male players | Amateur | One season | RCT | Footballers can complete part 2 of the 11+ outside of the training environment without compromising important physical performance adaptations for eccentric hamstring strength and lower limb power. No improvement in knee and ankle stability during single-leg landing was observed. |
| Whittaker et al. (2015)[32] | Canada | 14–16 | 23 adolescent female players | Amateur | 4 months | RCT | The 11+ may somehow alter the way in which the abdominal wall is being used or loaded. The morphological adaptations may be related to alterations in neuromuscular control of the trunk. |
| Zarei et al. (2018)[15] | Iran | U16 | 82 adolescent male players | Amateur | One season | RCT | Superior performance in the IAT, the vertical jump test, and the BCMJ test was found, while the dribbling test performance was possibly reduced. |

Abbreviations: BCMJ = Bosco counter movement jump; CMJ = counter movement jump; DJ = drop jump; FDG = fluorodeoxyglucose; FMS = functional movement screening; IAT = Illinois agility test; LESS = landing error scoring system; MOC = maximal oxygen consumption; NRES = non-randomized experimental study; NWP = new warm-up program; RCT = randomized controlled trial; ROM = range of motion; U = under; $VO_{2max}$ = maximal oxygen uptake.

### 3.1. *Effects of the 11+ on futsal players*

Three studies were undertaken with futsal players, of which one focused on physical performance and technical abilities and found that the 11+ significantly increases strength, sprinting, agility, jumping, balance, and slalom dribbling in amateur futsal players.[21] The other 2 studies conducted by Lopes et al.[34,39] failed to argue that performing the 11+ for 10 weeks improves balance and proprioception and that the improvements do not persist 10 weeks after the intervention.[39] They also found no significant improvement in knee muscle strength and ankle evertors muscle latency time immediately after the 11+.[34] However, they revealed that the 11+ would significantly enhance eccentric hamstring strength in the long term.[34]

### 3.2. *Effects of the 11+ on football players*

Experiments on football players can be classified into studies concentrated on physical/technical performance, functional screening tests, biomechanical measures, and physiological responses to the program.

#### 3.2.1. *Effects of the 11+ on technical performance and functional screening tests*

Only 1 study evaluated the effects of the 11+ on kicking accuracy, and it found a non-significant difference in pre- *vs*. post-test for this skill.[13] Two studies assessed dribbling ability following implementation of the program, and they demonstrated that the 11+ has no impact on that skill.[15,22] Five studies[38,39,41,42,47] evaluated the effects of the 11+ on functional screening tests, including the functional movement screen (FMS) and the landing error scoring system. The results demonstrated that the 11+ might not improve landing error scoring system and FMS composite scores;[40,41,46] however, the study of Akbari et al.[37] showed a significant improvement in landing pattern following an 8-week implementation of the 11+. Meanwhile, 1 study did show positive effects of the 11+ on some FMS components.[38]

#### 3.2.2. *Effects of the 11+ on physical performance*

Three studies indicated that the 11+ might significantly develop sprinting,[19,38,45] whereas 4 studies failed to find the same results.[12,20,22,48] A possible improvement of the 9.1

sprint test was also observed by Zarei et al.[15] Five studies highlighted the superior performance in agility that followed application of the 11+,[15,20,22,38,45] while 3 studies illustrated that the 11+ did not improve agility.[18,40,48] Contradictory results were found regarding the impacts of 11+ on change of direction measures.[19,50] Significant enhancement of vertical jump abilities was observed in 6 studies,[15,20,22,26,45,50] but in contrast, 6 other experiments failed to find the same result in their jump tests.[12,18,35,36,40,48] Regarding balance ability, 5 studies reported that the 11+ improves balance significantly,[13,33,35,42,45] while 1 study showed no difference in balance following performance of the 11+.[36] Another study suggested that the 11+ may not increase balance ability compared to a dynamic warm-up program.[17]

### 3.2.3. *Physiological responses to the FIFA 11+*

Following performance of the 11+ intervention, researchers from 1 study observed an increase in resting oxygen uptake from 325 mL/min ± 87 mL/min to 379 mL/min ± 142 mL/min, an increase in core temperature from 37.3 ˚C ± 0.3 ˚C to 37.7 ˚C ± 0.3 ˚C, and an increase in lactate from 1.0 mmol/L ± 0.2 mmol/L to 2.6 mmol/L ± 1.1 mmol/L.[45] Another study addressed changes in muscle activity in terms of increased glucose uptake in the sartorius, semimembranosus, biceps femoris, and hallux muscles, following use of the 11+.[47] Whittaker et al.[32] identified structural adaptations of the abdominal wall following performance of the program over a football season. They showed that the 11+ might alter how the abdominal wall is being used. More specifically, the morphological adaptations to the 11+ may be related to alterations in neuromuscular control of the trunk. In addition, Impellizzeri et al.[18] observed better performance in time to stabilization and core stability following application of the 11+. Nakase et al.[43] revealed that the hip abductor and 11+ abdominal rectus could be activated by performing part 2 of the 11+ program.

### 3.2.4. *The FIFA 11+ and biomechanical measures*

There literature consistently implied significant improvements in most biomechanical measures, including peak torque, quadrieceps:hamstring ratios, concentric/eccentric strength of the hamstring muscles in both dominant and non-dominant limbs, concentric strength of the quadriceps, and decrease in knee valgus collapse during a 90° cut.[16,17,22,26,33,34,44,49] Additionally, Pardos-Mainer et al.[50] and Arede et al.[19] reported that 11+ improves inter-limb asymmetries. Conversely, some studies documented a lack of improvement in knee and ankle stability, peak knee abduction moment, balance and proprioception, eccentric quadriceps strength, and ankle evertors latency time.[14,26,34,39] More details are presented in Table 1.

## 4. Discussion

This systematic review aimed to address concerns regarding the side effects of the 11+ on performance/biomechanical/physiological measures. The findings indicate that mid-to-long term implementation of the 11+ with higher adherence may noticeably develop the majority of the biomechanical measures, balance, and core stability but is defective in improving technical skills. However, precaution must be observed while using the 11+ before competition, as it may acutely reduce performance parameters such as sprinting and dribbling. Ankle responses to the program were not studied in football players, and limited evidence was available regarding effects on physiological measures such as resting oxygen uptake and core temperature.

Based on the parameter age, the 11+ literature can be divided into 3 main categories. The first category includes studies conducted on children players (U14), 2 of which indicated that the program produces no impact on the landing error scoring system and FMS scores, Y balance test, and T test.[40,46] One study reported that the 11+ improves agility, flexibility, and standing long jump but has no impact on sprinting and maximal oxygen uptake ($VO_{2max}$).[19] Conversely, 1 study showed a significant improvement in sprinting and change of direction.[20] That the 11+ improves functional and dynamic balance was also documented by Steffen et al.[42] and Dunsky et al.;[13] the latter also found no improvement in kicking accuracy following the 11+. Additionally, Thompson et al. showed that the 11+ might reduce some biomechanical risk factors associated with ACL injuries among children female players.

The second category involves studies evaluating adolescent/youth players aged 14−20 years. Four studies observed a significant improvement in hamstring strength following the program.[26,17,16,33] Two studies reported the usefulness of the 11+ for reducing biomechanical risk factors associated with noncontact ACL injuries.[37,49] However, Veith et al.[26] demonstrated no development in knee and ankle stability during single-leg landing following the program. Additionally, Arundale et al.[14] suggested that the 11+ may require some modifications to impact landing biomechanics and potentially risky movement patterns. Contradictory results were found regarding performance parameters such as agility, vertical jump, balance, dribbling, and sprinting.[15,21,22,33,36,38,39]

The last category consists of 10 studies evaluating adult (>20 years old) players. Takata et al.[47] and Nakase et al.[43] studied physiological responses and concluded that the 11+ increases glucose uptake as well as fluorodeoxyglucose in the abdominal, core area, and thigh muscles. One study highlighted that the 11+ may not improve the quality of functional movements.[41] Studies by Brito et al.,[44] Impellizzeri et al.,[18] and Lopes et al.[34] indicated that the 11+ significantly improves time to stabilization, knee muscle strength, and core stability, while the latter also showed that the program does not improve muscle latency time immediately.[34] That the 11+ may not improve vertical jump, sprinting, and agility was documented by Impellizzeri et al.[18] and Cloak et al.[48] Further, Ayala et al.[12] reported that the 11+ may acutely reduce sprinting ability, which is in contrast to the results of Bizzini et al.[45] Taken together, it appears that the 11+ improves the majority of biomechanical measures among youth and adult players. However, it may not improve performance parameters such as vertical jump, sprint, and agility in adults, while a lack of clarity exists regarding such parameters in youth players.

Although the current literature may confirm the capacity for the 11+ to develop the biomechanical characteristics of youth and adult players, there are important questions that should be

addressed in future studies. The 11+ has shown non-significant effects on the latency time of ankle evertors, proprioception improvement, and ankle stability in futsal players, particularly in the short term.[34,39] This may offer a reasonable explanation for the lower effects of the program with regard to preventing ankle injuries. The dynamic stability of the ankle is primarily dependent on muscular activity. Additionally, most ankle injuries (e.g., ankle sprains) occur in an inverted position where there is poor stability, making the joint prone to injury.[54] Therefore, delay in activation of ankle evertors, which draw back the joint to the proper alignment, reduces joint stability and exposes the athlete to a high risk of injury.[55] In the 11+ program, there are more static than dynamic exercises, particularly in part 2, and such a static structure could not stimulate the feedback and control mechanisms of the postural system.[56] In contrast, dynamic exercises may adequately optimize the neuromuscular system and improve proprioception, muscular activity, and joint stability.[57] However, the effects of the 11+ on the biomechanics of the ankle were only studied twice and those studies were exclusively conducted on futsal players. Thus, further clinical trials are highly recommended to clarify the effects of the 11+ on the biomechanics of the ankle among football players. Not only for the 11+ but also in general, the association of injury prevention programs, biomechanical risk factors, and football-specific performance has rarely been studied and remains unknown.[10,58] Filling in this gap by bridging injury-oriented and performance-oriented studies may help integrate injury prevention programs into daily routine training.

Only 4 studies[12,43,45,48] evaluated the acute effects of the 11+, 2 of which observed non-significant or even negative immediate effects on sprinting and agility compared to dynamic warm-ups.[12,48] These findings could at least partially explain why coaches and trainers are not interested in investing in this program in its current form and why they try to modify it according to football-specific demands.[10] Parameters such as agility and sprinting depend on the training features.[59] Thus, using exercises similar to football movement patterns/tasks may develop these parameters. Negative effects of the 11+ on acute performance reduce its applicability as a warm-up protocol for competitions and intensify the poor implementation and low compliance associated with the program. Therefore, the focus of an injury prevention program should not be restricted to injury prevention but should involve performance improvement. Considering that the 11+ should be a proper warm-up, a new framework is needed to incorporate different training components into this program.

Concerns regarding the mid- to long-term effects of the 11+ on parameters such as agility, sprinting, vertical jump, and change of direction cannot be addressed through this review due to the lack of clarity in the available literature. Hence, a further meta-analysis should be conducted to eliminate such bias. Although a few studies evaluated the program's effects on technical abilities, such as kicking accuracy and dribbling speed, the literature consistently indicates that the 11+ does not improve technical skills among football players.[12,13,22] However, a significant improvement in slalom dribbling was observed among futsal players following performance of the 11+.[21] Based on the similarity principle in training, such outcomes appear to be entirely realistic given that no football-specific drill is embedded in the 11+. Meanwhile, increasing the volume of dynamic exercises and adding Copenhagen adduction exercises into the program provides missing eccentric hip adduction strength and may potentially manipulate technical abilities such as kicking accuracy.[60] The latter, in particular, seems to be a two-fold modification, as it may improve the ability of the 11+ to prevent groin injuries and, more importantly, may help stabilize the lumbar−pelvic−hip complex during kicking and dribbling tasks.

Given the consistency in the current literature regarding the physiological responses to the program, it can be assumed that the 11+ alters how the core and tight muscles are being used[32] and causes a better core stability.[18,43] However, to tackle the barriers regarding the use of the 11+, the second part of the program can be applied outside of the training sessions, as that appeared to mitigate severe injuries and improve compliance.[25,61]

There were a few serious barriers to the way this systematic review was conducted. Most importantly, the follow-up periods were not clearly defined in the 11+ studies or in the sports science literature as a whole. Therefore, at some points, the terms "short term", "mid term", and "long term" were used with different meanings. Another limitation we encountered was the heterogeneous literature pertaining to the 11+. This systematic review considered all studies conducted on the 11+, which lead to a broad age range (10−32 years old). That broad age range caused some difficulty in terms of deriving a clear discussion, as the effects of any intervention program could differ significantly before, during, and after maturation and in adulthood.

## 5. Conclusion

Having summarized all the points about the 11+, it can be concluded that mid- to long-term (>6 weeks) application of the program improves the vast majority of biomechanical measures, core stability, and balance abilities. Nevertheless, further studies must evaluate the effects of the 11+ on the biomechanics of the ankle. Additionally, a meta-analysis study on the 11+ literature should eliminate the available bias regarding the effects of the 11+ on performance measures such as agility, sprinting, change of direction, and vertical jump. That the 11+ cannot improve technical skills indicates that football-specific exercises should be added to the program. Further, precaution must be observed for when using the 11+ before competition since it may acutely reduce sprinting and agility.

## Authors' contributions

MA wrote the first draft of the manuscript, and searched the literature, screened the references, reviewed the articles, and exported the data with BN; they also evaluated the risk of bias and applicability of the studies. MB and TJ revised the original manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

## Competing interests

The authors declare that they have no competing interests.

## Supplementary materials

Supplementary materials associated with this article can be found in the online version at doi:10.1016/j.jshs.2022.05.001.

## References


1. Hammes D, Aus der Fünten K, Kaiser S, Frisen E, Bizzini M, Meyer T. Injury prevention in male veteran football players—a randomised controlled trial using "FIFA 11+". *J Sports Sci* 2015;**33**:873–81.
2. Thorborg K, Krommes KK, Esteve E, Clausen MB, Bartels EM, Rathleff MS. Effect of specific exercise-based football injury prevention programmes on the overall injury rate in football: A systematic review and meta-analysis of the FIFA 11 and 11+ programmes. *Br J Sports Med* 2017;**51**:562–71.
3. Soligard T, Myklebust G, Steffen K, et al. Comprehensive warm-up programme to prevent injuries in young female footballers: Cluster randomised controlled trial. *BMJ* 2008;**337**:a2469. doi:10.1136/bmj.a2469.
4. Al Attar WSA, Soomro N, Pappas E, Sinclair PJ, Sanders RH. How effective are F-MARC injury prevention programs for soccer players? A systematic review and meta-analysis. *Sports Med* 2015;**46**:205–17.
5. AdA Fernandes, CDd Silva, ITd Costa, Marins JCB. The "FIFA 11+" warm-up programme for preventing injuries in soccer players: A systematic review. *Fisioterapia em Movimento* 2015;**28**:397–405.
6. Silvers-Granelli H, Mandelbaum B, Adeniji O, et al. Efficacy of the FIFA 11+ injury prevention program in the collegiate male soccer player. *Am J Sports Med* 2015;**43**:2628–37.
7. Bizzini M, Dvorak J. FIFA 11+: An effective programme to prevent football injuries in various player groups worldwide—A narrative review. *Br J Sports Med* 2015;**49**:577–9.
8. Owoeye O, Akinbo S, Tella BA, Olawale OA. Efficacy of the FIFA 11+ warm-up programme in male youth football: A cluster randomised controlled trial. *J Sports Sci Med* 2014;**13**:321–8.
9. Bizzini M, Junge A, Dvorak J. Implementation of the FIFA 11+ football warm up program: How to approach and convince the Football associations to invest in prevention. *Br J Sports Med* 2013;**47**:803–6.
10. O'Brien J, Young W, Finch CF. The use and modification of injury prevention exercises by professional youth soccer teams. *Scand J Med Sci Sports* 2017;**27**:1337–46.
11. Donaldson A, Callaghan A, Bizzini M, Jowett A, Keyzer P, Nicholson M. A concept mapping approach to identifying the barriers to implementing an evidence-based sports injury prevention programme. *Inj Prev* 2019;**25**:244–51.
12. Ayala F, Calderón-López A, Delgado-Gosálbez JC, et al. Acute effects of three neuromuscular warm-up strategies on several physical performance measures in football players. *PloS One* 2017;**12**:e0169660. doi:10.1371/journal.pone.0169660.
13. Dunsky A, Barzilay I, Fox O. Effect of a specialized injury prevention program on static balance, dynamic balance and kicking accuracy of young soccer players. *World J Orthop* 2017;**8**:317–21.
14. Arundale AJH, Silvers-Granelli HJ, Marmon A, Zarzycki R, Dix C, Snyder-Mackler L. Changes in biomechanical knee injury risk factors across two collegiate soccer seasons using the 11+ prevention program. *Scand J Med Sci Sports* 2018;**28**:2592–603.
15. Zarei M, Abbasi H, Daneshjoo A, et al. Long-term effects of the 11+ warm-up injury prevention programme on physical performance in adolescent male football players: A cluster-randomised controlled trial. *J Sports Sci* 2018;**36**:2447–54.
16. Daneshjoo A, Mokhtar AH, Rahnama N, Yusof A. The effects of injury prevention warm-up programmes on knee strength in male soccer players. *Biol Sport* 2013;**30**:281–8.
17. Ghareeb DM, McLaine AJ, Wojcik JR, Boyd JM. Effects of two warm-up programs on balance and isokinetic strength in male high school soccer players. *J Strength Cond Res* 2017;**31**:372–9.
18. Impellizzeri FM, Bizzini M, Dvorak J, Pellegrini B, Schena F, Junge A. Physiological and performance responses to the FIFA 11+ (Part 2): A randomised controlled trial on the training effects. *J Sports Sci* 2013;**31**:1491–502.
19. Arede J, Fernandes J, Moran J, Leite N, Romero-Rodriguez D, Madruga-Parera M. Effects of an integrative neuromuscular training protocol *vs.* FIFA 11+ on sprint, change of direction performance and inter-limb asymmetries in young soccer players. *Int J Sports Sci Coaching* 2022;**17**:54–62.
20. Trajković N, Gušić M, Molnar S, Mačak D, Madić DM, Bogataj Š. Short-term FIFA 11+ improves agility and jump performance in young soccer players. *Int J Environ Res Public Health* 2020;**17**:2017. doi:10.3390/ijerph17062017.
21. Reis I, Rebelo A, Krustrup P, Brito J. Performance enhancement effects of Federation Internationale de Football Association's "The 11+" injury prevention training program in youth futsal players. *Clin J Sport Med* 2013;**23**:318–20.
22. Daneshjoo A, Mokhtar AH, Rahnama N, Yusof A. Effects of the 11+ and Harmoknee warm-up programs on physical performance measures in professional soccer players. *J Sports Sci Med* 2013;**12**:489–96.
23. Soligard T, Nilstad A, Steffen K, et al. Compliance with a comprehensive warm-up programme to prevent injuries in youth football. *Br J Sports Med* 2010;**44**:787–93.
24. Al Attar WSA, Soomro N, Pappas E, Sinclair PJ, Sanders RH. Adding a post-training FIFA 11+ exercise program to the pre-training FIFA 11+ injury prevention program reduces injury rates among male amateur soccer players: A cluster-randomised trial. *J Physiother* 2017;**63**:235–42.
25. Whalan M, Lovell R, Steele JR, Sampson JA. Rescheduling Part 2 of the 11+ reduces injury burden and increases compliance in semi-professional football. *Scand J Med Sci Sports* 2019;**29**:1941–51.
26. Veith S, Whalan M, Williams S, Colyer S, Sampson JA. Part 2 of the 11+ as an effective home-based exercise programme in elite academy football (soccer) players: A one-club matched-paired randomised controlled trial: Submission type. *Sci Med Footb* 2021;**5**:339–46.
27. Ahmad SS, Hoos L, Perka C, Stöckle U, Braun KF, Konrads C. Follow-up definitions in clinical orthopaedic research: A systematic review. *Bone Jt Open* 2021;**2**:344–50.
28. Sadigursky D, Braid JA, De Lira DNL, Machado BAB, Carneiro RJF, Colavolpe PO. The FIFA 11+ injury prevention program for soccer players: A systematic review. *BMC Sports Sci Med Rehabil* 2017;**9**:18. doi:10.1186/s13102-017-0083-z.
29. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. *PLoS Med* 2009;**6**:e1000100. doi:10.1371/journal.pmed.1000100.
30. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *Ann Intern Med* 2009;**151**:264–9.
31. Harrison H, Griffin SJ, Kuhn I, Usher-Smith JA. Software tools to support title and abstract screening for systematic reviews in healthcare: An evaluation. *BMC Med Res Methodol* 2020;**20**:7. doi:10.1186/s12874-020-0897-3.
32. Whittaker JL, Emery CA. Impact of the FIFA 11+ on the structure of select muscles in adolescent female soccer players. *Phys Ther Sport* 2015;**16**:228–35.
33. Arsenis S, Gioftsidou A, Ispyrlidis I, et al. Effects of the FIFA 11+ injury prevention program on lower limb strength and balance. *J Phys Educ Sport* 2020;**20**:592–8.
34. Lopes M, Rodrigues JM, Monteiro P, et al. Effects of the FIFA 11+ on ankle evertors latency time and knee muscle strength in amateur futsal players. *Eur J Sport Sci* 2020;**20**:24–34.
35. Navarro-Santana MJ, Asín-Izquierdo I, Gómez-Chiguano GF, Albert-Lucena D, Plaza-Manzano G, Pérez-Silvestre Á. Effects of two exercise programmes on joint position sense, dynamic balance and countermovement jump in male amateur football players. A randomised controlled trial. *J Sports Sci* 2020;**38**:2620–30.
36. Rahlf AL, John C, Hamacher D, Zech A. Effects of a 10 *vs.* 20-min injury prevention program on neuromuscular and functional performance in

adolescent football players. *Front Physiol* 2020;**11**:578866. doi:10.3389/fphys.2020.578866.
37. Akbari H, Sahebozamani M, Daneshjoo A, Amiri-Khorasani M, Shimokochi Y. Effect of the FIFA 11+ on landing patterns and baseline movement errors in elite male youth soccer players. *J Sport Rehabil* 2020;**29**:730–7.
38. Hwang J, Kim J, Hwang J, Kim J. Effect of FIFA 11+ training program on soccer-specific physical performance and functional movement in collegiate male soccer players: A randomized controlled trial. *Exerc Sci* 2019;**28**:141–9.
39. Lopes M, Lopes S, Patinha T, et al. Balance and proprioception responses to FIFA 11+ in amateur futsal players: Short and long-term effects. *J Sports Sci* 2019;**37**:2300–8.
40. Parsons JL, Carswell J, Nwoba IM, Stenberg H. Athlete perceptions and physical performance effects of the FIFA 11+ program in 9−11 year-old female soccer players: A cluster randomized trial. *Int J Sports Phys Ther* 2019;**14**:740–52.
41. Rey E, Padrón-Cabo A, Penedo Jamardo E, González-Víllora S. Effect of the 11+ injury prevention programme on fundamental movement patterns in soccer players. *Biol Sport* 2018;**35**:229–36.
42. Steffen K, Emery CA, Romiti M, et al. High adherence to a neuromuscular injury prevention programme (FIFA 11+) improves functional balance and reduces injury risk in Canadian youth female football players: A cluster randomised trial. *Br J Sports Med* 2013;**47**:794–802.
43. Nakase J, Inaki A, Mochizuki T, et al. Whole body muscle activity during the FIFA 11+ Program evaluated by positron emission tomography. *PLoS One* 2013;**8**:e73898. doi:10.1371/journal.pone.0073898.
44. Brito J, Figueiredo P, Fernandes L, et al. Isokinetic strength effects of FIFA's "The 11+" injury prevention training programme. *Isokinetics Exerc Sci* 2010;**18**:211–5.
45. Bizzini M, Impellizzeri FM, Dvorak J, et al. Physiological and performance responses to the "FIFA 11+" (part 1): Is it an appropriate warm-up? *J Sports Sci* 2013;**31**:1481–90.
46. Baeza G, Paredes G, Vega P, Monrroy M, Gajardo-Burgos R. Effect of "FIFA 11+" on the pattern of fundamental movements in under-14 soccer players. *Revista Brasileira de Medicina do Esporte* 2017;**23**:465–8.
47. Takata Y, Nakase J, Inaki A, et al. Changes in muscle activity after performing the FIFA 11+ programme part 2 for 4 weeks. *J Sports Sci* 2016;**34**:2011–7.
48. Cloak R, Nevill A, Smith J, Wyon M. The acute effects of vibration stimulus following FIFA 11+ on agility and reactive strength in collegiate soccer players. *J Sport Health Sci* 2014;**3**:293–8.
49. Dix C, Arundale A, Silvers-Granelli H, Marmon A, Zarzycki R, Snyder-Mackler L. Biomechanical changes during a 90° cut in collegiate female soccer players with participation in the 11. *Int J Sports Phys Ther* 2021;**16**:671–80.
50. Pardos-Mainer E, Casajús JA, Gonzalo-Skok O. Adolescent female soccer players' soccer-specific warm-up effects on performance and inter-limb asymmetries. *Biol Sport* 2019;**36**:199–207.
51. Fard RB, Atri AE, Yazdi NK, Shahtahmassebi B. Assessing changes in static and dynamic postural stability in youth football players following the FIFA 11+ injury prevention program. *Sci Sports* 2022;**37**:215. doi:10.1016/j.scispo.2021.07.003.
52. Thompson JA, Tran AA, Gatewood CT, et al. Biomechanical effects of an injury prevention program in preadolescent female soccer athletes. *Am J Sports Med* 2017;45:294-301.
53. Whiting PF, Rutjes AW, Westwood ME, et al. QUADAS-2: A revised tool for the quality assessment of diagnostic accuracy studies. *Ann Intern Med* 2011;**155**:529–36.
54. Hoch MC, McKeon PO. Peroneal reaction time after ankle sprain: A systematic review and meta-analysis. *Med Sci Sports Exerc* 2014;**46**:546–56.
55. Linford CW, Hopkins JT, Schulthies SS, Freland B, Draper DO, Hunter I. Effects of neuromuscular training on the reaction time and electromechanical delay of the peroneus longus muscle. *Arch Phys Med Rehabil* 2006;**87**:395–401.
56. Delahunt E. Neuromuscular contributions to functional instability of the ankle joint. *J Bodywork Movement Ther* 2007;**11**:203–13.
57. Hübscher M, Zech A, Pfeifer K, Hänsel F, Vogt L, Banzer W. Neuromuscular training for sports injury prevention: A systematic review. *Med Sci Sports Exerc* 2010;**42**:413–21.
58. Perera NK, Hägglund M. We have the injury prevention exercise programme, but how well do youth follow it? *J Sci Med Sport* 2019;**23**:463–8.
59. Young WB, McDowell MH, Scarlett BJ. Specificity of sprint and agility training methods. *J Strength Cond Res* 2001;**15**:315–9.
60. Harøy J, Thorborg K, Serner A, et al. Including the Copenhagen adduction exercise in the FIFA 11+ provides missing eccentric hip adduction strength effect in male soccer players: A randomized controlled trial. *Am J Sports Med* 2017;**45**:3052–9.
61. Whalan M, Lovell R, Thorborg K, Sampson JA. The 11+ of the future: A primary injury prevention framework for sub-elite football. *Br J Sports Med* 2020. doi:10.1136/bjsports-2020-102788. [Epub ahead of print].

# 5. Introducing the Football+ program

## 5.1. A comprehensive warm-up program for injury prevention and performance enhancement.

Having critically synthesized the available literature on the 11+, it became evident that, although the program effectively reduces injury incidence and improves certain biomechanical and neuromuscular parameters, it may not optimally enhance acute performance, shows no consistent effects on technical skills, and provides limited improvements in long-term performance outcomes (Asgari, Nazari, et al., 2022). These findings are particularly relevant given that warm-up routines, as the final preparatory stage before intensive physical activity, are generally expected to fulfill dual purposes: reducing injury risk while simultaneously optimizing motor performance and performance readiness (Sople & Wilcox, 2025).

One potential explanation for this limitation is that most contemporary IPPs, including the 11+, have primarily been developed from a medical and injury-reduction perspective, with comparatively limited integration of performance-oriented training science. Consequently, many existing IPPs emphasize neuromuscular control and injury-risk reduction while insufficiently targeting football-specific performance demands. This issue, combined with the previously described implementation barriers, may partly explain the limited real-world adoption and compliance observed despite the well-established efficacy of these programs in reducing injuries. From a practical perspective, this issue may be particularly relevant in amateur football settings, where teams commonly train only two to three times per week. Under such conditions, coaches often prioritize tactical, technical, and physical preparation, leaving limited time for stand-alone IPPs. Consequently, “lack of time” has consistently been identified as one of the primary barriers to the implementation of IPPs in real-world football practice (Donaldson et al., 2019; O'Brien & Finch, 2016).

## 5.2. Development rationale of the Football+

Accordingly, a more integrated and football-specific approach that combines established IP principles with performance-oriented training strategies may represent a more practical and adoptable solution. Based on this rationale, a novel football-specific warm-up program, the Football+, was developed in collaboration with Borussia Dortmund (BVB09). The Football+ was designed as a dual-purpose intervention integrating evidence-based IP principles with

performance-enhancing training components, based on the premise that an effective warm-up should not only reduce injury risk, but also optimize performance.

The development of the Football+ was grounded in both scientific evidence and practical considerations. In addition to established IP concepts, the program incorporated recommendations from previous literature regarding potential improvements to the 11+ and other IPPs, particularly concerning football specificity, player engagement, exercise variability, and performance enhancement (Asgari, Alizadeh, Shahrbanian, Nolte, & Jaitner, 2022; Asgari, Nazari, et al., 2022; Bathe et al., 2023; Dalen-Lorentsen, O'Brien, & Harøy, 2024; Grooms, Bizzini, Silvers-Granelli, & Benjaminse, 2024; O'Brien & Finch, 2016; O'Brien et al., 2017; O'Brien, Young, & Finch, 2017; Wilke et al., 2018; Winstanley, Reid, & Fulcher, 2023). Consequently, the Football+ was specifically designed to improve ecological validity and practical applicability while maintaining the preventive mechanisms underlying successful IPPs.

From a training science perspective, adaptations are generally considered to be highly task- and context-specific. Therefore, interventions that more closely replicate the physical, technical, cognitive, and coordinative demands of football may produce superior transfer to real-game performance and movement behavior. This principle provided an additional theoretical foundation for the development of the Football+, which aimed to combine neuromuscular injury prevention with football-specific performance preparation within a single warm-up structure.

## 5.3. Structure and components of the Football+

The primary objectives of the Football+ are to reduce injury risk, enhance motor performance, and improve long-term adherence by ensuring that the exercises closely align with football-specific demands. Further, the program was intentionally designed to be user-friendly and to require minimal equipment, thereby facilitating its application across different playing levels and training environments without substantial logistical constraints.

The Football+ consists of three progressive phases, each targeting important injury-related and performance-related factors. The first phase, Foundation building, focuses on running mechanics, strength, dynamic mobility, and neuromuscular control. This phase aims to

establish an appropriate neuromuscular and biomechanical foundation while preparing players for more demanding movement tasks.

The second phase, Ball-based training, incorporates football-specific drills and small-sided games designed to improve decision-making, coordination, technical skills, and functional movement quality under more sport-specific conditions. By integrating ball-related and cognitively demanding exercises, this phase seeks to enhance both player engagement and ecological validity.

The third phase, Explosive performance, includes plyometric, agility, sprinting, and change-of-direction exercises targeting power, speed, acceleration, and dynamic movement control. These exercises were specifically selected to prepare players for the high-intensity actions commonly performed during football training and competition. Collectively, the structure of the Football+ reflects a sequence of progressively demanding movement activities, ensuring that players are adequately prepared for the physiological and neuromuscular demands of the subsequent training session. In contrast to many traditional IPPs, the Football+ therefore aims not only to reduce injury risk but also to function as a comprehensive football-specific warm-up capable of optimizing immediate and long-term performance readiness.

To facilitate progression and long-term adaptation, the program follows a three-level difficulty system that allows players to gradually increase exercise intensity and complexity every four to six weeks according to their development and training response. For optimal results, a training frequency of three sessions per week is recommended. Detailed descriptions of the exercises, progressions, and implementation guidelines are provided in the Football+ manual and poster included in the appendices of this dissertation.

## 5.4. Research aims and hypothesis

Concerning conceptual models ranging from the “Sequence of Prevention” framework (Van Mechelen et al., 1992) to the Translating Research into Injury Prevention Practice (TRIPP) framework (O’Brien et al., 2019), a critical step in the validation of IPPs is the evaluation of their effects on injury-related risk factors (Finch, 2006; O’Brien et al., 2019). Accordingly, detailed biomechanical investigations are essential for understanding the mechanisms through which the Football+ may contribute to injury-risk reduction.

Further, as a warm-up program, the Football+ was specifically designed not only to reduce injury risk but also to enhance motor performance, thereby positioning itself as a dual-purpose, time-efficient intervention. Therefore, the experimental phase of this dissertation was structured into three stages, each examining the effects of the Football+ on key aspects of IP and performance enhancement in amateur female football players. Specifically, the project investigated the program's effects on (i) acute and long-term motor performance outcomes, (ii) knee kinematic and kinetic parameters associated with lower-extremity injury risk, particularly ACL injuries (Leppänen et al., 2017; Mausehund & Krosshaug, 2024; Ramachandran et al., 2025), and (iii) landing biomechanics in previously injured female players.

By systematically evaluating these factors, this dissertation aimed to bridge the gap between theoretical IP frameworks and real-world football application by providing scientific evidence for the Football+ as a practical, football-specific, and performance-oriented IP strategy. In all three experimental studies, the 11+ served as the primary reference intervention, allowing direct comparison between the effects of the two programs on the investigated parameters. It was hypothesized that implementing the Football+ with high compliance would: (i) demonstrate at least comparable positive effects on knee biomechanics relative to the 11+ and superior outcomes compared with traditional warm-up routines, and (ii) produce greater improvements in motor performance measures than both the 11+ and control conditions.

The findings of this dissertation are intended to provide a scientific foundation for future large-scale RCTs evaluating the effects of the Football+ on injury incidence and injury severity, thereby representing an important step in the long-term validation process of the program.

# 6. Empirical evaluation of the Football+ program: Effects on injury risk factors and motor performance

PLOS ONE

RESEARCH ARTICLE

# Acute effects of the FIFA11+ and Football+ warm-ups on motor performance. A crossover randomized controlled trial

**Mojtaba Asgari*, Marcus Schmidt☯, Benedikt Terschluse☯, Maximilian Sueck☯, Thomas Jaitner☯**

Institute for Sport and Sport Science, TU Dortmund University, Dortmund, Germany

☯ These authors contributed equally to this work.
* mojtaba.asgari@tu-dortmund.de

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**Data Availability Statement:** All relevant data are within the paper and its Supporting Information files.

## Abstract

### Introduction

Few studies including contradictory results have addressed the acute effects of the 11+ on motor performance, indicating a potentially reduced applicability of the program for warming up before competitions. This study aims to compare the acute effects of a soccer-specific warm-up (Football+) and the 11+ on motor performance.

### Materials and methods

Thirty-eight volunteer collegiate players (22 males; age = 21.1±1.9 years, height = 1.81± 0.06 m, weight = 73.4± 9.5 kg; 16 females; age = 21.3±1.5 years; height = 1.71± 0.07 m, weight = 67.8± 8.5 kg) underwent the 11+ and the Football+ in a randomized crossover design with a one-week washout. The Football+ starts with a self-estimated 40–50 percent running, followed by dynamic stretching of the hip muscles, shoulder contact, controlled lunge, Copenhagen exercise, and modified Nordic hamstring exercise. The second part involves roughly intensive small-sided games, followed by plyometric and anaerobic exercises in the third part. The warm ups' effects on performance were determined by a linear sprinting test (20 m), countermovement jump performance (CMJ), Illinois agility (IA), and dribbling speed (DS) tests. Within-subject differences were reported as the means and SD. Pairwise t tests at the significance level of $p<0.05$ were used to calculate the significant differences.

### Results

Overall, except for the CMJ (mean = -0.43±3.20 cm, p = 0.21, d = -0.13), significant differences for the 20 m sprint (mean = 0.04±0.10 s, p = 0.005, d = 0.42), IA (mean = 0.65±0.45 s, p = 0.01, d = 1.43), and DS (mean = 0.60±1.58 s, p = 0.012, d = 0.38) were observed. In females, significant differences observed only for IA (mean difference = 0.52±0.42 s, $p<0.001$, d = 1.24) and DS (mean difference = 1.29±1,77 s, p = 0.005, d = 0.73), with the Football+ showing superiority. In males, significant differences were found only for 20 m

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sprinting (mean difference = 0.06±0.09, p = 0.005, d = 0.60) and IA (mean difference = 0.74 ±0.46, p<0.001, d = 1.62), with the Football+ having superiority.

## Discussion

Although practicable for injury prevention, the 11+ may not optimize acute performance and prepare players for high-intensity physical tasks as well as a well-structured, roughly intensive warm-up. Further gender-specific studies should evaluate the long-term effects of the Football+ on performance and injury prevention.

## Introduction

Primarily designed as an injury prevention-oriented warm-up, the 11+ has been proven to reduce overall, hamstring, groin, and knee injury incidences by 40%, 66%, 48%, 46%, respectively [1–6]. Meanwhile, one recent systematic review on the 11+ has demonstrated that an abundant number of studies have also addressed the side effects of the 11+ on biomechanical measures and performance parameters [7]. The outcomes affirm that mid- to long-term application of the 11+ reveals positive effects on biomechanical measures such as concentric and eccentric strength of the hamstrings, concentric strength of the quadriceps, core strength and stability, and balance [7]. Nevertheless, contradictory results have been reported for performance parameters such as agility, sprinting, vertical jump and change of direction [8–14].

Regarding the acute effects of the 11+ on performance, however, the literature is tightly limited, sparse, and inconsistent. To date, only four studies including small samples (N<20) have been published [15–18], three of which have investigated common maneuvers in soccer, such as agility, sprinting, and vertical jumping, among amateur male players. Cloak et al. (2014) stated that the 11+ has no impact on agility and vertical jump [18], whereas Bizzini et al. (2013) showed that the 11+ might optimize agility and sprinting [16]. More recently, Ayala et al. (2017) reported that, compared to a dynamic warm-up, the 11+ may even reduce acute sprinting in adult male and female amateur players and highlighted that soccer-specific dynamic warm-ups are more beneficial for player preparation for high-intensity performance [15]. This is the only study that has investigated acute effects of the 11+ on female players. However, given the limited sample and that the results were not presented for females separately, the outcomes might not be generalized. As a result, a serious lack of gender-specific knowledge exists regarding the level of technical ability and physical performance in general and immediately after the application of 11+ [19], though research has shown that the physiological, metabolic and anthropometric requirements of male and female soccer players are too similar [20].

It is widely accepted that a practical warm-up should optimize motor performance. Several studies have addressed the advantages of dynamic warm-ups on acute performance and concluded that high-intensity warm-ups involving small-sided games and anaerobic exercises result in superior performance in intermittent-sprint running, reactive agility, countermovement jump, and 20-m sprinting [21–23]. In this concept, the 11+ must demonstrate its ability to optimize the common performance measures in soccer, such as sprinting, jumping, dribbling, and agility, so that it could be promoted at the level of routine warm-ups currently used in amateur football.

The weak effects of the 11+ on acute performance might result from a low intensity and suboptimal sequencing of the exercises embedded in this program. The 11+ starts with jogging

exercises, dynamic stretches and controlled contacts followed by 10-minute strengthening exercises and ends with 2-min anaerobic exercises. Such a sequence is highly acknowledged for injury prevention [14] but may not properly prepare players for further intensive loads. Furthermore, known as a purely dynamic sport, soccer is characterized by a variety of anaerobic tasks, and warm-up modalities, as the last phase of athletes' preparation before high-intensity performance, are required to not only prevent injuries but also optimize players' performance acutely [24].

Taken together, the acute effects of the 11+ on performance and consequently its applicability for warming up before competitions and matches remain questionable. This is a prominent challenge considering that the acute effects of the 11+ on performance highly interact with the compliance and implementation of the program, which have shown a strong correlation to the success of each injury prevention protocol and to team success [25]. Additionally, only a pilot study including a small sample and potentially underpowered results has investigated the acute effects of the 11+ on female players [15]. However, that study did not compare male and female players, and whether they react differently to the 11+ remains questionable. Therefore, the primary aim of this study is to compare the acute effects of the 11+ and a newly developed football-specific dynamic warm-up (Football+) on sprinting, agility, vertical jump, and dribbling speed among collegiate players. The secondary aim is to determine any possible differences in males and females following application of the warm-up modalities. To develop the Football+, we extended the 11+ with more dynamic, soccer-oriented, and anaerobic exercises with the intention of preserving the positive effects on injury prevention and ensuring better preparation for subsequent intensive movement tasks using the available literature [22, 26–28]. Given the soccer-specific and dynamic nature of the Football+ program, we assume that it results in superior acute performance compared to the 11+.

## Methods

### Study design

The current study was conducted in accordance to the Helsinki declaration guidelines. The ethics committee of TU Dortmund University read and approved the study protocol. Participation was voluntary, and before study commencement, all participants signed a written informed consent letter. In a randomized crossover design, participants conducted two warm-up modalities with a 1-week washout phase in between. Following the application of each warm-up, participants' performance was tested using a standardized test battery for performance assessment. To reach the best allocation concealment and avoid the learning effect from occasion to occasion, an ABBA approach was applied [29], implying that half of the subjects began with the 11+, while the other half started with a dynamic warm-up. To eliminate the time slot between the warm ups and the tests, we randomly divided the participants into four subgroups in accordance with the ABBA approach guidelines [29] and performed the interventions and measurements in two consecutive sessions (9–10 and 10–11 AM) in a day. With that setup, the players underwent the test battery immediately after completion of the warm-ups. In the following week, the interventions and the test order were swapped. Two certified research assistants with two years of the 11+ experience were responsible for conducting the warm-ups and test battery. The test battery comprised counter movement jump (CMJ), linear sprinting, Illinois agility (IA), and dribbling speed (DS) tests and was run immediately after the warm-ups. Prior to the measurements, all players participated in two familiarization sessions. The measurements were conducted in the mornings under comparable conditions (sunny weather, 21–22˚Celsius, 55–60% humidity) on the artificial turf where the players performed their routine training sessions. The players were asked to not perform heavy physical

activities 24 h before measurements, sleep no later than 12 pm the night before measurements and drink only caffeine-free liquids 4 h before measurements. They were also asked to put on the normal soccer shoes that are regularly used in artificial turf.

## Inclusion/exclusion criteria

This study included collegiate students who were actively playing football. Participants had to be at least 18 years old and participate in at least two training sessions per week. Those with a history of injury within the last four weeks were excluded. Participants were also excluded if they missed a measurement session, were engaged in intensive physical activities 24 hours before the test session, fell ill or contracted an infection during the study period.

## Participants

G*Power software [30] calculated a sample of 34 for an expected effect size of 0.5, α error probability of 0.05 and power of 0.80 [31]. Indeed, forty-two collegiate players voluntarily agreed to attend the study and signed a written informed consent form. Four participants dropped out during the study period due to coronavirus infection. Thus, twenty-two male (age = 21.1±1.9 years; height = 1.81± 0.06 m, weight = 73.4± 9.5 kg) and 16 female (age = 21.3±1.5 years; height = 1.71± 0.07 m, weight = 67.8± 8.5 kg) players completed both warm-ups and the test battery and were included for statistical analyses.

## Interventions

Both interventions consist of three parts lasting 25 minutes but differ in content. The 11+ aims to tackle modifiable injury risk factors such as neuromuscular control, static and dynamic balance, and the hamstring/quadriceps strength ratio [32]. The first part includes 8 minutes of running exercises at low speed combined with active stretching and controlled contact with a partner. The running course consists of six to ten pairs of cones depending on the number of players, approximately five to six meters apart (length and width). The second part involves six different sets of exercises, including strength, balance, and jumping, lasting 10 minutes, followed by 2 minutes of speed running combined with football-specific movements and sudden changes in direction in the last part.

The 11+ exercises were described in detail by Soligard et al. [32]. The Football+ begins with a 2-min self-estimated running across the pitch at approximately 40–50% of maximal pace, followed by dynamic stretch of the hip (hip in/out, hip abduction/adduction, hip flexion/extension, backward and side running, shoulder contact and landing, controlled lunges, two dynamic core stability exercises, Copenhagen and a modified Nordic Hamstring Exercises. The second part includes 5-min roughly intensive small-sided games, namely, active passing, unanticipated dribbling tasks, and one vs one, followed by plyometric and anaerobic exercises in the third part lasting 5 min (see appendix one).

## Performance tests

The warm ups' effects on performance were measured through a linear 5-, 10-, and 20-m sprint (Fig 1) [8, 10], CMJ (Fig 2) [8, 9], IA (Fig 3) [8, 33], and DS (Fig 4) [34]. Each subject performed each test twice, and the best results were considered for data analysis.

For linear sprinting, the players stood a meter behind the baseline and tried to run through the path with a maximal pace. The IA is performed in a rectangle of 10×5 m. The players start in a prone position, run toward the barrier at 10 m at maximum speed, return, and perform a zigzag run around four barriers, each 3.3 m apart. The test ends with another straight run to



**Fig 1. Sprinting test.**

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the end of the rectangle [33]. For the DS, the players start running with ball 3 m, then dribble the ball in a zigzag shape around three poles with a distance of half a meter each, then run with ball another 3 m and dribble the ball in a zigzag shape around last three poles with a distance of half a meter each. The test ends when the players pass the finish line. The CMJ is performed in a standing position on the mat and attempts to jump as high as possible. The flight time measure (Optojump Next System Microgate, Bolzano, Italy) measured the jump height. All tests were conducted in self-command start mode so that each player freely started the tests without receiving any external signal/command. Double-light time gates (90–110 cm height) were used to accurately measure the linear sprinting times at 5, 10 and 20 m distances as well as the time for completing the IA and DS [35].

### Statistical analyses

Descriptive measures, such as the means, SD and mean standard error (SE), were calculated for each outcome measure. Normal distribution of the data was proven for all variables using the Shapiro–Wilks test. Subsequently, the within-subject effects of the warm ups were analyzed by paired sample t tests. The level of significance was set at $\alpha < .05$. Magnitudes of differences were assessed using Cohen´s d effect sizes and interpreted as small (.25), medium (.5), and large (1.0) [36]. All statistical analyses were performed using SPSS version 28.

## Results

Table 1 presents the mean values, standard deviation (SD) and SE for the 11+ and the Football + (n = 38). As we expected that the results of the 5-, 10- and 20-m sprints were highly correlated, Pearson correlation coefficients were calculated for those variables. Due to the high values of r = 0.90–0.99 (p = 0.001), only the outcomes of the 20-m sprinting are presented in the results section.

Except for the CMJ (mean difference = -0.43±3.20 cm, p = 0.21, d = -0.13), the pairwise t test analyses revealed significant differences for the 20-m sprint (mean difference = 0.09±0.10 s, p = 0.005, d = 0.42), IA (mean difference = 0.65±0.45 s, p = 0.01, d = 1.43), and DS (mean difference = 0.60±1.58 s, p = 0.012, d = 0.38).

According to gender, males outperformed females across all parameters regardless of the warm ups ($p \leq 0.005$). In females, although differences were observed in 20 m sprinting and CMJ, the pairwise t test revealed significant differences only for IA (mean difference = 0.52 ±0.42 s, $p < 0.001$, d = 1.24) and DS (mean difference = 1.29±1,77 s, p = 0.005, d = 0.73), with the Football+ showing superiority. In males, although differences were observed in DS, the statistical analysis revealed significant differences only for 20 m sprinting (mean difference = 0.06

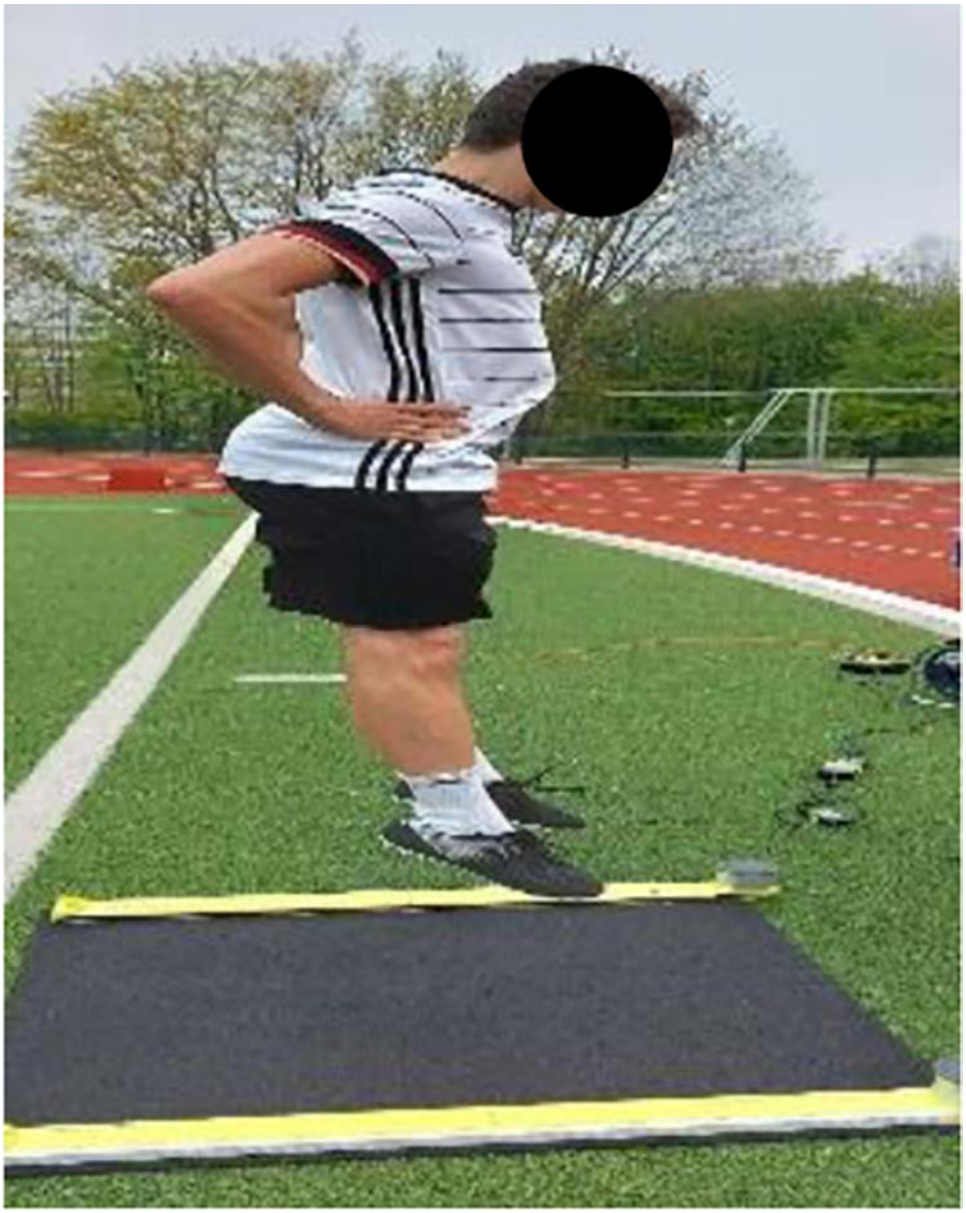


**Fig 2. Countermovement jump test.**

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±0.09, p = 0.005, d = 0.60) and IA (mean difference = 0.74±0.46, p<0.001, d = 1.62), with the Football+ having superiority.

## Discussion

The primary aim of this study was to compare the acute effects of the 11+ and Football+ on motor performance and address concerns regarding the use of the 11+ as an appropriate warm-up modality before high-intensity training and competitions. In general, the findings demonstrate that the Football+ program appropriately optimizes acute performance, leading to superior operation in sprinting, agility, and dribbling, but not in the vertical jump, compared to the 11+ program in collegiate players. Our outcomes strongly support Ayala et al.



**Fig 3. Illinois agility test.**

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(2017), who found no acute impact on sprinting or vertical jump following the application of the 11+ compared to a dynamic warm-up among amateur male and female soccer players [15]. Interestingly, given the identical study design and the mixed sample being undertaken,



**Fig 4. Dribbling test.**

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**Table 1. Mean values, standard deviation (SD) and mean standard error (mean SE) for the 11+ and Football+.**

| | | Overall | | | | Females | | | | Males | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean(s) | SD(s) | Mean SE(s) | Cohen's d | Mean(s) | SD(s) | Mean SE | Cohens's d | Mean(s) | SD(s) | Mean SE | Cohens's d |
| 20 m | 11+ | 3.26 | 0.23 | 0.04 | 0.42 | 3.39 | 0.21 | 0.03 | | 3.17 | 0.19 | 0.02 | |
| | Football+ | 3.17 | 0.44 | 0.07 | | 3.36 | 0.20 | | 0.22 | 3.11 | 0.20 | | 0.61 |
| IA | 11+ | 17.68 | 0.95 | 0.15 | 1.43 | 18.31 | 0.82 | 0.11 | | 17.23 | 0.77 | 0.10 | |
| | Football+ | 17.03 | 1.03 | 0.17 | | 17.78 | 0.72 | | 1.24 | 16.48 | 0.87 | | 1.62 |
| DS | 11+ | 14.33 | 3.24 | 0.52 | 0.38 | 16.29 | 3.25 | 0.44 | | 12.90 | 2.42 | 0.26 | |
| | Football+ | 13.72 | 2.53 | 0.41 | | 14.99 | 3.40 | | 0.73 | 12.79 | 2.24 | | 0.09 |
| CMJ | 11+ | 31.20 | 7.60 | 1.23 | -0.13 | 28.39 | 6.56 | 0.95 | -0.27 | 33.98 | 6.76 | 0.57 | |
| | Football+ | 31.63 | 7.21 | 1.17 | | 27.36 | 7.16 | | | 33.99 | | 6.86 | -0.003 |

SD = standard deviation, SE = standard Error

https://doi.org/10.1371/journal.pone.0284702.t001

the outcomes of Ayala et al. are highly comparable with the current study. Meanwhile, that study suffers from a tightly limited sample (n = 16) and potentially underpowered results [15]. Additionally, Cloak et al. (2014) compared the acute effects of the 11+ alone with a combination of the 11+ and acute vibration training and found no difference in agility among collegiate players [18]. On the other hand, Bizzini et al. (2013), by investigating 20 male amateur players, found that the 11+ could be an appropriate warm-up, optimizing agility, sprinting, and vertical jump [16]. However, that study did not compare the 11+ to any other warm-up modality and only compared the outcomes with the literature and a resting control condition. That this study undertook a male sample and the current study consisted of a mixed sample could be another reason to testify such inconsistency [16].

There have been several studies assessing the effects of different warm-ups on acute performance, the majority of which reported the applicability of dynamic and intensive warm-ups to properly prepare athletes for high-level performance [22, 23, 37–39]. For example, Abade et al. (2017) suggested that plyometric and repeated changes of direction appear to be useful warm-up exercises to optimize sprinting and jump performance [39]. Hence, improvements in agility and sprinting following application of the Football+ could be due to highly intensive plyometric and anaerobic exercises and cutting maneuvers. Additionally, Zois et al. (2015) showed that small-sided games during warm-up optimize subsequent performance compared with team-sport warm-up [22]. Thus, improvements in the dribbling skill could be due to the small-sided games integrated into the Football+ program. Conducting a dynamic warm-up while benefiting from ball-based exercises may not only prepare players right in the soccer context but also link the warm-up strategy to soccer-specific demands. That the 11+ produces no effect on technical skills appears to be very realistic given that no soccer-specific drill exists in the program.

It has been demonstrated that walking lunges and plyometric exercises improve jump height [27, 39]. Additionally, it has been proven that the 11+ increases quadriceps and hamstring strength, which can contribute to enhancement of lower extremity power in soccer players [7]. The nonsignificant difference in CMJ can be explained by the fact that both warm-ups included that exercise, although the dosage of plyometric exercises in the Football+ group was nearly twice that in the 11+ group. On the other hand, the 11+ includes squat exercises that might improve jump performance [27, 39]. Tobin et al. (2014) demonstrated that performing a series of plyometrics significantly improves CMJ and could be an efficient method of obtaining advantages of the postactivation potentiation phenomenon (PAP) [40].

The differences in agility and sprinting following application of the 11+ and Football + warm-ups can be discussed based on their structure. The 11+ involves more static than

dynamic exercises, with a focus on strengthening core and hip muscles. Although highly effective in terms of injury prevention, such a static structure, including high volume strength exercises, may not prepare the players for further intensive skilled tasks. Parameters such as agility and sprinting depend on the training features, including coordination, mobility, leg power, and speed [28, 41]. Thus, applying exercises that stimulate those features may optimize them. The volume of anaerobic exercises in the Football+ is approximately twice that in the 11+, which seems to be the main reason for the optimized agility and sprinting. In this regard, Faigenbaum et al. (2005) found that performance in the vertical jump, long jump, and shuttle run decreased by 6.5%, 1.9% and 2.6%, respectively, following a low-intensity aerobic warm-up and concluded that pre-event low intensity exercises might be suboptimal for preparing kids for activities requiring high power [42]. Thomas et al. (2009) indicated that plyometric exercises could improve players' muscular power and agility [43].

According to gender, males outperformed females across all parameters regardless of the warm-ups, which is entirely in line with previous studies [19, 44]. Further, although differences were observed across all parameters, the paired t test failed to reach a statistically significant level for 20-m sprinting and CMJ in females and DS and CMJ in males, which is most likely due to the shrinking sample size determined by power analysis. On the other hand, such a contradictory results might also emphasize that trainers should consider gender-specific characteristics to establish goals about the technical and physical performance profiles of players. Meanwhile, further gender-specific studies with larger samples are required to address the acute effects of both programs on male and female players separately. In this regard, it has been demonstrated that utilization of the same exercise method or implementation of the same training volume for both genders may lead to weak training effects [20].

Although useful in injury prevention, the current findings highlight that the 11+ is not a proper warm-up for competitions and matches, as it may not prepare amateur players for subsequent skilled tasks and optimize their performance. Given that delivery of the 11+ to football administrations has remained challenging, such a lack of efficacy on acute performance potentially reduces the 11+ applicability for being used before competitions and consequently lowers the compliance and implementation of the program. Therefore, fundamental modifications on the 11+ aiming to link performance and injury prevention approaches appear to be intransitive and turn to the center of attention considering that the 11+ has not been updated since its launch in 2006. Trainers in amateur football are recommended to apply the Football+ program as a warm-up routine before competitions and high-load training sessions and benefit from its advantage in optimizing motor performance.

## Conclusion

A well-structured football-specific dynamic warm-up including dynamic stretching, roughly intensive running exercises, strengthening, small-sided games, and plyometrics properly optimizes acute performance and improves sprinting, agility, and dribbling compared to the 11+. Although practical in injury prevention, the 11+ may not optimize acute performance properly and should not be performed before competitions and high-demand training sessions. A new framework to incorporate both soccer-specific and injury prevention exercise into the program may justify the applicability of the 11+ as a warm-up routine and may potentially enhance the delivery and compliance of the program. This study provides empirical evidence behind the applicability of the Football+ program before matches and competitions in amateur football. Practitioners and trainers are highly recommended to apply the Football+ program and benefit from its advantage in performance optimization before competitions and matches. Further studies should evaluate the long-term effects of the Football+ on performance and injury prevention.

### Limitations

This study involved no control group, and therefore, we could not compare the effects of two warm-up modalities with traditional warm-ups being used in amateur football. Further, given that the sample size was relatively small, dividing the players based on gender resulted in non-significant and contradictory results. Therefore, further gender-specific studies including larger samples are required to better identify the acute 11+ effects on different genders.

## Supporting information

**S1 Data.**
(XLSX)

**S1 Table. Mean values, standard deviation (SD) and mean standard error (mean SE) for the 11+ and Football+.**
(DOCX)

**S1 Appendix. The Football+ program.**
(DOCX)

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## Author Contributions

**Conceptualization:** Mojtaba Asgari.

**Data curation:** Benedikt Terschluse, Maximilian Sueck.

**Formal analysis:** Mojtaba Asgari.

**Methodology:** Mojtaba Asgari.

**Project administration:** Mojtaba Asgari.

**Supervision:** Thomas Jaitner.

**Writing – original draft:** Mojtaba Asgari.

**Writing – review & editing:** Marcus Schmidt, Thomas Jaitner.

## References

1. Al Attar WSA, Soomro N, Pappas E, Sinclair PJ, Sanders RH. How effective are F-MARC injury prevention programs for soccer players? A systematic review and meta-analysis. Sports medicine. 2016; 46 (2):205–17. https://doi.org/10.1007/s40279-015-0404-x PMID: 26403470
2. Bizzini M, Dvorak J. FIFA 11+: an effective programme to prevent football injuries in various player groups worldwide—a narrative review. British Journal of Sports Medicine. 2015; 49(9):577–9. https://doi.org/10.1136/bjsports-2015-094765 PMID: 25878073
3. Thorborg K, Krommes KK, Esteve E, Clausen MB, Bartels EM, Rathleff MS. Effect of specific exercise-based football injury prevention programmes on the overall injury rate in football: a systematic review and meta-analysis of the FIFA 11 and 11+ programmes. British journal of sports medicine. 2017; 51 (7):562–71. https://doi.org/10.1136/bjsports-2016-097066 PMID: 28087568
4. Al Attar WSA. The FIFA 11+ injury prevention program reduces the incidence of knee injury among soccer players: a systematic review and meta-analysis of randomized controlled trials. Journal of Science and Medicine in Sport. 2022; 25:S2–S3. https://doi.org/10.1016/j.jsams.2022.09.113

5. Al Attar WSA. The FIFA 11+ injury prevention program reduces the incidence of groin injury among soccer players: a systematic review and meta-analysis of randomized controlled trials. Journal of Science and Medicine in Sport. 2022; 25:S2. https://doi.org/10.1016/j.jsams.2022.09.112
6. Al Attar WSA. The FIFA 11+ injury prevention program reduces the incidence of hamstring injury among soccer players: a systematic review and meta-analysis. Journal of Science and Medicine in Sport. 2022; 25:S1–S2. https://doi.org/10.1016/j.jsams.2022.09.111
7. Asgari M, Nazari B, Bizzini M, Jaitner T. Effects of the FIFA 11+ program on performance, biomechanical measures, and physiological responses: A systematic review. Journal of Sport and Health Science. 2022. https://doi.org/10.1016/j.jshs.2022.05.001 PMID: 35659964
8. Zarei M, Abbasi H, Daneshjoo A, Barghi TS, Rommers N, Faude O, et al. Long-term effects of the 11+ warm-up injury prevention programme on physical performance in adolescent male football players: a cluster-randomised controlled trial. Journal of sports sciences. 2018; 36(21):2447–54. https://doi.org/10.1080/02640414.2018.1462001 PMID: 29638190
9. Impellizzeri FM, Bizzini M, Dvorak J, Pellegrini B, Schena F, Junge A. Physiological and performance responses to the FIFA 11+ (part 2): a randomised controlled trial on the training effects. Journal of Sports Sciences. 2013; 31(13):1491–502. https://doi.org/10.1080/02640414.2013.802926 PMID: 23855764
10. Arede J, Fernandes J, Moran J, Leite N, Romero-Rodriguez D, Madruga-Parera M. Effects of an integrative neuromuscular training protocol vs. FIFA 11+ on sprint, change of direction performance and inter-limb asymmetries in young soccer players. International Journal of Sports Science & Coaching. 2021:17479541211011438. https://doi.org/10.1177/17479541211011438
11. Trajković N, Gušić M, Molnar S, Mačak D, Madić DM, Bogataj Š. Short-term FIFA 11+ improves agility and jump performance in young soccer players. International journal of environmental research and public health. 2020; 17(6):2017. https://doi.org/10.3390/ijerph17062017 PMID: 32197538
12. Rahlf AL, John C, Hamacher D, Zech A. Effects of a 10 vs. 20-min injury prevention program on neuromuscular and functional performance in adolescent football players. Frontiers in physiology. 2020; 11:1299. https://doi.org/10.3389/fphys.2020.578866 PMID: 33178045
13. Navarro-Santana MJ, Asín-Izquierdo I, Gómez-Chiguano GF, Albert-Lucena D, Plaza-Manzano G, Pérez-Silvestre Á. Effects of two exercise programmes on joint position sense, dynamic balance and countermovement jump in male amateur football players. A randomised controlled trial. Journal of Sports Sciences. 2020; 38(22):2620–30. https://doi.org/10.1080/02640414.2020.1794472 PMID: 32686996
14. Asgari M, Alizadeh MH, Shahrbanian S, Nolte K, Jaitner T. Effects of the FIFA 11+ and a modified warm-up programme on injury prevention and performance improvement among youth male football players. PloS one. 2022; 17(10):e0275545. https://doi.org/10.1371/journal.pone.0275545 PMID: 36264894
15. Ayala F, Calderón-López A, Delgado-Gosálbez JC, Parra-Sánchez S, Pomares-Noguera C, Hernández-Sánchez S, et al. Acute effects of three neuromuscular warm-up strategies on several physical performance measures in football players. PloS one. 2017; 12(1):e0169660. https://doi.org/10.1371/journal.pone.0169660 PMID: 28060927
16. Bizzini M, Impellizzeri FM, Dvorak J, Bortolan L, Schena F, Modena R, et al. Physiological and performance responses to the "FIFA 11+" (part 1): is it an appropriate warm-up? Journal of sports sciences. 2013; 31(13):1481–90. https://doi.org/10.1080/02640414.2013.802922 PMID: 23855725
17. Nakase J, Inaki A, Mochizuki T, Toratani T, Kosaka M, Ohashi Y, et al. Whole Body Muscle Activity during the FIFA 11+ Program Evaluated by Positron Emission Tomography. PLOS ONE. 2013; 8(9): e73898. https://doi.org/10.1371/journal.pone.0073898 PMID: 24066082
18. Cloak R, Nevill A, Smith J, Wyon M. The acute effects of vibration stimulus following FIFA 11+ on agility and reactive strength in collegiate soccer players. Journal of Sport and Health Science. 2014; 3(4):293–8. https://doi.org/10.1016/j.jshs.2014.03.014.
19. Datson N, Hulton A, Andersson H, Lewis T, Weston M, Drust B, et al. Applied physiology of female soccer: an update. Sports Medicine. 2014; 44:1225–40. https://doi.org/10.1007/s40279-014-0199-1 PMID: 24803162
20. Perroni F, Gallotta MC, Pisano S, Reis VM, Emerenziani GP, Guidetti L, et al. Gender differences in anthropometric parameters and technical performance of youth soccer players. Sport Sciences for Health. 2018; 14:399–405.
21. Anderson P, Landers G, Wallman K. Effect of warm-up on intermittent sprint performance. Research in Sports Medicine. 2014; 22(1):88–99. https://doi.org/10.1080/15438627.2013.852091 PMID: 24392774
22. Zois J, Bishop D, Aughey R. High-intensity warm-ups: effects during subsequent intermittent exercise. International Journal of Sports Physiology and Performance. 2015; 10(4):498–503. https://doi.org/10.1123/ijspp.2014-0338 PMID: 25393323

23. Zois J, Bishop DJ, Ball K, Aughey RJ. High-intensity warm-ups elicit superior performance to a current soccer warm-up routine. Journal of science and medicine in sport. 2011; 14(6):522–8. https://doi.org/10.1016/j.jsams.2011.03.012 PMID: 21907619

24. Fradkin AJ, Zazryn TR, Smoliga JM. Effects of warming-up on physical performance: a systematic review with meta-analysis. The Journal of Strength & Conditioning Research. 2010; 24(1):140–8. https://doi.org/10.1519/JSC.0b013e3181c643a0 PMID: 19996770

25. Bizzini M, Junge A, Dvorak J. Implementation of the FIFA 11+ football warm up program: how to approach and convince the Football associations to invest in prevention. British journal of sports medicine. 2013; 47(12):803–6. https://doi.org/10.1136/bjsports-2012-092124 PMID: 23813485

26. Harøy J, Thorborg K, Serner A, Bjørkheim A, Rolstad LE, Hölmich P, et al. Including the Copenhagen adduction exercise in the FIFA 11+ provides missing eccentric hip adduction strength effect in male soccer players: a randomized controlled trial. The American journal of sports medicine. 2017; 45(13):3052–9. https://doi.org/10.1177/0363546517720194 PMID: 28806100

27. de Villarreal ES, Kellis E, Kraemer WJ, Izquierdo M. Determining variables of plyometric training for improving vertical jump height performance: a meta-analysis. J Strength Cond Res. 2009; 23(2):495–506. Epub 2009/02/07. https://doi.org/10.1519/JSC.0b013e318196b7c6 PMID: 19197203.

28. Vescovi JD, Mcguigan MR. Relationships between sprinting, agility, and jump ability in female athletes. Journal of sports sciences. 2008; 26(1):97–107. https://doi.org/10.1080/02640410701348644 PMID: 17852692

29. Kim J, Shin W. How to do random allocation (randomization). Clinics in orthopedic surgery. 2014; 6 (1):103–9. https://doi.org/10.4055/cios.2014.6.1.103 PMID: 24605197

30. Faul F, Erdfelder E, Buchner A, Lang A-G. Statistical power analyses using G* Power 3.1: Tests for correlation and regression analyses. Behavior research methods. 2009; 41(4):1149–60. https://doi.org/10.3758/BRM.41.4.1149 PMID: 19897823

31. Serdar CC, Cihan M, Yücel D, Serdar MA. Sample size, power and effect size revisited: simplified and practical approaches in pre-clinical, clinical and laboratory studies. Biochem Med (Zagreb). 2021; 31 (1):010502. Epub 2021/01/01. https://doi.org/10.11613/BM.2021.010502 PMID: 33380887; PubMed Central PMCID: PMC7745163.

32. Soligard T, Myklebust G, Steffen K, Holme I, Silvers H, Bizzini M, et al. Comprehensive warm-up programme to prevent injuries in young female footballers: cluster randomised controlled trial. Bmj. 2008; 337. https://doi.org/10.1136/bmj.a2469 PMID: 19066253

33. Hachana Y, Chaabene H, Ben Rajeb G, Khlifa R, Aouadi R, Chamari K, et al. Validity and reliability of new agility test among elite and subelite under 14-soccer players. PloS one. 2014; 9(4):e95773. https://doi.org/10.1371/journal.pone.0095773 PMID: 24752193

34. Höner O, Roth K. Erläuterungen zu den individuellen Spielerauswer-tungen im Rahmen der technisch-motorischen Leistungsdiagnostik an den DFB-Stützpunkten. Zugriff am. 2015; 7:2020.

35. Castagna C, Ganzetti M, Ditroilo M, Giovannelli M, Rocchetti A, Manzi V. Concurrent validity of vertical jump performance assessment systems. The Journal of Strength & Conditioning Research. 2013; 27 (3):761–8. https://doi.org/10.1519/JSC.0b013e31825dbcc5 PMID: 22648140

36. Rhea MR. Determining the magnitude of treatment effects in strength training research through the use of the effect size. The Journal of Strength & Conditioning Research. 2004; 18(4):918–20. https://doi.org/10.1519/14403.1 PMID: 15574101

37. Van den Tillaar R, von Heimburg E. Comparison of two types of warm-up upon repeated-sprint performance in experienced soccer players. Journal of Strength and Conditioning Research. 2016; 30 (8):2258–65. https://doi.org/10.1519/JSC.0000000000001331 PMID: 26808861

38. Zois J, Bishop D, Fairweather I, Ball K, Aughey R. High-intensity re-warm-ups enhance soccer performance. International journal of sports medicine. 2013; 34(09):800–5. https://doi.org/10.1055/s-0032-1331197 PMID: 23444096

39. Abade E, Sampaio J, Gonçalves B, Baptista J, Alves A, Viana J. Effects of different re-warm up activities in football players' performance. PLoS One. 2017; 12(6):e0180152. https://doi.org/10.1371/journal.pone.0180152 PMID: 28662123

40. Tobin DP, Delahunt E. The Acute Effect of a Plyometric Stimulus on Jump Performance in Professional Rugby Players. The Journal of Strength & Conditioning Research. 2014; 28(2):367–72. https://doi.org/10.1519/JSC.0b013e318299a214 23689338-201402000-00009.

41. Rössler R, Donath L, Bizzini M, Faude O. A new injury prevention programme for children's football–FIFA 11+ Kids–can improve motor performance: a cluster-randomised controlled trial. Journal of Sports Sciences. 2016; 34(6):549–56. https://doi.org/10.1080/02640414.2015.1099715 PMID: 26508531

42. Faigenbaum AD, Bellucci M, Bernieri A, Bakker B, Hoorens K. Acute effects of different warm-up protocols on fitness performance in children. The Journal of Strength & Conditioning Research. 2005; 19 (2):376–81. https://doi.org/10.1519/R-15344.1 PMID: 15903378

43. Thomas K, French D, Hayes PR. The effect of two plyometric training techniques on muscular power and agility in youth soccer players. The Journal of Strength & Conditioning Research. 2009; 23(1):332–5. https://doi.org/10.1519/JSC.0b013e318183a01a PMID: 19002073

44. Schons P, Birk Preissler AA, Oliveira R, Brito JP, Clemente FM, Droescher de Vargas G, et al. Comparisons and correlations between the anthropometric profile and physical performance of professional female and male soccer players: Individualities that should be considered in training. International Journal of Sports Science & Coaching. 0(0):17479541221131649. https://doi.org/10.1177/17479541221131649

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# Alterations in knee biomechanics and motor performance following 3 months training with the Football+ and 11+ warm-up programs among amateur female players. A three-armed cluster allocated, non-randomized intervention study

Mojtaba Asgari [a,*], Martin Hägglund [b], Benedikt Terschluse [c], Maximilian Sueck [a], Kevin Nolte [a], Marcus Schmidt [a], Thomas Jaitner [a]

[a] Training and Movement Science Group, Institute for Sport and Sport Science, TU Dortmund University, Dortmund, Germany
[b] Department of Health, Medicine and Caring Sciences, Unit of Physiotherapy, Linköping University, Linköping, Sweden
[c] Sports Scientist/Strength and Conditioning Coach Girls' and Women's Football Department, BVB09, Dortmund, Germany

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ABSTRACT

*Objective:* This cluster alocated comparative study (DRKS00036644) primarily evaluated the effects of the Football+ and the established FIFA 11+ (the 11+) on knee biomechanical risk factors. A secondary outcome included performance measures and their retention following a 10-week no-intervention period.

*Methods:* Three German amateur women's teams (24.3 ± 5.3 years, 1.73 ± 0.07 m, 64.3 ± 8.0 kg) completed the introductory sessions and were team allocated into the Football+ (n = 22), 11+ (n = 19), or control (n = 16) groups. Baseline assessment included a standardized 3D motion analysis of knee biomechanics during single-leg landing and cutting maneuvers and a performance test battery (sprinting, counter movement jump (CMJ), agility, and dribbling speed. Following a 3-month, twice-weekly supervised intervention, post-intervention testing was performed. A 10-week follow-up tested retention of the performance outcomes. Statistical significance was set at $\alpha \leq 0.05$.

*Results:* ANOVA revealed significant time and time × group interactions across multiple knee biomechanical variables. The Football+ showed consistently larger magnitudes of change compared with the 11+, while the control group demonstrated limited changes (p = .005-0.047; $\eta^2$ = 0.14-0.24). Similar interaction effects were observed for sprinting, agility, and dribbling performance (p = .002-0.01; $\eta^2$ = 0.13-0.23). Performance improvements were not retained after a 10-week no-intervention period.

*Conclusion:* The Football+ and 11+ programs improved high-risk movement patterns associated with an increased risk of knee injury, with more consistent and larger effects observed for the Football+. Improvements in performance measures were observed only following the Football+, supporting its potential as a time-efficient, dual-purpose warm-up. The performance improvements were not maintained following the no-intervention period.

## 1. Introduction

Warm-up strategies as the final preparatory stage before intensive physical activity, are expected to serve dual purposes: reducing injury risk and enhancing motor performance.[1] However, most injury prevention programs (IPPs), including the established FIFA 11+ (the 11+), designed in the form of warm-up programs have demonstrated limited effectiveness in performance enhancement [2–4]. One argumentative explanation for this issue is that majority of IPPs, including the 11+, have been developed primarily by medical professionals with a focus on injury risk reduction and limited input from sport scientists, resulting in programs that emphasize prevention but insufficiently target performance.[5] This major limitation combined with implementation challenges such as time constraints, lack of perceived relevance to football-specific goals, and low engagement and enjoyment of the players have restricted the real-world adoption of the 11+ and other

* Corresponding author. Institute for Sport and Sport Science, Postal code: 44227, Otto-Hahn- Str. 3, Dortmund, Germany.
*E-mail address:* mojtaba.asgari@tu-dortmund.de (M. Asgari).

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IPPs, despite their well-proven efficacy on injury prevention (IP).[6–9]

Although consistent implementation of the 11+ has shown to reduce the incidence of lower limb, overuse, acute, lower back, and knee injuries from 30 to 63% [10–15] low real-world adaptation rates in Germany, Australia, and Saudi Arabia ranging from only 10 to 40%[8,9,16] indicate that even strong evidence for IP alone may not be sufficient to promote widespread adoption of IPPs. A dual-focus strategy that integrates established IP principles with performance-oriented training science may offer a more aligned and adoptable IP approach.

The Football+ was developed as a dual-purpose warm-up program aiming to simultaneously modify biomechanical risk indicators and improve football-specific motor performance. Building on the existing literature and recommendations to improve the 11 + [2,5,7,8,17–21], the Football+ integrates intensive football-specific exercises with proven IP methods into a structured, engaging, and time-efficient warm-up. It features three progressive modules: (1) dynamic mobility, strength, and neuromuscular control; (2) small-sided games to enhance coordination, decision-making, and technical skills; and (3) plyometric, sprint, and agility drills for explosive movement development. A three-level progression system enables players to gradually increase training intensity based on their readiness and feedback.

Previous investigations revealed that the Football+ yields superior acute benefits in sprinting, agility, jumping, and dribbling speed compared to the 11+.[22] Further, it has demonstrated significant improvements in landing technique among female players with and without a history of severe ankle or knee injuries, again compared to the 11+ and control group.[23] Meanwhile, the program's effects on injury risk factors as well as long-term performance adaptations remain unexplored. With regard to conceptual models from “the sequence of prevention” (van Mechelen et al., 1992) to Team-sport Injury Prevention (TIP) cycle (O'Brien et al., 2018), a critical factor for all IPPs is the need to understand and assess their effects on injury risk factors.[24,25]

Knee kinematic and kinetic parameters are key indicators of knee injury risk, particularly for ACL injuries [26–28]. A detailed biomechanical analysis is thus essential to evaluate the clinical relevance and effectiveness of the Football+ program in mitigating knee injury risk. In addition, evidence on the 11+ impacts on knee biomechanics remains limited and inconsistent [29–31]. For instance, Arundale et al. (2021) found no significant improvements in dynamic knee valgus during landing tasks among amateur female players following a season-long application of the program.[30] Conversely, Dix et al. (2021) reported a clinically meaningful reduction in knee valgus during a 90-degree cutting maneuver after 12 weeks of implementation in a similar cohort.[29] The inconclusive nature of the 11+ literature highlights the need for further investigation into the underlying biomechanical mechanisms by which the 11+ may mitigate knee injury risk.

This study, therefore, aimed to evaluate the effects of three months training with the Football+ or the 11+ with a control group (CG) on key knee kinematic and kinetic parameters during high-risk movement patterns, single-leg landing (SLL) and cutting, as well as on performance measures. We hypothesized that the Football+ would demonstrate at least comparable positive effects on knee biomechanics relative to the 11+ and superior outcomes compared to the CG, while yielding greater improvements in performance measures than both the 11+ and CG.

## 2. Methods

### 2.1. Study design and ethics

This three-arm, cluster-allocated, non-randomized interventional study (DRKS00036644) included two intervention groups and one control group (CG). Cluster allocation at the team level was chosen to ensure feasible and standardized implementation of the warm-up interventions within routine training settings; however, the potential risk of selection bias associated with this approach is acknowledged and addressed in the Limitations section. The study design comprised baseline and post-intervention assessments of knee biomechanics and motor performance, as well as a follow-up assessment of performance outcomes after a 10-week no-intervention period. The study was conducted in accordance with the Declaration of Helsinki and received ethical approval from the Ethics Committee of TU Dortmund University (GEK-TUDO-2022-43). All participants provided written informed consent prior to enrollement.

### 2.2. Inclusion and exclusion criteria

Eligible participants were female football players aged 18 years or older with at least 3 years of football experience, injury-free at baseline, having 3 training sessions weekly in addition to a weekend match, and registered with their teams for the 2022-2023 season. Exclusion criteria included missing two or more intervention sessions, concurrent participation in other organized sports, a history of severe lower extremity injury 6 weeks before study commencement, and absence from any measurement session.

### 2.3. Participants

A priory power analysis was conducted using G*Power (version 3.1.9.4) for a repeated-measures ANOVA (within-between interaction, 3 groups $\times$ 2 time points). It estimated a sample of 42 as suitable for an expected effect size of 0.25, an $\alpha$ error probability of 0.05 and a power of 0.80.[32] Participants were recruited from three women's teams competing in German amateur football leagues. Initially, 57 players (24.3 $\pm$ 5.3 years, 1.73 $\pm$ 0.07 m, 64.3 $\pm$ 8.0 kg) enrolled in the study voluntarily, completed on-site instructional workshops and underwent baseline demographic, motor performance, and biomechanical assessments. However, 15 players, primarily from the CG, were excluded due to dropouts or other exclusion criteria, resulting in a final sample of 42 players with complete performance and biomechanical datasets. The larger dropout in the control group was primarily due to scheduling conflicts, sustaining injuries and personal reasons unrelated to the study protocol. Group-specific characteristics were as follows: the Football+ (n = 20; age: 25.5 $\pm$ 1.08 years; height: 1.68 $\pm$ 0.14 m; body mass: 62.7 $\pm$ 2.25 kg), 11+ (n = 16; age: 22.9 $\pm$ 1.17 years; height: 1.70 $\pm$ 0.08 m; body mass: 65.5 $\pm$ 2.05 kg), and CG (n = 6; age: 23.8 $\pm$ 2.9 years; height: 1.71 $\pm$ 0.03 m; body mass: 66.5 $\pm$ 2.7 kg).

### 2.4. Study preparation

During the 2022-2023 preseason, participants attended three familiarization sessions addressing laboratory protocols, interventions, and measurement procedures. Biomechanical assessments were carried out in the biomechanics laboratory at the Institute for Sport and Sport Science, TU Dortmund University. Motor performance assessments were conducted at each team's training facility on artificial turf, in comparable time of day (evenings), and similar weather conditions (cloudy, 50-60% humidity), while temperatures differed accoring to the season (20-23 °C in July, 11-14 °C in October, 2-5 °C in December).

### 2.5. Intervention

Both interventions consist of three parts, lasting 20-25 min in

practice and require minimum equipment. The 11+ was implemented according to the original protocol described by Soligard et al..[33] The Football+ poster and manual are available at https://doi.org/10.17877/DE290R-26479 and https://doi.org/10.17877/DE290R-26478. To support adherence and proper implementation, players received comprehensive educational materials, including video tutorials, program-specific manuals, and posters. Close collaboration with the coaching staff was maintained throughout the intervention period via regular communication from the lead researcher and on-site support from the research assistants who were blinded to the study's hypotheses and outcomes. Each intervention group completed their assigned warm-up twice per week over a 12-week period, starting in week four of the preseason and continuing through week 10 of the competitive season. This was followed by a 10-week no-intervention phase during which the teams discontinued their assigned programs and resumed their traditional warm-up routines. This was intended to determine whether any observed performance gains were directly attributable to the interventions and whether those effects would persist without continued exposure. The CG continued its common warm-up routine throughout the entire study. This typically included light jogging, static stretching, basic technical drills, and 2-3 min of moderate-paced running across the pitch.

### 2.6. Biomechanical data acquisition

To evaluate the programs‘ effects on biomechanical measures a standardized test battery comprising single-leg landing and cutting tasks was administrated in a pre-post design. Following a 5-min standardized warm-up on a treadmill at 7-9 km/h and familiarization trials for both the landing and cutting tasks, players‘ anthropometrics were documented. This was followed by a static standing calibration trial during which the participants stood upright on a force plate with arms extended laterally and feet shoulder-width apart. This position was used for full-body skeletal modelling.[28,34]

### 2.7. SLL test

Players first performed single-leg drop landings from a 30-cm box onto a force plate. They were instructed to step off and land on the same leg, maintaining balance for at least 3 s post-landing. Trials were repeated until three valid attempts per leg were recorded. A trial was considered valid if the entire foot contacted the force plate and the participant maintained stability without extra steps or visible loss of balance.[28,34]

### 2.8. Cutting maneuover

Participants then performed cutting maneuvers after a 5-m approach run. They were instructed to execute the cut at match-like intensity, simulating a real 1-vs-1 offensive scenario. The task involved changing direction at approximately 45° angle using a pre-assigned leg, while the cutting angle was not strictly controlled, allowing for natural execution, with the direction and sequence of cuts randomized to avoid bias. A trial was valid if the entire foot landed within the force plate boundaries and no premature deceleration or missteps occurred.[28,34] All assessments were supervised by two trained investigators (MA, MS), who monitored technique, ensured protocol compliance, and paused the session in case of fatigue, discomfort, or technical issues.

### 2.9. Motion capturing and data processing

The tasks were captured by a markerless motion capture system including 14 high-speed video cameras (200Hz, Oqus 4, Qualisys, Gothenburg, Sweden) integrated with two AMTI force plates (1000 Hz; Watertown, Massachusetts, USA).[35,36] Qualisys Track Manager (QTM) was used to synchronize kinetic and kinematic data in real time, to calibrate the capture volume, and to export trial recordings. Recorded video and force data were subsequently processed using Theia3D (Theia Markerless Inc., Canada).[35,36] Initial ground contact was defined as the first frame in which vGRF exceeded 10 N. Data were processed using Visual3D (C-Motion Inc.) The average of three valid trials per limb was used for each test condition.

### 2.10. Kinetic and kinematic measures

Knee valgus angle at initial contact (KValIC), knee valgus moment at initial contact (KValMomIC), maximum knee valgus moment (MaxKValMom), vertical ground reaction force (vGRF), knee flexion angle at initial contact (KFlexIC), and maximum knee flexion angle (MaxKFlex) were calculated as primary indicators of knee injury risk, particularly ACL injuries [26–28,37].

### 2.11. Performance assessment

A standardized test battery was administrated at baseline, immediately after the 3-month intervention, and 10 weeks post-intervention to evaluate the programs‘ effects on motor performance and the retention of the potential gains. The test battery included linear 20-m sprint,[3] countermovement jump (CMJ),[4] Illinois agility (IA) test,[3] and dribbling speed (DS) test.[38] Testing procedures adhered to procedures outlined by Asgari et al.[22] Dual-light timing gates were used for time-based measurements including sprinting, agility, and dribbling (90-110 cm height). Jump height was recorded via the OptojumpNext system (Microgate, Bolzano, Italy).[39] To avoid acute warm-up effects from the Football+ or 11+ programs, all teams performed a standardized 10-min general warm-up before testing (see Fig. 1).

### 2.12. Statistical analysis

Descriptive statistics were computed for all outcomes. After confirming normality and homogeneity of variance, a 2 × 3 repeated-measures ANOVA and follow-up post-hoc LSD tests were used to assess within- and between-group differences. Significant time × group interactions from pre-to post-test were interpreted as program effects. Effect sizes were reported as partial eta squared ($\eta^2$) and classified as small (0.01), medium (0.06), or large (0.14).[40] Statistical analyses were performed using “R“version 4.5.0, and SPSS version 29, with significance set at $\alpha < 0.05$.

## 3. Results

Minor deviations from normal distribution were noted for a few variables, including vGRF, and KFlexICL. However, given the moderate sample size (n = 42) and the robustness of repeated measures ANOVA to moderate violations of normality, all primary analyses proceeded using parametric methods.[41]

### 3.1. Compliance and exposure time

Of the 25 scheduled intervention sessions, only one was cancelled




**Fig. 1.** Performance test battery: a. linear sprint, b. countermovement jump, c. illinois agility test, d. dribbling test.

**Table 1**
Pre-post changes in knee biomechanics during the SLL.

| variable | limb | group | pre (mean ± sd) | post (mean ± sd) | time effect p | time × group p | effect size ($\eta p^2$) | Interpretation and post hoc analyses |
|---|---|---|---|---|---|---|---|---|
| KFlexIC | L | Football+ | 16.6 ± 3.7 | 21.9 ± 6.0 | <0.001 | 0.071 | 0.308 | The Football+ showed the largest within-group effect (d = 0.86), while the 11+ displayed a moderate improvement (d = 0.47). |
| | | 11+ | 15.3 ± 4.0 | 18.0 ± 4.2 | | | | |
| | | Control | 18.7 ± 3.6 | 20.0 ± 7.9 | | | | |
| KFlexIC | R | Football+ | 18.2 ± 3.4 | 21.7 ± 3.8 | <0.001 | 0.009 | 0.310 | The Football+ and 11+ showed significant improvments in knee flexion during landing. |
| | | 11+ | 17.8 ± 2.8 | 19.4 ± 3.3 | | | | |
| | | Control | 16.2 ± 4.6 | 16.4 ± 3.6 | | | | |
| KValIC | L | Football+ | −1.15 ± 1.91 | −0.31 ± 1.24 | 0.003 | 0.541 | 0.210 | The Football+ produced the greatest change toward neutral knee alignment. The 11+ showed a mild reduction in valgus angle. |
| | | 11+ | −0.80 ± 1.56 | −0.39 ± 1.59 | | | | |
| | | Control | −1.39 ± 2.17 | −0.58 ± 3.33 | | | | |
| KValIC | R | Football+ | −2.54 ± 2.41 | −1.30 ± 1.39 | 0.003 | 0.040 | 0.205 | The Football+ significantly improved knee valgus control. The 11+ showed mild effect; while the control group showed no change. |
| | | 11+ | −1.83 ± 1.45 | −1.27 ± 1.02 | | | | |
| | | Control | −1.40 ± 1.49 | −1.37 ± 1.36 | | | | |
| KValMomIC | L | Football+ | 0.156 ± 0.170 | 0.080 ± 0.059 | 0.184 | 0.170 | 0.045 | Both the Football+ and the 11+ reduced valgus moment, but changes were not statistically significant. |
| | | 11+ | 0.137 ± 0.127 | 0.069 ± 0.102 | | | | |
| | | Control | 0.085 ± 0.139 | 0.130 ± 0.118 | | | | |
| KValMomIC | R | Football+ | 0.075 ± 0.138 | 0.063 ± 0.085 | 0.590 | 0.947 | 0.008 | No meaningful change were observed in any group. Valgus moments remained stable. |
| | | 11+ | 0.100 ± 0.110 | 0.097 ± 0.129 | | | | |
| | | Control | 0.102 ± 0.108 | 0.077 ± 0.133 | | | | |
| KValMomMAX | L | Football+ | 1.030 ± 0.367 | 0.871 ± 0.285 | 0.001 | 0.223 | 0.239 | The Football+ and 11+ reduced peak valgus moments, but no interaction effect was observed. |
| | | 11+ | 1.240 ± 0.454 | 0.992 ± 0.248 | | | | |
| | | Control | 0.961 ± 0.335 | 0.914 ± 0.298 | | | | |
| KValMomMAX | R | Football+ | 1.001 ± 0.308 | 0.874 ± 0.280 | 0.511 | 0.068 | 0.011 | No meaningful change in the groups. Variables remained stable. |
| | | 11+ | 1.071 ± 0.234 | 1.028 ± 0.212 | | | | |
| | | Control | 0.930 ± 0.390 | 1.027 ± 0.268 | | | | |
| vGRF | L | Football+ | 3.75 ± 0.67 | 3.42 ± 0.63 | 0.006 | 0.030 | 0.180 | The Football+ showed a significant decrease in impact force, the 11+ showed small improvement while the CG worsened. |
| | | 11+ | 3.98 ± 0.63 | 3.71 ± 0.52 | | | | |
| | | Control | 4.01 ± 0.93 | 4.11 ± 1.24 | | | | |
| vGRF | R | Football+ | 3.78 ± 0.76 | 3.56 ± 0.67 | <0.001 | 0.034 | 0.250 | The Football+ significantly reduced vGRF, the 11+ improved slightly, and the CG showed no change. |
| | | 11+ | 4.11 ± 0.69 | 3.89 ± 0.52 | | | | |
| | | Control | 4.20 ± 1.26 | 4.23 ± 1.24 | | | | |
| KFlexMAX | L | Football+ | 58.4 ± 9.2 | 57.5 ± 8.2 | 0.739 | 0.873 | 0.003 | No meaningful change in the groups. Variables remained stable. |
| | | 11+ | 53.3 ± 9.6 | 53.6 ± 11.0 | | | | |
| | | Control | 51.9 ± 8.5 | 51.3 ± 12.4 | | | | |
| KFlexMAX | R | Football+ | 60.3 ± 8.6 | 58.0 ± 7.3 | 0.462 | 0.277 | 0.014 | No meaningful change in the groups. Variables remained stable. |
| | | 11+ | 55.8 ± 9.8 | 55.9 ± 8.1 | | | | |
| | | Control | 55.2 ± 9.8 | 55.5 ± 7.7 | | | | |

KValIC= Knee valgus angle at initial contact, KValMomIC = knee valgus moment at initial contact, MaxKValMom = maximum knee valgus moment, vGRF = vertical ground reaction force, KFlexIC = knee flexion angle at initial contact, MaxKFlex = maximum knee flexion angle.

due to complete training cancellation, resulting in a compliance rate of 96% in both interventions. Between pre and post tests, total training exposure amounted to 720 h in the Football+ group and 576 h in the 11+ group (lower training hours in the 11+ group refer to the smaller number of players in that group). Of these, 176 and 141 h specifically dedicated to the respective programs (approximately 25% of the total training time).

### 3.2. Program effects on the knee biomechanics

Analysis of the SLL and cutting outcomes revealed side and task-specific effects across the groups. Significant time × group interactions were observed in favor of the Football+ group, especially for KFlexIC, vGRF, and KValIC, while the 11+ group showed moderate improvements and the CG did not change during the study. Details are presented in Tables 1 and 2.

For the SLL, within-group effect sizes were predominantly moderate-to-large in the Football+ group (d ≈ 0.60-0.90) for primary landing mechanics, whereas effects in the 11+ were small-to-moderate and trivial in the control group. Observed effect sizes for significant interaction effects were moderate-to-large ($\eta p$ = 0.18-0.31), indicating meaningful intervention-related changes despite reduced sample size in the control group. Observed power for significant interaction effects ranged between 0.72 and 0.88.

**Table 2**
Pre-post changes in knee biomechanics during cutting.

| variable | limb | group | pre (mean ± sd) | post (mean ± sd) | time effect p | time × group p | effect size ($\eta p^2$) | Interpretation and post hoc analyses |
|---|---|---|---|---|---|---|---|---|
| KFlexIC | L | Football+ | 20.6 ± 2.9 | 24.5 ± 3.4 | 0.004 | 0.040 | 0.197 | The Football+ and 11+ showed a significant increase in knee flexion, indicating improved shock absorption on the left side. |
| | | 11+ | 17.6 ± 2.7 | 20.4 ± 4.5 | | | | |
| | | Control | 24.4 ± 6.4 | 23.7 ± 3.6 | | | | |
| KFlexIC | R | Football+ | 22.2 ± 4.7 | 25.5 ± 5.2 | <0.001 | 0.475 | 0.300 | All groups improved, but with no interaction effect. The Football+ led the improvement, indicating better landing strategies across groups. |
| | | 11+ | 19.7 ± 4.7 | 22.5 ± 3.3 | | | | |
| | | Control | 21.4 ± 4.7 | 22.7 ± 3.9 | | | | |
| KValIC | L | Football+ | −3.13 ± 3.2 | −1.82 ± 1.7 | 0.965 | 0.050 | 0.143 | Football+ showed the most favorable change, with valgus angle moving toward neutral. |
| | | 11+ | −1.76 ± 1.8 | −1.71 ± 1.7 | | | | |
| | | Control | −0.79 ± 3.4 | −2.09 ± 4.4 | | | | |
| KValIC | R | Football+ | −4.48 ± 1.9 | −3.00 ± 1.5 | 0.114 | 0.032 | 0.161 | Significant group effect: Football+ improved frontal plane control. 11+ showed improvement. |
| | | 11+ | −3.67 ± 3.6 | −2.63 ± 3.2 | | | | |
| | | Control | −2.71 ± 3.5 | −3.62 ± 3.0 | | | | |
| KValMomIC | L | Football+ | −0.18 ± 0.16 | −0.07 ± 0.10 | 0.179 | 0.013 | 0.199 | The Football+ showed a significant reduction in medial knee loading. 11+ showed no change. |
| | | 11+ | −0.15 ± 0.12 | −0.17 ± 0.16 | | | | |
| | | Control | −0.19 ± 0.23 | −0.19 ± 0.26 | | | | |
| KValMomIC | R | Football+ | −0.26 ± 0.21 | −0.13 ± 0.11 | 0.295 | 0.047 | 0.145 | The Football+ reduced knee valgus moment with large effect sizes; the 11+ showed minimal change. |
| | | 11+ | −0.22 ± 0.15 | −0.19 ± 0.11 | | | | |
| | | Control | −0.29 ± 0.12 | −0.35 ± 0.17 | | | | |
| KValMomMAX | L | Football+ | 0.55 ± 0.32 | 0.41 ± 0.18 | 0.036 | 0.125 | 0.108 | All groups improved over time, especially the Football+. No significant interaction was oberved. |
| | | 11+ | 0.55 ± 0.30 | 0.45 ± 0.27 | | | | |
| | | Control | 0.48 ± 0.08 | 0.52 ± 0.06 | | | | |
| KValMomMAX | R | Football+ | 0.58 ± 0.23 | 0.37 ± 0.26 | 0.341 | 0.096 | 0.113 | No significant changes were observed. |
| | | 11+ | 0.48 ± 0.53 | 0.53 ± 0.24 | | | | |
| | | Control | 0.62 ± 0.40 | 0.61 ± 0.27 | | | | |
| vGRF | L | Football+ | 2.14 ± 0.55 | 1.83 ± 0.38 | 0.004 | 0.182 | 0.193 | The Football+ significantly reduced impact forces during landing. The 11+ improved slightly. |
| | | 11+ | 2.34 ± 0.68 | 2.18 ± 0.52 | | | | |
| | | Control | 2.53 ± 1.14 | 2.48 ± 0.73 | | | | |
| vGRF | R | Football+ | 2.31 ± 0.60 | 2.11 ± 0.52 | 0.357 | 0.019 | 0.184 | Significant group interaction changes favoring the Football+ |
| | | 11+ | 2.47 ± 0.60 | 2.25 ± 0.64 | | | | |
| | | Control | 2.54 ± 0.93 | 2.79 ± 0.83 | | | | |
| KFlexMAX | L | Football+ | 64.3 ± 6.3 | 67.0 ± 5.5 | 0.207 | 0.005 | 0.240 | Significant group difference favoring the Football+. |
| | | 11+ | 63.6 ± 7.3 | 63.3 ± 7.2 | | | | |
| | | Control | 72.5 ± 9.5 | 66.4 ± 8.2 | | | | |
| KFlexMAX | R | Football+ | 66.3 ± 4.9 | 67.9 ± 5.0 | 0.425 | 0.026 | 0.171 | Group interaction observed: the Football+ and 11+ showed improvement. |
| | | 11+ | 66.5 ± 6.6 | 67.4 ± 7.3 | | | | |
| | | Control | 70.4 ± 5.8 | 66.0 ± 6.1 | | | | |

KValIC= Knee valgus angle at initial contact, KValMomIC = knee valgus moment at initial contact, MaxKValMom = maximum knee valgus moment, vGRF = vertical ground reaction force, KFlexIC = knee flexion angle at initial contact, MaxKFlex = maximum knee flexion angle.

For the cutting task, significant interaction effects were associated with moderate-to-large effect sizes ($\eta p^2$ = 0.145–0.240), indicating meaningful intervention-related changes in frontal and sagittal plane mechanics during cutting. Within-group effect sizes were consistently larger in the Football+ group compared with the 11+ and control groups.

### 3.3. Program effects on motor performance

A significant time × group interaction was observed in sprinting, IA, and DS, ($p < .05$), favoring the Football+ group. According to the post hoc tests, the Football+ showed the most substantial improvements in both sprint ($p = .003$) and agility ($p = .002$) times, outperforming the 11+ and control groups. For dribbling, the Football+ group demonstrated meaningful enhancement post-intervention (p= .01), while the 11+ group showed inconsistent or even deteriorating performance (Table 3). Significant improvement in CMJ was observed in both intervention groups again favoring the Football+. However, none of the performance gains were maintained after the 10-week no-intervention period: sprinting ($p = 0.23$), CMJ ($p = 0.47$), DS ($p = 0.65$), IA ($p = 0.32$) (Fig. 2).

**Table 3**
Pre-post changes in motor performance.

| measure | group | pre (mean ± SD) | post (mean ± SD) | follow-up (mean ± SD) | time effect (p) | time × group (p) | effect size ($\eta p^2$) |
|---|---|---|---|---|---|---|---|
| 20m Sprint | Football+ | 3.51 ± 0.12 | 3.34 ± 0.12 | 3.46 ± 0.13 | 0.003 | 0.003 | 0.142 |
| | 11+ | 3.47 ± 0.13 | 3.46 ± 0.12 | 3.44 ± 0.15 | | | |
| | Control | 3.54 ± 0.10 | 3.47 ± 0.12 | 3.41 ± 0.10 | | | |
| CMJ (cm) | Football+ | 26.04 ± 3.41 | 29.17 ± 3.05 | 27.26 ± 2.88 | <0.001 | 0.081 (ns) | 0.195 |
| | 11+ | 26.18 ± 2.34 | 27.49 ± 2.07 | 26.91 ± 2.42 | | | |
| | Control | 25.02 ± 4.25 | 25.88 ± 4.10 | 26.09 ± 2.89 | | | |
| Dribbling (s) | Football+ | 11.48 ± 0.59 | 11.14 ± 0.59 | 12.25 ± 0.74 | <0.001 | 0.01 | 0.215 |
| | 11+ | 11.70 ± 1.05 | 12.21 ± 0.61 | 12.42 ± 1.09 | | | |
| | Control | 12.12 ± 0.89 | 12.14 ± 0.97 | 12.49 ± 0.71 | | | |
| Agility (s) | Football+ | 18.23 ± 0.54 | 17.29 ± 0.44 | 17.49 ± 0.29 | <0.001 | 0.002 | 0.230 |
| | 11+ | 17.93 ± 0.86 | 17.58 ± 0.58 | 17.67 ± 0.45 | | | |
| | Control | 17.86 ± 0.50 | 17.75 ± 0.56 | 17.95 ± 0.60 | | | |

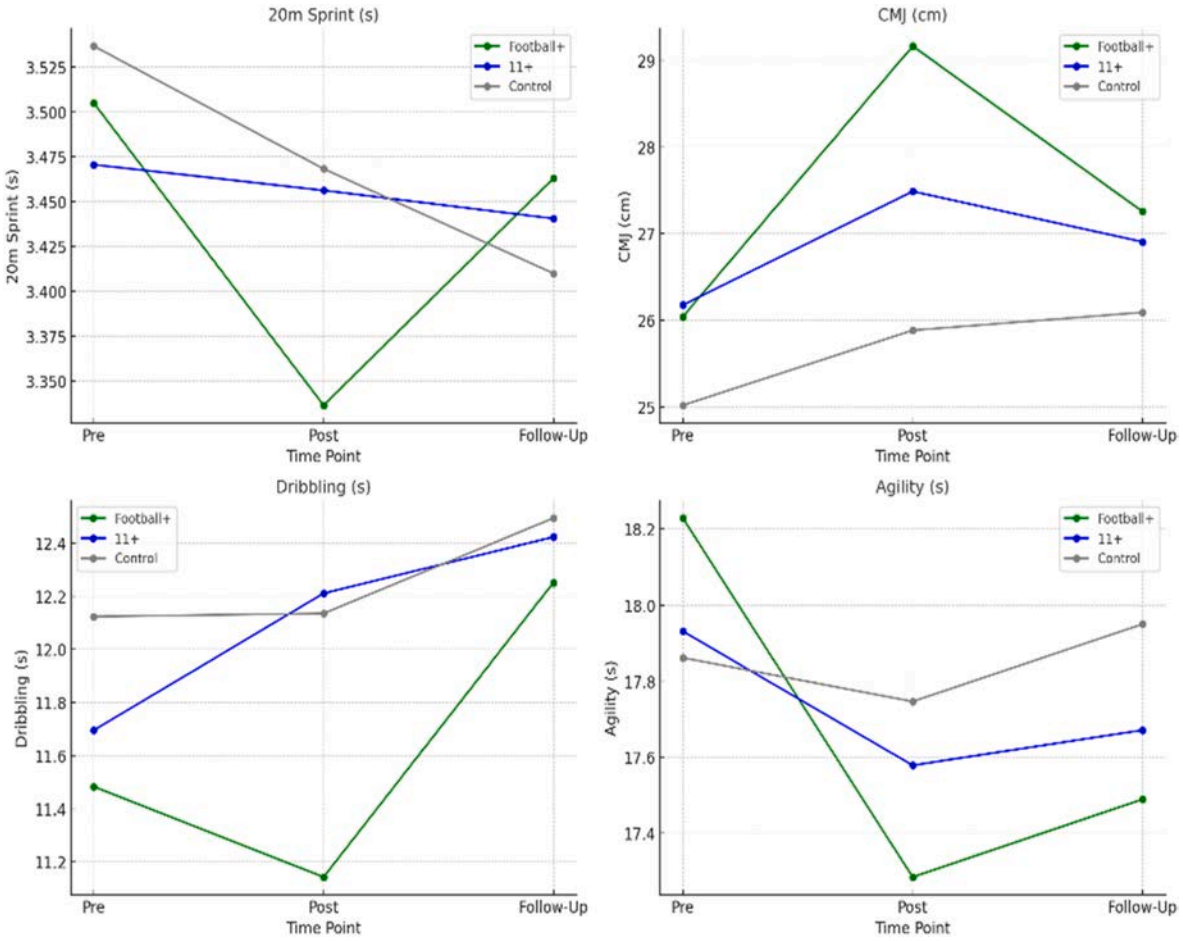



**Fig. 2.** Changes in performance measures at baseline, post-intervention and follow-up testing.

## 4. Discussion

This study evaluated the effects of the Football+ on key indicators of knee injury risk and performance enhancement in amateur female players compared to the established 11+ and a CG. A supervised adherence rate of 96% in this study played a pivotal role in the successful outcomes of both IPPs, particularly the Football+.[42] Further, an analysis of training exposure revealed that approximately 25% of total training time was devoted to warm-up activities. This significant investment reinforces the practical need for warm-up routines that simultaneously support both IP and performance enhancement, especially in amateur settings where training time is limited. This may also help explain why compliance with IPPs remains low, despite their well-established preventive benefits. In amateur football, where teams typically train twice weekly, coaches often prioritise tactical, technical, and physical preparation leaving little room for stand-alone IPPs, which is why "lack of time" has frequently been cited as a barrier to implementation.[6,7]

Overall, our findings suggest that the Football+ program not only improves biomechanical risk factors associated with knee injury risk but also improves important aspects of motor performance, such as sprinting, agility, dribbling, and jumping with large effect sizes. These dual benefits underscore the Football+ as a time-efficient, practical and engaging alternative to traditional IPPs which may potentially gain higher acceptance and fidelity in real practice. Research demonstrates that application of dynamic warm-ups before athletic activity offers physiological, psychological, neurological, and cardiovascular benefits, all of which contribute to enhanced performance and reduced injury risk.[1]

Improvements during SLL were predominantly seen in the dominant leg, whereas cutting performance improvements were largely bilateral, and this may reflect habitual loading patterns and task specificity in football. Players naturally rely more on their dominant limb for kicking, cutting, and stabilizing, which could lead to differential neuromuscular adaptations over time. These side-specific adaptations highlight the importance of including both dominant and non-dominant limb assessments when evaluating intervention efficacy. Clinically, although asymmetries were present, the magnitude of differences were relatively small and likely not detrimental; however, addressing these asymmetries may further optimize performance and reduce injury risk.

It should be noted that our kinematic and kinetic analyses relied on markerless motion capture technology. While this method allows for efficient and non-invasive data collection in field settings, it might be less precise than marker-based systems, particularly in estimating very small joint angles and moments. Consequently, some knee kinetics and kinematics outcomes, especially subtle differences between limbs should be interpreted with caution. Future research combining markerless and gold-standard marker-based systems could further validate these findings.

Increased knee flexion has been consistently associated with a reduction in anterior tibial shear forces and ACL loading, thereby lowering the risk of ACL injury.[43,44] This suggests that the Football+ effectively promotes safer landing strategies. This aligns with our previous study, which demonstrated the efficacy of the Football+ in improving landing quality, as measured by the Landing Error Scoring System (LESS), among female players both with and without a history of severe ankle and knee injuries.[23]

In addition, the Football+ group displayed reduced knee valgus

angles and moments, a finding of particular importance given that excessive dynamic valgus has been identified as a strong predictor of ACL injury risk, especially among female players [44–46]. The incorporation of cutting and directional-change drills in the Football+ program likely contributed to these improvements by reinforcing proper alignment of the lower extremity complex under dynamic loading conditions. Our findings, on the other hand, echo's Arundale et al. (2021) reporting no significant improvements in dynamic knee valgus during landing tasks among amateur female players following a season-long application of the 11+.

Another key finding was the reduction of vGRF. Elevated vGRFs are known to increase mechanical stress on the knee and hip joints and are often associated with both acute ligament injuries and overuse conditions.[47] The Football+ likely addressed this through the integration of plyometric training combined with technique-oriented landing tasks, which train players to absorb forces more efficiently through increased knee and hip flexion.

The first and third components of the Football+ include a combination of dynamic stretches, functional strength, and plyometric exercises which are associated with favorable adaptations in landing and cutting mechanics. Strengthening exercises, particularly those targeting the gluteal, hamstring, and core muscle groups have been shown to improve lower limb alignment and reduce dynamic valgus and knee joint loading [48–51]. Similarly, plyometric training has been consistently linked to increased knee flexion at initial contact and decreased ground reaction forces, primarily by improving joint stiffness regulation, proprioception, and neuromuscular control.[49,52,53] These mechanisms align with the observed improvements in knee biomechanics across both SLL and cutting tasks, supporting the program's capacity to target injury-relevant movement patterns effectively.

Although some of these exercises are also included in the 11+ program, the overall dosage of dynamic and plyometric drills in the Football+ is nearly double, likely contributing to its greater impact. In contrast, the 11+ contains a higher proportion of static exercises, particularly in part two[54] that are more effective in optimizing neuromuscular system and improving proprioception, both of which are essential for reducing the risk of severe ankle and knee injuries.[55] Such exercises also promote musculoskeletal adaptations, including increased joint range of motion and improved force production.[1,56]

Although previous studies have reported inconsistent effects of the 11+ on jumping performance, especially among male players, our findings showed notable improvements in jump ability among female participants, which aligns with some earlier studies.[2] This discrepancy may be explained by sex-specific differences in physical performance, where the moderate intensity of the 11+ may sufficiently challenge female players, but not their male counterparts. In contrast, the Football+ incorporates nearly twice the volume and intensity of plyometric and anaerobic exercises compared to the 11+ likely explaining its superior effects on sprinting, agility, and jumping performance in our cohort.[57,58]

Dribbling performance, a technical skill closely tied to sport specificity, improved significantly only in the Football+ group, demonstrating that the football-specific components of Football+ resulted in enhanced dribbling speed and coordination, while these effects were not seen in the 11+ group, being a more generic program. These findings are consistent with those of Daneshjoo et al. (2013) And Zarei et al. (2018).[3,59] The football-specific drills and small-sided games embedded in the Football+ appear to be critical in enhancing sport-relevant motor skills, supporting existing evidence on the effectiveness of game-based training methods for technical development.[60]

The CG followed a traditional warm-up routine that included light jogging across the pitch, prolonged static stretching, and short intervals of moderate-paced running. While it is often assumed that knowledge transfer into practice is more effective in European amateur women's football, our observations suggest otherwise. Unfortunately, outdated warm-up routines remain prevalent, highlighting the need for improved education and dissemination of evidence-based practices at the grassroots level.

Notably, the performance gains observed in our study were not maintained after the 10-week no intervention period. This underscores the importance of ongoing implementation, aligning with the training principle of reversibility, which states that physiological adaptations diminish without continued stimulus intervention.[61,62] Therefore, regular incorporation of the Football+ into weekly training sessions is strongly recommended, though additional research is needed to explore the Football+ impacts on other biomechanical measures, as well as effects on injury incidence. In particular, further comprative studies on the Football+ impacts on groin muscles as well as ankle biomechanics are needed since they account for nearly 12% and 22% of total football injuries at the amateur level.[63] While the 11+ has shown the lowest effects on these injuries, the Football+ integrates the Coppenhagen exercise and higher dosage of plyometrics to address this gap.

### 4.1. Conclusion and practical implications

A 3-month supervised application of both the Football+ and 11+ programs led to improvements in knee kinematics and kinetics, with the Football+ demonstrating superior efficacy in modifying biomechanical risk indicators in amateur female players. Beyond its injury prevention potential, the Football+ also significantly enhanced dribbling speed, agility, vertical jump, and sprinting performance, whereas the 11+ yielded meaningful improvements only in vertical jump. Given the limited training time available in amateur football, the Football+ appears to offer a time-efficient, engaging, and dual-purpose program that can be seamlessly integrated into routine practice.

### 4.2. Limitations

Several limitations should be acknowledged. First, the unequal group sizes, particularly in the CG, may limit the generalizability of the findings. Second, the study focused exclusively on amateur female players, and results may not be directly transferable to male or elite populations. Third, while biomechanical and performance outcomes were evaluated, injury incidence was not tracked, and long-term effects remain unknown. Finally, kinematic and kinetic analyses relied on markerless motion capture technology. While this method allows for efficient and non-invasive data collection in field settings, it might be less precise than marker-based systems, particularly in estimating very small joint angles and moments. Consequently, some knee kinetics and kinematics outcomes, especially subtle differences between limbs should be interpreted with caution. Future studies should aim to include larger cohorts, assess longitudinal outcomes, evaluate effects on injury rates, and combine markerless and gold-standard marker-based to further validate the Football+ program.

## Ethics approval and consent to participate

This study received ethics approval from Ethics committee of TU Dortmund University.

## Consent for publication

The authors have the same contribution, read, and approved the final manuscript.

## Availability of data and material

The datasets used during the current study are available from the corresponding author on reasonable request.

## Trial registration number

DRKS00036644.

## Authors' contributions

MA derived the study concept, developed the Football+ program, and drafted the manuscript. MH reviewed and revised the manuscript and refined the methodology. BT, MS[1], performed the interventions, data collection, and preparation. MS[2] managed the intervention phase and performed the introductory workshops, KN, performed the statistical analysis, TJ supervised the project, reviewed, and refined the manuscript.

* The manuscript is **not** already available on a preprint server.

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## Declaration of competing interest

None.

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## References

1. Sople D, Wilcox RB. Dynamic warm-ups play pivotal role in athletic performance and injury prevention. *Arthroscopy, Sports Medicine, and Rehabilitation*. 2025;7(2), 101023.
2. Asgari M, Nazari B, Bizzini M, Jaitner T. Effects of the FIFA 11+ program on performance, biomechanical measures, and physiological responses: A systematic review. *J Sport Health Sci*. 2023;12(2):226–235.
3. Zarei M, et al. Long-term effects of the 11+ warm-up injury prevention programme on physical performance in adolescent male football players: a cluster-randomised controlled trial. *J Sports Sci*. 2018;36(21):2447–2454.
4. Impellizzeri FM, et al. Physiological and performance responses to the FIFA 11+ (part 2): a randomised controlled trial on the training effects. *J Sports Sci*. 2013;31 (13):1491–1502.
5. Winstanley C, Reid D, Fulcher ML. Suggested improvements to the 11+ as identified by coaches, players, strength and conditioning staff and medical staff in New Zealand football. *BMJ Open Sport & Exercise Medicine*. 2023;9(2), e001463.
6. Donaldson A, et al. A concept mapping approach to identifying the barriers to implementing an evidence-based sports injury prevention programme. *Inj Prev*. 2019;25(4):244–251.
7. O'Brien J, Finch CF. Injury prevention exercise programmes in professional youth soccer: understanding the perceptions of programme deliverers. *BMJ open sport & exercise medicine*. 2016;2(1), e000075.
8. Wilke J, et al. Is the message getting through? Awareness and use of the 11+ injury prevention programme in amateur level football clubs. *PLoS One*. 2018;13(4), e0195998.
9. Al Attar WSA, et al. Implementation of an evidence-based injury prevention program in professional and semi-professional soccer. *Int J Sports Sci Coach*. 2017;13(1): 113–121.
10. Sadigursky D, et al. The FIFA 11+ injury prevention program for soccer players: a systematic review. *BMC Sports Sci Med Rehabil*. 2017;9(1):18.
11. Owoeye OBA, VanderWey MJ, Pike I. Reducing injuries in soccer (football): an umbrella review of best evidence across the epidemiological framework for prevention. *Sports Med Open*. 2020;6(1):46.
12. Al Attar WSA, et al. How effective are F-MARC injury prevention programs for soccer players? A systematic review and meta-analysis. *Sports Med*. 2016;46(2): 205–217.
13. Bizzini M, Dvorak J. Fifa 11+: an effective programme to prevent football injuries in various player groups worldwide—a narrative review. *Br J Sports Med*. 2015;49(9): 577–579.
14. Thorborg K, et al. Effect of specific exercise-based football injury prevention programmes on the overall injury rate in football: a systematic review and meta-analysis of the FIFA 11 and 11+ programmes. *Br J Sports Med*. 2017;51(7):562–571.
15. Al Attar WSA, et al. Effectiveness of the FIFA 11+ injury prevention programs in reducing acute lower back injury among soccer players: A systematic review and meta-analysis. *Int J Sports Sci Coach*. 2025;20(6):2729–2741.
16. O'Brien J, Young W, Finch C. The use and modification of injury prevention exercises by professional youth soccer teams. *Scand J Med Sci Sports*. 2017;27(11): 1337–1346.
17. Asgari M, et al. Effects of the FIFA 11+ and a modified warm-up programme on injury prevention and performance improvement among youth male football players. *PLoS One*. 2022;17(10), e0275545.
18. O'Brien J, Young W, Finch CF. The delivery of injury prevention exercise programmes in professional youth soccer: comparison to the FIFA 11+. *J Sci Med Sport*. 2017;20(1):26–31.
19. Bathe C, et al. Training interventions to reduce the risk of injury to the lower extremity joints during landing movements in adult athletes: a systematic review and meta-analysis. *BMJ Open Sport & Exercise Medicine*. 2023;9(2), e001508.
20. Dalen-Lorentsen T, O'Brien J, Harøy J. Real-world implementation of the copenhagen adduction exercise: what do football teams modify and why? *BMJ Open Sport & Exercise Medicine*. 2024;10(3), e001982.
21. Grooms DR, et al. Neurocognitive & ecological motor learning considerations for the 11+ ACL injury prevention program: a commentary. *Int J Sports Phys Ther*. 2024;19 (11):1362.
22. Asgari M, et al. Acute effects of the FIFA11+ and football+ warm-ups on motor performance. A crossover randomized controlled trial. *PLoS One*. 2023;18(4), e0284702.
23. Asgari M, et al. Four months training with the Football+ and 11+ improves the landing quality of female players. *Int J Sports Med*. 2026.
24. O'Brien J, et al. A new model for injury prevention in team sports: the Team-sport injury prevention (TIP) cycle. *Science and Medicine in Football*. 2019;3(1):77–80.
25. Finch C. A new framework for research leading to sports injury prevention. *J Sci Med Sport*. 2006;9(1-2):3–9.
26. Ramachandran AK, et al. Influence of Neuromuscular Training Interventions on Jump-Landing Biomechanics and Implications for ACL Injuries in Youth Females: A Systematic Review and Meta-analysis. *Sports Med*. 2025;55(5):1265–1292.
27. Leppänen M, et al. Stiff landings are associated with increased ACL injury risk in young female basketball and floorball players. *Am J Sports Med*. 2017;45(2): 386–393.
28. Mausehund L, Krosshaug T. Knee biomechanics during cutting maneuvers and secondary ACL injury risk: a prospective cohort study of knee biomechanics in 756 female elite handball and soccer players. *Am J Sports Med*. 2024;52(5):1209–1219.
29. Dix C, et al. Biomechanical changes during a 90° cut in collegiate female soccer players with participation in the 11. *Int J Sports Phys Ther*. 2021;16(3):671–680.
30. Arundale AJH, et al. Changes in biomechanical knee injury risk factors across two collegiate soccer seasons using the 11+ prevention program. *Scand J Med Sci Sports*. 2018;28(12):2592–2603.
31. Bahari Fard R, et al. Assessing changes in static and dynamic postural stability in youth football players following the FIFA 11+ injury prevention program. *Sci Sports*. 2022;37(3):215.e1–215.e8.
32. Faul F, et al. Statistical power analyses using G* power 3.1: tests for correlation and regression analyses. *Behav Res Methods*. 2009;41(4):1149–1160.
33. Soligard T, et al. Comprehensive warm-up programme to prevent injuries in young female footballers: cluster randomised controlled trial. *Br Med J*. 2008;337.
34. Mok KM, Bahr R, Krosshaug T. Reliability of lower limb biomechanics in two sport-specific sidestep cutting tasks. *Sports Biomech*. 2018;17(2):157–167.
35. Ripic Z, et al. A comparison of three-dimensional kinematics between markerless and marker-based motion capture in overground gait. *J Biomech*. 2023;159, 111793.
36. Riazati S, et al. Absolute reliability of gait parameters acquired with markerless motion capture in living domains. *Front Hum Neurosci*. 2022;16, 2022.
37. Ali N, Rouhi G, Robertson G. Gender, vertical height and horizontal distance effects on single-leg landing kinematics: implications for risk of non-contact ACL injury. *J Hum Kinet*. 2013;37:27–38.
38. Höner O, Roth K. Erläuterungen zu den individuellen Spielerauswer-tungen im Rahmen der technisch-motorischen Leistungsdiagnostik an den DFB-Stützpunkten. *Zugriff am*. 2015;7:2020.
39. Castagna C, et al. Concurrent validity of vertical jump performance assessment systems. *J Strength Condit Res*. 2013;27(3):761–768.
40. Rhea MR. Determining the magnitude of treatment effects in strength training research through the use of the effect size. *J Strength Condit Res*. 2004;18(4): 918–920.
41. Blanca MJ, et al. Non-normal data in repeated measures ANOVA: impact on type I error and power. *Psicothema*. 2023;35(1):21–29.
42. Eirale C, et al. Low injury rate strongly correlates with team success in Qatari professional football. *Br J Sports Med*. 2013;47(12):807–808.
43. Krosshaug T, et al. The vertical drop jump is a poor screening test for ACL injuries in female elite soccer and handball players: a prospective cohort study of 710 athletes. *Am J Sports Med*. 2016;44(4):874–883.
44. Hewett TE, et al. Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study. *Am J Sports Med*. 2005;33(4):492–501.
45. Myer GD, et al. The influence of age on the effectiveness of neuromuscular training to reduce anterior cruciate ligament injury in female athletes:a meta-analysis. *Am J Sports Med*. 2013;41(1):203–215.
46. Benjaminse A, et al. Revised approach to the role of fatigue in anterior cruciate ligament injury prevention: a systematic review with meta-analyses. *Sports Med*. 2019;49(4):565–586.
47. Yu B, Garrett WE. Mechanisms of non-contact ACL injuries. *Br J Sports Med*. 2007;41 (suppl 1):i47–i51.
48. Myer GD, et al. Differential neuromuscular training effects onACL injury risk factors in"high-risk" versus "low-risk" athletes. *BMC Muscoskelet Disord*. 2007;8(1):39.
49. Markovic G, Mikulic P. Neuro-musculoskeletal and performance adaptations to lower-extremity plyometric training. *Sports Med*. 2010;40(10):859–895.
50. Chaudhari AMW, et al. Reducing core stability influences lower extremity biomechanics in novice runners. *Med Sci Sports Exerc*. 2020;52(6):1347–1353.
51. Dello Iacono A, Johnny P, Ayalon M. Core stability training on lower limb balance strength. *J Sports Sci*. 2016;34(7):671–678.

52. Chappell JD, Limpisvasti O. Effect of a neuromuscular training program on the kinetics and kinematics of jumping tasks. *Am J Sports Med*. 2008;36(6):1081–1086.
53. Herman DC, et al. Effect of strength training on jump-landing biomechanics in adolescent females. *Sport Health*. 2022;14(1):69–76.
54. Delahunt E. Neuromuscular contributions to functional instability of the ankle joint. *J Bodyw Mov Ther*. 2007;11(3):203–213.
55. Hübscher M, et al. Neuromuscular training for sports injury prevention: a systematic review. *Med Sci Sports Exerc*. 2010;42(3):413–421.
56. Behm DG, et al. Acute effects of muscle stretching on physical performance, range of motion, and injury incidence in healthy active individuals: a systematic review. *Appl Physiol Nutr Metabol*. 2016;41(1):1–11.
57. Abade E, et al. Effects of different re-warm up activities in football players' performance. *PLoS One*. 2017;12(6), e0180152.
58. Thomas K, French D, Hayes PR. The effect of two plyometric training techniques on muscular power and agility in youth soccer players. *J Strength Condit Res*. 2009;23 (1):332–335.
59. Daneshjoo A, et al. Effects of the 11+ and harmoknee warm-up programs on physical performance measures in professional soccer players. *J Sports Sci Med*. 2013;12(3):489.
60. Zois J, Bishop D, Aughey R. High-intensity warm-ups: effects during subsequent intermittent exercise. *Int J Sports Physiol Perform*. 2015;10(4):498–503.
61. Lopes M, et al. Balance and proprioception responses to FIFA 11+ in amateur futsal players: short and long-term effects. *J Sports Sci*. 2019;37(20):2300–2308.
62. Neil-Sztramko SE, et al. Updated systematic review of exercise studies in breast cancer survivors: attention to the principles of exercise training. *Br J Sports Med*. 2019;53(8):504–512.
63. Whalan M, et al. The incidence and burden of time loss injury in Australian men's sub-elite football (soccer): a single season prospective cohort study. *J Sci Med Sport*. 2019;22(1):42–47.

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# Four Months Training with the Football+ and 11+ Improves the Landing Quality of Female Players

Mojtaba Asgari[1], Martin Hägglund[2], Benedikt Terschluse[1], Maximilian Sueck[1], Kevin Nolte[1], Marcus Schmidt[1], Thomas Jaitner[1]

Affiliation addresses are listed at the end of the article.

## Abstract

The effectiveness of the Football+- and 11+-programs in improving landing quality among players with a history of severe ankle or knee injury remains unexplored. This study examined (i) the efficacy of these programs in developing landing assessed via the Landing Error Scoring System (LESS) and (ii) the association between injury history and landing quality. Fifty-six amateur female players (24.12 ± 5.37 y) reported their injury history and completed the LESS test before and after a 4-month intervention. Repeated-measures analysis of variance and independent *t*-tests analyzed the outcomes at $p \leq 0.05$. Players with a history of severe ankle (6.33 ± 1.53; $p = 0.019$ and $d = -0.76$) or knee (5.92 ± 0.74; $p = 0.041$, $d = -0.77$) injury exhibited higher LESS scores com-pared to the non-injured counterparts (5.25 ± 1.37). Analysis of variance revealed a significant time ($p = 0.001$ and $\eta^2 = 0.31$) and time-group effects ($p = 0.002$ and $\eta^2 = 0.24$) following the 11+ (5.59 ± 1.35 vs. 5.04 ± 1.47) and the Football+ (5.76 ± 1.55 vs. 4.65 ± 1.37). A history of severe knee or ankle injury reduces the landing quality. Both the Football+ and 11+ improved land-ing, with the Football+ demonstrating greater efficacy. Previously injured players benefited most, although their landing perfor-mance remained inferior to non-injured peers. While the injury history is traditionally regarded as a non-modifiable risk factor, targeted neuromuscular programs may partially mitigate its impact on movement quality.

**Keywords** Injury history, women's football, landing technique, injury prevention, LESS

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**Correspondence** Mojtaba Asgari, Institute for Sport and Sport Science, TU Dortmund, Otto-Hahn-Str. 3, 44227 Dortmund, Germany, Email: mojtaba.asgari@tu-dortmund.de

## Introduction

Up to 30 million females play football officially across 176 coun-tries, reflecting an extraordinary development in the female foot-ball population worldwide.[1, 2] Alongside this growth, a concerning trend emerges from injury surveillance studies conducted in wom-en's European, American and African national football leagues. By reporting injury incidences from 12.5 to 55.5 and 1.4 to 10.9 per 1,000 hours of match and training, respectively, with the knee, ankle, and hip being the most frequently affected,[3–8] they under-score a noteworthy issue: female players may experience as high as or potentially higher injury incidences and severity compared to their male counterparts. However, the proportion of research addressing females in all disciplines significantly lags behind that addressing males.[9]

Preparticipation screening to identify athletes who are prone to injury based on their demographics has become an area of in-terest especially in team sports and large settings.[10] Due to its us-er-friendly nature, a good to excellent inter-rater (intraclass corre-lation coefficient [ICC]: 0.83–0.92) and intrarater (ICC: 0.82–0.99) reliability, validity,[11] and acceptable sensitivity (77–86 %) and spec-ificity (64–65 %),[12] the Landing Error Scoring System (LESS) has been considered a widespread screening tool that identifies the biomechanical characteristics of the trunk and lower extremities during a jump-landing maneuvere.[13] It involves a double-leg jump-landing task that is typically captured by two video cameras in the frontal and sagittal planes. Examiners then inspect the vid-eos frame by frame and visually assess aberrant lower extremity and trunk kinematics from initial ground contact to peak knee flex-ion and note the number of movement errors observed. A higher score represents a poorer landing pattern, which is characterized by observable movement deficits such as excessive knee valgus, limited knee and hip flexion, asymmetric foot placement, trunk instability, or improper foot contact upon landing. These move-ment errors indicate suboptimal neuromuscular control and are associated with an increased risk of lower extremity injuries. Padua et al. (2015) showed that the relative risk of sustaining anterior cruciate ligament (ACL) injury is 10.5 times higher when the LESS score is ≥ 5.[12]



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Scrutinizing the literature reveals that age, sex, intervention programs, and history of injury are factors influencing the LESS score.[14] The latter, in particular, has been the objective of seven studies, six of which address the association between a history of knee injuries and the LESS scores.[14] The outcomes underscore that those with a history of ACL injury or anterior cruciate ligament reconstruction (ACLR) have noticeably worse LESS scores ($p = 0.004$), while having a clinically meaningful mean difference of 1.2 scores,[14] although the quality of the studies was assessed to be low.

However, research on the association between a history of ankle injuries (AIs) and the LESS score is scarce, despite that they are highly prevalent in football.[5–7,15] Only one study has explored this link and observed that those with chronic ankle instability had significantly higher LESS scores compared to healthy controls, while having a meaningful difference of 1.3 errors.[16] Research emphasizes that the history of AI can lead to recurrent injuries, with up to one-third experiencing further AIs within 3 years,[17,18] and around 73 % developing chronic ankle instability.[17] Moreover, since the lower extremity operates as a kinetic chain, previous AIs may not only heighten the risk of recurrent AIs but also influence knee and hip functions, increasing susceptibility to various lower extremity injuries.[19] Thus, assessing landing quality, a common risky move-ment pattern in football, post-severe AI and KI is essential for evaluating lower extremity functions, establishing effective prevention strategies, and identifying athletes at a higher risk of recurrent injury.

While neuromuscular training programs have shown to signif-icantly reduce the LESS scores,[14] research on the effects of the 11+, the most studied injury prevention program (IPP), on the LESS scores is limited and yields conflicting results.[20,21] Only two stud-ies, involving different age groups and sexes, have examined the impact of the 11+ on the LESS scores. Parsons et al. (2019) found no significant effects of the 11+ on the LESS scores in a study of 47 female child players,[21] while Akbari et al. (2020) observed reduced LESS scores and improved landing patterns in 24 young male foot-ball players following the midterm implementation of the 11+.[20] Since sex and age influence the LESS score, these findings may not be applicable to adult female players and the impact of the 11+-pro-gram on reducing the LESS scores among this population remains unclear.

Recently, a football-specific IPP, named the Football+-program, has been launched as a warm-up regimen designed to tackle barriers hindering the implementation of IPPs. The Football+-program integrates football-specific exercises with injury prevention (IP) routines into a structured warm-up protocol. Drawing on existing literature studies and recommendations to enhance the 11+,[22–27] this program aims to ensure acceptance and compliance within football administrations. While it has shown superior effectiveness in optimizing acute performance including agility, sprinting, ver-tical jump, and dribbling compared to the 11+, its impact on biomechanical measures remains unexplored.[28]

Therefore, this study aims to (i) evaluate the effects of 4-month training with the 11+ and Football+ programs on improving land-ing quality in amateur female players, (ii) compare the effects of these programs on landing between players with and without a history of severe knee injury (KI) or AI, and (iii) analyze the overall influence of a history of severe injury on landing biomechanics. We assume that female players with a history of severe AI and KI will perform differently on the LESS compared with non-injured play-ers and that both programs develop landing quality and reduce the LESS scores.

## Methods

### Study design and ethics

This study included documentation of previous severe AI and KI, followed by a baseline LESS screening session. This was succeeded by a 4-month intervention involving two experimental groups and a control group followed by a post-test LESS screening session. This study adhered to the principles outlined in the Helsinki Declara-tion and received approval from the ethics committee of TU Dort-mund University. Participation was voluntary, and all players pro-vided written consent prior to study commencement.

### Participants and data collection

A priory power analysis was conducted using G*Power (version 3.1.9.4) for repeated-measures analysis of variance (ANOVA) with a within-between interaction (3 groups × 2 time points). It estimat-ed a sample of 52 as suitable for an expected effect size of 0.7, an $\alpha$ error probability of 0.05 and a power of 0.80.[29] Hence, 56 female players (24.12 ± 5.37 y, 1.69 ± 0.06 h, and 64.1 ± 7.74 kg) from three teams competing in German amateur leagues were invited and agreed to participate in the study and underwent a baseline LESS test. Two players failed to complete the subsequent interven-tion phase and dropped out, one due to injury and the other due to a team change. Consequently, out of the initial 56 players, 54 (24.30 ± 5.35 y, 1.69 ± 0.07 h, and 64.3 ± 8.0 kg) successfully com-pleted both the intervention and the follow-up post-test.


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## Inclusion criteria

All registered players from the three participating teams, includ-ing goalkeepers, were eligible and included in the study. Each team had a typical weekly routine consisting of two 90-minute training sessions and one match (either official or friendly). Although play-ers had varied backgrounds in terms of position and football expe-rience, these factors were not individually recorded for analysis. Participants were also required to be (i) at least 18 years old at baseline and (ii) fully injury free and cleared for unrestricted par-ticipation in training and matches for at least 1 month prior to the measurement session. They were excluded if they (i) had a history of any musculoskeletal (lower extremity) surgery, head concus-sion, or severe cardiovascular problems 3 months before the study; (ii) participated in other sports simultaneously; and (iii) missed more than 10 % of the training sessions or one of the testing ses-sions.

## Procedures

At baseline, the participants provided their injury history for the past 2 years through an online brief questionnaire (LimeSurvey, TU Dortmund) derived from the German translation of the OSTRC[30] and the foot and ankle questionnaires.[31] Previous injuries were considered severe AI and KI which resulted in a player being una-ble to participate in training and competitions for more than 28 days (time-loss aspect of injury definition) regardless of the injury type.[32]

Subsequently, the players performed the LESS test and were then assigned to the 11+, the Football+, or control group based on their respective teams and underwent a 4-month intervention.

Each team performed its specific warm-up twice a week before the main body of training under the supervision of a research assistant with 2 years of experience in the implementation of the 11+. The LESS test was repeated at the end of the intervention, and the pre-to-post differences were analyzed to indicate the training effects.

## Interventions

Both interventions consist of three parts lasting 22–25 minutes in practice, but differ in content. The 11+ begins with an 8-minute running at low speed combined with active stretching and con-trolled contact with a partner. The second part involves six differ-ent sets of exercises, including strength, balance, and jumping, lasting 10 minutes, followed by 2 minutes of speed running com-bined with football-specific movements and changes in direction in the last part. The 11+ exercises were described in detail by Soli-gard et al.[33].

The Football+ kicks off with a 2-minute self-estimated running across the pitch at approximately 40–50 % of maximal pace, serv-ing as a gradual introduction to physical activity, followed by crossover running, dynamic stretch of the hip, controlled lunges, tuck-jumps, three dynamic core stability exercises, Copenhagen exercise, hamstring walkout, and a modified Nordic Hamstring Exercises. The second part involves 5-minute, small-sided games, namely, active passing, unanticipated dribbling tasks, and one vs one, followed by plyometric and sprinting exercises in the third part lasting 5 minutes. The Football+-program poster and manual are available at: http://dx.doi.org/10.17877/DE290R-26478, and: http://dx.doi.org/10.17877/DE290R-26479 ). The Football+ exer-cises are categorized into three difficult levels and adapt every 4–6 weeks depending on the players' abilities and progress.

## Landing Error Scoring System

The LESS test was performed identical to the method proposed by Padua et al.[13] A 30-cm height box was adjusted at a distance of 50 % of each participant's height to the landing line. Two digital video camera recorders (Sony HD 24.5 mega pixel, HDR- PJ810E) were set up in the frontal and sagittal views to the landing direc-tion and recorded the landing at a frame rate of 50 frames/s. The players were instructed to stand on the box and jump off the box with both feet over the landing line and rebound for a maximal ver-tical jump immediately after landing. If anyone failed to jump with both feet simultaneously, jumped off the box visibly in the vertical direction, did not pass the landing line, or ultimately could not complete the task smoothly, the trial was repeated. Each player performed two practice jumps followed by three successful trials; the average of the successful trials was considered the LESS score. In cases where a trial did not meet these criteria, it was repeated until three successful trials were completed. To eliminate the pos-sibility of inter-rater reliability bias, a single expert examiner with a between-day reliability of 0.95 scored the recorded videos on a computer.

To score the LESS, the rater manually digitized body landmarks of the foot (foot tip, heel, and joint center of the ankle), knee (joint center), hip (trochanter major) and shoulder (acromion) in frontal and sagittal plans using the open-source 2D software Kinovea (ver-sion 0.9.5; http://www.kinovea.org). 2D flexion angles of the ankle, knee, hip and trunk as well as knee valgus and lateral trunk flexion angles were calculated at an initial ground contact (LESS items 1–6) and a maximum knee flexion (items 12–15). The foot position was assessed at three time points: initial contact (item 11), when the entire foot was on the ground (items 7 and 8) and between the in-itial contact and the peak knee flexion (items 9 and 10). The total sagittal-plane displacement and the overall landing strategy (items 16 and 17) were evaluated qualitatively.[12,13]


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Although the minimum and maximum LESS scores are theoret-ically 0 and 19, respectively, Hanzlíková et al. (2021) suggested that it is unlikely that an individual does a wide and narrow stance or external and internal rotations of the foots simultaneously; the actual maximum score is therefore 17.[14] However, from the au-thors' point of view, an individual might exhibit an external rota-tion in one foot and an internal rotation in another one simultane-ously; the actual maximum score would then be 18. A higher score represents a poorer landing pattern and a higher risk of sustaining lower extremity injuries. Padua et al. (2015) showed that the rela-tive risk of sustaining ACL injury is 10.5 times higher when the LESS score is ≥ 5.[12]

### Statistical analysis

A repeated-measures ANOVA was used to assess the effects of time (pre vs. post), groups (the Football+, the 11+, and control), and in-jury history (ankle or knee injured vs. non-injured) on LESS scores. Independent sample *t*-tests were used to compare LESS scores be-tween injured and non-injured players at baseline and to explore specific post-intervention between-group differences. Addition-ally, the paired-sample *t*-test was conducted to specifically assess within-group pre-to-post differences in LESS scores for the Foot-ball+ and 11+ groups. While the ANOVA tests for main effects and interactions across all groups and time points, it does not directly indicate whether each individual group improved significantly from pre- to post-test. Effect sizes were reported as partial eta squared ($\eta^2$) for ANOVA (small = 0.01, medium = 0.06, and large = 0.14) and Cohen's *d* for *t*-tests (small = 0.2, medium = 0.5, and large = 0.8). The statistical analyses were conducted using SPSS29 at a signifi-cance level of $p \leq 0.05$.[34]

## Results

For the ankle and knee, 15 and 10 severe previous injuries were reported, respectively, and the players fell into the AI or KI and the healthy group. Independent sample *t*-tests revealed that, at base-line, players with a history of severe AI had significantly higher LESS scores ($p = 0.019$ and Cohen's $d = -0.76$) than the healthy players ($n = 15$, $6.33 \pm 1.53$ vs $n = 31$, $5.25 \pm 1.37$). Meanwhile, players re-porting a history of severe KI had significantly ($p = 0.041$ and Co-hen's $d = -0.77$) higher LESS scores ($n = 10$, $5.92 \pm 0.74$ vs. $n = 31$, $5.25 \pm 1.37$) than the healthy players.

To analyze the intervention effects on the LESS scores, the re-peated measures ANOVA revealed a significant time effect ($p = 0.001$ and $\eta^2 = 0.31$) and time-group interaction ($p = 0.002$ and $\eta^2 = 0.24$) following the application of the 11+ ($n = 21$, $5.59 \pm 1.35$ vs. $5.04 \pm 1.47$) and the Football+ ($n = 23$, $5.76 \pm 1.55$ vs. $4.65 \pm 1.37$) with the Football+ showing greater improvement. A paired sample *t*-test revealed significant pre-to-post differences in the LESS scores following the application of the Football+ ($p = 0.001$ and Cohen's $d = 1.11$) and the 11+ ($p = 0.004$ and Cohen's $d = 0.70$) programs (**Table 1**).

An additional analysis was performed to address the interven-tion effects on the players with and without injury history. Among players with a history of severe injury, 6 players were a part of the Football+ group, 11 players belonged to the 11+ group, and 5 play-ers were in the control group. Due to the team-level random as-signment, the distribution across groups was uneven. Therefore, we did not differentiate between the intervention groups or types of injuries. Independent sample *t*-tests revealed no significant dif-ferences between players with and without a history of severe AI or KI ($n = 17$, $5.29 \pm 1.23$; vs. $n = 27$, $4.55 \pm 1.47$; $p = 0.06$ and Co-hen's $d = -0.53$) following the application of the Football+ and the 11+, regardless of the intervention. Further descriptive analysis re-vealed that although the application of the Football+ and 11+ pro-grams notably improved the landing technique, players with a his-tory of severe injury still exhibited poorer landing technique com-pared to non-injured players did (**Table 2**).

**Table 1** Results of the repeated measures ANOVA

| Source | *F* value | Sig. | $\eta 2$ |
|---|---|---|---|
| Time | 20.40 | < 0.001 | 0.312 |
| Time × injury history | 3.09 | 0.055 | 0.121 |
| Time × group | 7.05 | 0.002 | 0.239 |
| Time × injury history × group | 1.69 | 0.171 | 0.130 |

Abbreviations: ANOVA, analysis of variance; Sig., significance. Note: The significance level is $p \leq 0.05$.


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## Discussion

This study demonstrated that female players with a history of se-vere knee or AI exhibit poorer landing patterns, as reflected by significantly higher LESS scores before intervention. Following 4 months of training, both the Football+ and 11+-programs im-proved landing quality, with the Football+ producing larger effects (Cohen's $d = 1.11$) than the 11+ (Cohen's $d = 0.70$). The significant time–group interaction confirmed that improvements differed be-tween interventions, with the Football+ group achieving the great-est gains. In addition, the near-significant time-injury history in-teraction revealed that players with previous injuries may benefit more from neuromuscular training, although their landing perfor-mance still did not fully match that of non-injured players.

These findings align with the existing literature demonstrating that neuromuscular training programs may improve landing and reduce the LESS scores,[35, 36] and that those with a history of severe injury and poorer landing gain more improvements than healthy players with superior initial landing.[20] In contrast, Parsons et al. (2019) failed to find the same results in female children players following 5 months of the 11+ treatment, supporting the idea that sex and age are the key factors influencing the LESS.[21]

A history of injury is traditionally considered a non-modifiable risk factor for future injuries as it causes neuromuscular control deficits or strength imbalances. Our current findings, however, challenge this view suggesting that the movement deficits caused by previous injuries might be partially modified through the appli-cation of the targeted IPPs such as the Football+ and 11+. Howev-er, whether these improvements translate into a measurable re-duction in injury risk requires confirmation in prospective injury surveillance studies.

Four months of training with these programs improved the landing technique of previously injured female players to a level almost comparable to that of uninjured players. One explanation for this could be that these individuals likely have a larger scope for development than their healthy counterparts with better initial

**Table 2** Results of the paired sample *t*-test: mean LESS scores before and after the intervention

| | Injury history | *N* | Pre-test LESS scores (s.d.) | Post-test LESS scores (s.d.) | Pre–post difference | Sig. | Cohen's *d* |
|---|---|---|---|---|---|---|---|
| Football+ group | Non-injured | 17 | 5.52 (1.43) | 4.51 (1.41) | 1.02 | 0.002 | 0.83 |
| | Injured | 6 | 6.44 (1.82) | 5.05 (1.25) | 1.39 | 0.007 | 1.34 |
| | Total | 23 | 5.76 (1.55) | 4.65 (1.37) | 1.11 | 0.001 | **1.11** |
| 11+ group | Non-injured | 10 | 5.03 (1.37) | 4.63 (1.64) | 0.40 | 0.17 | 0.26 |
| | Injured | 13 | 6.02 (1.22) | 5.42 (1.26) | 0.60 | 0.03 | 0.49 |
| | Total | 23 | 5.59 (1.35) | 5.04 (1.47) | 0.55 | 0.004 | **0.70** |
| Control group | Non-injured | 5 | 4.73 (1.14) | 4.81 (1.16) | − 0.08 | 0.68 | 0.07 |
| | Injured | 5 | 6.26 (0.83) | 6.19 (0.72) | 0.06 | 0.82 | 0.08 |
| | Total | 10 | 5.49 (1.24) | 5.50 (1.22) | − 0.01 | 0.93 | 0.01 |

Abbreviations: LESS, Landing Error Scoring System; s.d., standard deviation; Sig., significance.
Note: The significance level is $p \leq 0.05$.
The bold data represent the total effect sizes for each intervention, which are interpreted as mid-to-large for the 11+ and as very large for the Football+.

techniques, indicating the importance and efficacy of employing targeted IP interventions. Hence, extending the duration or tailor-ing interventions more specifically might attain parity with the landing technique of healthy players. However, further well-estab-lished studies are needed to verify our outcomes by comparing the effects of these programs among healthy and previously injured athletes.

Following a severe AI, subconscious adaptive movement strat-egies, which play a protective role, gradually alter lower extremity functions across various movement tasks. Nevertheless, some of these adaptations may result in malalignments that not only ele-vate the risk of recurrent AIs but also proximal kinetic segment in-juries, as the lower extremity works as a unit.[37] This could possibly create situations leading to injuries associated with the transfer of forces throughout the chain.[38] In this regard, it has been demon-strated that previous ankle sprains with ligamentous damage in-crease the risk of recurrent lower extremity injuries.[39] Specifically, one-third of athletes with a history of ankle sprain sustain at least one recurrent AI,[17, 18] and almost 75 % of these individuals suffer from subsequent symptoms such as pain, weakness or instability.[40] Therefore, identifying at-risk athletes through a user-friendly screening tool could help to establish targeted prevention strate-gies.

In line with the findings of Gokeler et al. (2014), Bell et al. (2014), Kuenze et al. (2015), and Padua et al. (2015),[12, 41–43] our study confirms that players with previous severe knee injuries exhibit poorer landing as measured by LESS. However, while previous studies focused on LESS scores after ACLR, our study considered all types of knee injuries. The ACL is the main location of mechanoreceptors in the knee, highlighting its pivotal role in knee proprioception.[44] Thus, changes in knee proprioception following ACLR could be more pronounced compared to other knee injuries, potentially resulting in poorer landing techniques and higher LESS scores. Conversely, our findings contradict those of Kenneth et al. (2014), who reported no associations between previous ACL injuries and the LESS scores among female athletes.[45]


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Both the Football+- and 11+-programs offer substantial poten-tial to improve the LESS scores. It has also been demonstrated pre-viously that the IPPs, including strength, core stability, balance, plyometric, and agility exercises, are superior for reducing the LESS scores than training methods that do not benefit from neuromus-cular control exercises.[46] Since these exercises are included in both programs, we hypothesize that the improvements in the LESS scores following four months of application of these programs are due to improvements in neuromuscular control, potential inter-in-tra limb asymmetry, balance and proprioception.

The greater efficacy of the Football+ compared to the 11+ may be explained by its more demanding, football-specific structure, which incorporates almost twice the volume of plyometric exer-cises, core stability, and match-relevant physical tasks, and it's spe-cific focus on dynamic movements and skills inherent to football. The observed greater effect size (Cohen's $d$ = 1.11) in the Foot-ball+-group underscores the program's efficacy in eliciting signif-icant changes, emphasizing the potential benefits of incorporat-ing sport-specific interventions for enhancing the movement qual-ity and IP beyond more generic training approaches such as the 11+.

## Conclusions

Adult female players with a history of severe AI or KI exhibit poor-er landing and higher LESS scores and might be at greater risk of sustaining lower extremity injuries. Four months of training with the Football+ and 11+ improves the landing quality measured by the LESS, with the Football+ demonstrating greater efficacy, and may thus potentially reduce the subsequent risk of sustaining lower extremity injuries. Previously injured players might derive greater benefits from these programs compared to those with better ini-tial landing, but may still have poorer landing quality. Future re-search should aim to replicate our findings using 3D biomechani-cal assessments and individual participant allocation to better iso-late intervention effects. Studies with longer follow-up periods could also evaluate the durability of improvements and their im-pact on injury incidence. Although the findings should be taken with some caution due to the absence of individual-based rand-omization, we recommend female football administrations to adopt the Football+-program in their weekly routine training.

### Limitations and future implications

This study has limitations that should be considered. First, the move-ment assessment was conducted using 2D video analysis, which, despite being a reliable and practical tool for field-based screening lacks the precision of 3D motion analysis, particularly for complex joint kinematics such as dynamic knee valgus. Furthermore, the dis-tribution of participants with and without prior injuries was not bal-anced across the intervention groups due to the team-based group assignment, which may have affected group-level comparisons.


## Author Affiliations

1 Institute for Sport and Sport Science, TU Dortmund, Dortmund, Germany

2 Department of Health, Medicine and Caring Sciences, Linköping University, Linköping, Sweden


## Statements and Additional Information

**Conflict of Interest** The authors declare that they have no conflict of interest.

**Contributors' Statement** Mojtaba Asgari: conceptualization, methodology, project administration, and writing—original draft. Martin Hagglund: conceptualiza-tion and writing—review and editing. Benedikt Terschluse: data curation and investi-gation. Maximilian Sueck: data curation and investigation. Kevin Nolte: formal analysis. Marcus Schmidt: project administration and writing—review and editing. Thomas Jaitner: conceptualization, supervision, and writing—review and editing.

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## References


1 Del Coso J, Herrero H, Salinero JJ. Injuries in Spanish female soccer players. J Sport Health Sci 2018;7:183–190

2 Geertsema C, Geertsema L, Farooq A, et al. Injury prevention knowledge, beliefs and strategies in elite female footballers at the FIFA Women's World Cup France 2019. Br J Sports Med 2021;55:801–806. doi:10.1136/bjsports-2020-103131




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3 Hartmut G, Becker A, Walther M, et al. Injuries in women's soccer: a 1-year all players prospective field study of the women's Bundesliga (German premier league). Clin J Sport Med 2010;20:264–271

4 Ibikunle PO, Efobi KC, Nwankwo MJ, et al. UEFA model in identification of types, severity and mechanism of injuries among footballers in the Nigerian Women's Premier League. BMJ Open Sport Exerc Med 2019;5:e000386. doi:10.1136/ bmjsem-2018-000386

5 Jacobson I, Tegner Y. Injuries among Swedish female elite football players: a prospective population study. Scand J Med Sci Sports 2007;17:84–91

6 Ekstrand J, Hägglund M, Fuller C. Comparison of injuries sustained on artificial turf and grass by male and female elite football players. Scand J Med Sci Sports 2011;21:824–832

7 Babwah TJ. The incidence of injury in a Caribbean amateur women's football league. Res Sports Med 2014;22:327–333

8 Horan D, Blake C, Hägglund M, et al. Injuries in elite-level women's football—a two-year prospective study in the Irish Women's National League. Scand J Med Sci Sports 2022;32:177–190

9 Kirkendall DT, Krustrup P. Studying professional and recreational female footballers: A bibliometric exercise. Scand J Med Sci Sports 2022;32:12–26. doi:10.1111/sms.14019

10 Asgari M, Alizadeh S, Sendt A, et al. Evaluation of the Functional Movement Screen (FMS) in Identifying Active Females Who are Prone to Injury. A Systematic Review. Sports Med Open 2021;7:85. doi:10.1186/s40798-021-00380-0

11 Hanzlíková I, Hébert-Losier K. Is the Landing Error Scoring System Reliable and Valid? A Systematic Review. Sports Health 2020;12:181–188. doi:10.1177/1941738119886593

12 Padua DA, DiStefano LJ, Beutler AI, et al. The Landing Error Scoring System as a Screening Tool for an Anterior Cruciate Ligament Injury–Prevention Program in Elite-Youth Soccer Athletes. J Athl Train 2015;50:589–595. doi:10.4085/1062-6050-50.1.10

13 Padua DA, Marshall SW, Boling MC, et al. The Landing Error Scoring System (LESS) Is a Valid and Reliable Clinical Assessment Tool of Jump-Landing Biomechanics: The JUMP-ACL Study. Am J Sports Med 2009;37:1996–2002. doi:10.1177/0363546509343200

14 Hanzlíková I, Athens J, Hébert-Losier K. Factors influencing the Landing Error Scoring System: Systematic review with meta-analysis. J Sci Med Sport 2021;24:269–280

15 Tegnander A, Olsen OE, Moholdt TT, et al. Injuries in Norwegian female elite soccer: a prospective one-season cohort study. Knee Surg Sports Traumatol Arthrosc 2008;16:194–198

16 John C, Stotz A, Gmachowski J. Is an elastic ankle support effective in improving jump landing performance, static and dynamic balance in young adults with and without chronic ankle instability? J Sport Rehabil 2019;29:789–794

17 van Rijn RM, Van Os AG, Bernsen RM, et al. What is the clinical course of acute ankle sprains? A systematic literature review. Am J Med 2008;121:324–331.e6

18 Verhagen E, Bay K. Optimising ankle sprain prevention: a critical review and practical appraisal of the literature. Br J Sports Med 2010;44:1082–1088

19 Hoch MC, McKeon PO. Peroneal reaction time after ankle sprain: a systematic review and meta-analysis. Med Sci Sports Exerc 2014;46:546–556

20 Akbari H, Sahebozamani M, Daneshjoo A, et al. Effect of the FIFA 11+ on Landing Patterns and Baseline Movement Errors in Elite Male Youth Soccer Players. J Sport Rehabil 2020;29:730–737. doi:10.1123/jsr.2018-0374

21 Parsons JL, Carswell J, Nwoba IM, et al. Athlete perceptions and physical performance effects of the fifa 11+ program in 9-11 year-old female soccer players: a cluster randomized trial. Int J Sports Phys Ther 2019;14:740

22 Winstanley C, Reid D, Fulcher ML. Suggested improvements to the 11+ as identified by coaches, players, strength and conditioning staff and medical staff in New Zealand Football. BMJ Open Sport Exerc Med 2023;9:e001463

23 Asgari M, Alizadeh MH, Shahrbanian S, et al. Effects of the FIFA 11+ and a modified warm-up programme on injury prevention and performance improve-ment among youth male football players. PLoS One 2022;17:e0275545

24 Asgari M, Nazari B, Bizzini M, et al. Effects of the FIFA 11+ program on performance, biomechanical measures, and physiological responses: A systematic review. J Sport Health Sci 2023;12:226–235. doi:10.1016/ j.jshs.2022.05.001

25 O'Brien J, Finch CF. Injury prevention exercise programmes in professional youth soccer: understanding the perceptions of programme deliverers. BMJ Open Sport Exerc Med 2016;2:e000075

26 O'Brien J, Young W, Finch C. The use and modification of injury prevention exercises by professional youth soccer teams. Scand J Med Sci Sports 2017;27:1337–1346

27 O'Brien J, Young W, Finch CF. The delivery of injury prevention exercise programmes in professional youth soccer: Comparison to the FIFA 11+. J Sci Med Sport 2017;20:26–31

28 Asgari M, Schmidt M, Terschluse B, et al. Acute effects of the FIFA11+ and Football+ warm-ups on motor performance. A crossover randomized controlled trial. PLoS One 2023;18:e0284702. doi:10.1371/journal.pone.0284702

29 Faul F, Erdfelder E, Buchner A, et al. Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. Behav Res Methods 2009;41:1149–1160

30 Hirschmüller A, Steffen K, Fassbender K, et al. German translation and content validation of the OSTRC Questionnaire on overuse injuries and health problems. Br J Sports Med 2017;51:260–263

31 Gribble PA, Delahunt E, Bleakley C, et al. Selection criteria for patients with chronic ankle instability in controlled research: a position statement of the International Ankle Consortium. J Orthop Sports Phys Ther 2013;43:585–591

32 Fuller CW, Ekstrand J, Junge A, et al. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. Scand J Med Sci Sports 2006;16:83–92

33 Soligard T, Myklebust G, Steffen K, et al. Comprehensive warm-up programme to prevent injuries in young female footballers: cluster randomised controlled trial. BMJ 2008;337:a2469

34 Rhea MR. Determining the magnitude of treatment effects in strength training research through the use of the effect size. J Strength Cond Res 2004;18:918–920

35 Scarneo SE, Root HJ, Martinez JC, et al. Landing Technique Improvements After an Aquatic-Based Neuromuscular Training Program in Physically Active Women. J Sport Rehabil 2017;26:8–14. doi:10.1123/jsr.2015-0052

36 Parsons JL, Sylvester R, Porter MM. The effect of strength training on the jump-landing biomechanics of young female athletes: results of a randomized controlled trial. Clin J Sport Med 2017;27:127–132

37 Glasgow P, Bleakley CM, Phillips N. Being able to adapt to variable stimuli: the key driver in injury and illness prevention? Br J Sports Med. 47:2013:64–65

38 Theisen A, Day J. Chronic ankle instability leads to lower extremity kinematic changes during landing tasks: a systematic review. Int J Exerc Sci 2019;12:24

39 Gribble PA, Bleakley CM, Caulfield BM, et al. Evidence review for the 2016 International Ankle Consortium consensus statement on the prevalence, impact and long-term consequences of lateral ankle sprains. Br J Sports Med 2016;50:1496–1505

40 Anandacoomarasamy A, Barnsley L. Long term outcomes of inversion ankle injuries. Br J Sports Med 2005;39:e14

41 Bell DR, Smith MD, Pennuto AP, et al. Jump-Landing Mechanics After Anterior Cruciate Ligament Reconstruction: A Landing Error Scoring System Study. J Athl Train 2014;49:435–441. doi:10.4085/1062-6050-49.3.21

42 Kuenze CM, Foot N, Saliba SA, et al. Drop-Landing Performance and Knee-Extension Strength After Anterior Cruciate Ligament Reconstruction. J Athl Train 2015;50:596–602. doi:10.4085/1062-6050-50.2.11

43 Gokeler A, Eppinga P, Dijkstra P, et al. Effect of fatigue on landing performance assessed with the landing error scoring system (less) in patients after ACL reconstruction. A pilot study. Int J Sports Phys Ther 2014;9:302

44 Han YH, Li B, Wen Y. Distribution, quantity and gene expression of mechanore-ceptors in ligaments and tendons of knee joint in rabbits. J Mol Histol 2020;51:233–240

45 Lam KC, Valovich McLeod TC. The Impact of Sex and Knee Injury History on Jump-Landing Patterns in Collegiate Athletes: A Clinical Evaluation. Clin J Sport Med 2014;24:373–379. doi:10.1097/jsm.0000000000000053

46 O'Malley E, Murphy JC, Persson UM, et al. The effects of the gaelic athletic association 15 training program on neuromuscular outcomes in gaelic football and hurling players: a randomized cluster trial. J Strength Cond Res 2017;31:2119–2130

# 7. Discussion

This dissertation aimed to address key performance-related barriers limiting the implementation of the 11+, the most extensively studied IPP, by systematically evaluating its effects on performance and translating these insights into a novel football-specific intervention. To achieve this objective, the project followed a sequential and integrated research strategy consisting of evidence synthesis, program development, and experimental validation in amateur female football players.

The first phase of the dissertation involved a systematic review examining the effects of the 11+ on motor performance outcomes. The review demonstrated that, although the 11+ effectively improves several biomechanical and neuromuscular parameters and reduces injury incidence, its effects on motor performance are inconsistent and, in many cases, limited. In particular, the program showed minimal effects on technical skills and acute performance enhancement despite being implemented as a warm-up routine. These findings are particularly important because warm-up strategies are generally expected not only to reduce injury risk, but also to optimize performance readiness before high-intensity training and competition. Consequently, the review highlighted a potential mismatch between the structure of traditional IPPs and the practical performance demands of football, thereby providing the scientific rationale for the development of an alternative and more performance-oriented approach (Asgari, Nazari, et al., 2022).

Based on these findings, the Football+ was developed as a football-specific, dual-purpose warm-up program integrating established IP principles with performance-oriented training components. The subsequent experimental studies systematically examined whether this integrated approach could overcome some of the known limitations of traditional IPPs while maintaining their preventive efficacy.

The first experimental phase investigated the acute effects of the Football+ on motor performance. Compared with the 11+, the Football+ produced significant improvements in sprinting, agility, and dribbling performance, whereas no substantial differences were observed in vertical jump performance. These findings indicate that the Football+ fulfills one of the primary functions of a warm-up routine by enhancing immediate performance readiness. From a practical perspective, this observation is particularly relevant because concerns regarding impaired or insufficient performance enhancement may negatively

influence the willingness of coaches and players to consistently implement IPPs in real-world football settings (Asgari, Schmidt, Terschluse, Sueck, & Jaitner, 2023).

The second experimental phase focused on long-term adaptations following implementation of the Football+ program compared to the 11+ and warm-up routines. The findings demonstrated improvements in key knee kinematic and kinetic parameters associated with lower-extremity injury risk during high-risk football-specific tasks such as cutting and single-leg landing. In addition, improvements were observed in motor performance variables, including sprinting, agility, dribbling, and vertical jump performance. These results indicate that integrating performance-oriented training components into an IPP does not compromise preventive efficacy. Rather, the inclusion of football-specific, multiplanar, and dynamic movement tasks may further enhance neuromuscular adaptations and movement quality under conditions that closely resemble the demands of football competition (Asgari et al., 2026a).

The third experimental phase examined landing mechanics in players with and without a history of severe lower-extremity injury. The results revealed that both the Football+ and the 11+ improve landing quality and movement technique, while the Football+ produced larger improvements, particularly in previously injured players. Importantly, previously injured players continued to demonstrate inferior landing performance compared with non-injured players despite substantial improvement over time. These findings suggest that injury-related neuromuscular deficits may be partially modifiable through targeted training interventions, although complete normalization may require longer or more individualized approaches. Consequently, the Football+ may also possess considerable potential as a secondary prevention strategy for athletes at elevated risk of reinjury (Asgari et al., 2026b).

Collectively, the findings of this dissertation suggest that the effectiveness of IPPs may not depend solely on their capacity to reduce injury incidence or modify isolated biomechanical risk factors, but also on their ability to align with the practical and performance-related demands of football. The Football+ attempted to address this challenge through a more holistic and ecologically valid approach to IP. Within the context of this dissertation, the term holistic refers to the simultaneous integration of neuromuscular control, biomechanical optimization, football-specific movement patterns, technical execution, and motor

performance enhancement within a single warm-up structure. Rather than treating IP and performance enhancement as separate or competing objectives, the Football+ aimed to integrate both components into a unified and practically applicable training strategy.

One of the most important findings emerging from this dissertation is the apparent interaction between acute performance enhancement and long-term adherence potential. The acute improvements observed following application of the Football+ may positively influence player motivation, engagement, and coach acceptance, thereby addressing one of the most frequently reported barriers to IPP implementation. Simultaneously, the long-term biomechanical and neuromuscular adaptations observed following supervised implementation suggest that regular exposure to football-specific neuromuscular stimuli may contribute to sustained improvements in movement quality and reductions in injury-related risk factors. Consequently, short-term and long-term adaptations should not be viewed as isolated outcomes, but rather as interacting mechanisms that collectively influence the practical effectiveness of IP strategies.

The present findings are particularly relevant in female football players. Female athletes demonstrate elevated susceptibility to severe lower-extremity injuries, especially ACL injuries, while remaining comparatively underrepresented in IP research. Consequently, this dissertation contributes important evidence regarding the effects of a football-specific and performance-oriented IPP in amateur female players. The observed improvements in knee biomechanics, landing technique, and motor performance suggest that integrated neuromuscular and football-specific interventions may represent a promising strategy for addressing injury-related challenges in women's football.

Overall, the hypotheses of this dissertation were largely supported. The Football+ demonstrated at least comparable, and in several parameters superior effects on biomechanical risk factors relative to the 11+, while consistently producing greater improvements in acute and long-term motor performance outcomes. Importantly, integrating performance-oriented components did not compromise preventive efficacy. Instead, the findings suggest that combining IP principles with football-specific performance demands may improve both practical applicability and long-term adherence potential.

From a scientific perspective, this dissertation contributes to the growing body of literature indicating that IP and performance enhancement should not be viewed as competing objectives, but rather as complementary components of an effective training strategy. Further, the findings support the notion that more sport-specific and ecologically valid interventions may produce superior outcomes compared with generic prevention approaches. Consequently, the Football+ may represent an important step toward more integrated, performance-oriented, and practically applicable IP strategies in football.

Despite the promising findings observed across the experimental phases, several considerations should be acknowledged when interpreting the practical transferability of the Football+ program. The interventions were implemented under structured and supervised conditions, which may not fully reflect the realities of amateur football environments characterized by limited resources, varying coaching expertise, inconsistent compliance, and scheduling constraints. Additionally, although the Football+ was designed to enhance ecological validity and player engagement, adherence to structured warm-up routines in real-world settings remains inherently challenging and may substantially influence the magnitude of achievable benefits. Therefore, the effectiveness of the program in broader football contexts will likely depend not only on the intervention itself but also on implementation quality, coach education, organizational support, and long-term player adherence.

# 8. Practical implications

Based on the evidence presented in this dissertation, several practical recommendations can be made for stakeholders in women's football. These implications are grounded in the demonstrated dual capacity of the Football+ to improve both biomechanical risk factors and sport-specific performance.

## 8.1. For coaches, trainers, and players

The findings of this dissertation indicate that consistent implementation of the Football+ can effectively modify biomechanical risk factors associated with lower-extremity injuries while simultaneously enhancing key performance components such as sprinting, agility, dribbling, and movement quality. This dual effect is particularly important because it directly addresses one of the primary barriers to the implementation of traditional IPPs: the perception that such programs do not contribute to performance enhancement.

Coaches and trainers are therefore encouraged to integrate the Football+ as a primary warm-up routine prior to training sessions and competitions. Emphasizing both its preventive and performance-enhancing benefits may improve player motivation, engagement, and long-term adherence. Meanwhile, previously injured players may particularly benefit from the program's landing, cutting, and neuromuscular control components, which specifically target common mechanisms underlying reinjury.

## 8.2. For clubs and associations

At the organizational level, implementation of the Football+ may contribute to improved team performance and competitiveness by reducing injury-related player unavailability throughout the season. Given the established relationship between injury burden, player availability, and competitive success, reducing injury incidence may have direct implications for match outcomes and league performance. In addition, injury reduction may decrease medical, rehabilitation, and compensation-related costs, thereby providing economic benefits for clubs and sporting organizations. Consequently, the Football+ may represent not only an evidence-based health strategy, but also a practical and cost-effective performance management approach.

## 8.3. For policymakers and governing bodies

From a broader perspective, policymakers and governing bodies play an essential role in facilitating the large-scale implementation of IP strategies. The findings of this dissertation suggest that promoting football-specific and performance-oriented warm-up programs such as the Football+ through coach education, certification pathways, and digital dissemination platforms may improve adoption across different levels of play. Long-term implementation of such strategies may contribute to public health objectives by reducing injury-related burden, improving player retention in sport, and supporting the sustainable development of women's football.

## 8.4. Limitations

While the findings of this dissertation are promising, several limitations should be considered when interpreting the results and evaluating the broader applicability of the Football+ program. Importantly, these limitations also highlight areas requiring further investigation before definitive conclusions regarding the program's overall IP efficacy can be established. First, the studies were conducted in adult amateur female football players, which may limit the generalizability of the findings to male players, youth populations, or elite-level athletes. Future research should therefore aim to examine the effectiveness of the Football+ across diverse populations and competitive levels.

Second, the sample sizes in at least one of the experimental studies were relatively modest, which may reduce statistical power and the ability to detect smaller effects. Future studies should therefore incorporate larger samples and prospective injury surveillance designs to evaluate the long-term effectiveness of the Football+.

Another important limitation is that the dissertation focused primarily on selected biomechanical and performance-related parameters and did not comprehensively assess all known modifiable injury risk factors. Although knee kinematics and kinetics, landing mechanics, and motor performance represent highly relevant indicators of lower-extremity injury risk, additional factors such as balance, muscular strength, fatigue resistance, proprioception, psychological readiness, and broader neuromuscular characteristics were not

directly evaluated. Given the multifactorial nature of sports injuries, future investigations should adopt more comprehensive assessment models integrating multiple physiological, neuromuscular, biomechanical, and psychological dimensions.

Finally, although the Football+ was intentionally designed to enhance ecological validity and practical applicability, variations in implementation fidelity, supervision quality, motivation, and exercise execution across teams and training environments cannot be fully controlled. Since adherence and exercise quality are critical determinants of IPP effectiveness, future research should further investigate compliance behavior, implementation quality, and contextual factors influencing long-term adoption in real-world football settings.

# 9. Future research

Although this dissertation provides important empirical evidence for the applicability and benefits of the Football+ program, and while we continue to investigate its effects on long-term performance as well as trunk and hamstring strength, further research is warranted to expand upon and validate the present findings. The following directions are recommended:

## 9.1. Clinical studies

This dissertation primarily focused on the effects of the Football+ program on knee kinetics and kinematics. However, a wider spectrum of risk factors remains unexplored. Future clinical studies should therefore investigate the program's impacts on additional parameters, such as neuromuscular control, proprioception, muscle strength, muscle activity, balance, and fatigue resistance, to provide a more comprehensive understanding of its preventive potential.

## 9.2. Large-scale RCTs

The present work primarily focused on biomechanical risk factors and performance-related outcomes. To establish definitive evidence for injury reduction, future studies should conduct large-scale, multicenter RCTs across different levels of play, age groups, and competitive environments. Such trials will be essential to determine the Football+ program's effectiveness in reducing injury incidence and severity. Additionally, randomized hybrid implementation-effectiveness trials are recommended to evaluate the program's real-world effectiveness.

## 9.3. Longitudinal studies on compliance and adherence

Low compliance remains one of the greatest barriers to IPP effectiveness. Future research should explore long-term compliance with the Football+ and identify facilitators and barriers across diverse cultural, social, and organizational contexts. Implementation science approaches, including coach education and behavioral strategies, could provide valuable insights into how compliance can be sustained over multiple seasons.

## 9.4. Broader population studies

While this dissertation focused on amateur female football players, it is crucial to investigate the program's efficacy in other populations, including male players and youth players, for whom IP is critical for long-term development.

## 9.5. Integration with performance science

Given that performance benefits strongly influence buy-in, future studies should examine the Football+ program's effects on a broader range of technical, physical, and physiological variables. Wearable technologies and advanced biomechanical analyses could provide deeper insights into how performance improvements interact with injury risk reduction.

## 9.6. Program optimization and personalization

The Football+ was designed as a practical, football-specific warm-up, but future work should consider adaptive versions tailored to age, sex, training level, and positional demands. Individualized monitoring approaches may also enhance the program's precision and personalization.

## 9.7. Socioeconomic and public health Impact

Finally, research should assess the broader impact of the Football+ on healthcare costs, player availability, and long-term participation in football. Such analyses could provide compelling evidence for policymakers, clubs, and health systems, thereby supporting the widespread adoption and funding of IPPs.

# 10. Conclusion

This cumulative dissertation provides a comprehensive, multi-level evaluation of IP strategies in football and introduces the Football+ as an evidence-based and practically applicable response to one of the most persistent challenges in sports medicine: the gap between the proven efficacy of IPPs and their limited real-world implementation.

Building upon the current state of knowledge, the systematic review (Publication 1) demonstrated that, although the 11+ effectively improves several biomechanical and neuromuscular parameters, its effects on motor performance are inconsistent and may, in some cases, acutely impair performance-related outcomes. These findings highlight a key limitation of many existing IPPs: their insufficient alignment with the practical and performance-related demands of football. This mismatch may contribute substantially to the well-documented problems of low compliance, limited player engagement, and poor long-term implementation observed in real-world settings.

Addressing this limitation, the Football+ was developed as a dual-purpose, football-specific warm-up intervention integrating established IP principles with performance-oriented training science. The subsequent experimental investigations provide consistent and converging evidence supporting this integrated approach.

The acute crossover trial (Publication two) demonstrated that the Football+ significantly improves sprinting, agility, and dribbling performance compared with the 11+. These findings are particularly relevant from a practical perspective, as they directly address one of the major barriers to IPP implementation: the expectation that warm-up routines should optimize immediate performance readiness before high-intensity training and competition. In contrast to many traditional IPPs, the Football+ fulfilled this requirement while simultaneously maintaining its preventive structure.

From a biomechanical perspective, the cluster-allocated intervention study (Publication three) provided detailed insights into the underlying biomechanical mechanisms associated with injury-risk reduction. Both programs improved knee kinematics and kinetics during high-risk tasks such as single-leg landing and cutting; however, the Football+ consistently demonstrated larger and more robust effects while simultaneously enhancing motor performance. The absence of retained adaptations following the detraining period further

emphasizes the importance of continuous implementation and supports the principle that sustained neuromuscular adaptations require ongoing training exposure.

Extending these findings, the four-month intervention study (Publication four) demonstrated that both the Football+ and the 11+ improved landing quality, a well-established surrogate marker of lower-extremity injury risk. Importantly, the Football+ produced larger improvements, particularly in players with a history of severe knee or ankle injuries. This finding is especially important because it suggests that targeted neuromuscular interventions may partially mitigate persistent movement deficits associated with previous injuries, which are traditionally considered among the strongest and least modifiable injury risk factors.

Collectively, the findings of this dissertation suggest that effective IP in football should not be viewed solely through a medical or biomechanical lens, but rather as a holistic and performance-oriented process integrating neuromuscular control, movement quality, football-specific demands, and motor performance enhancement. In this regard, the Football+ demonstrated that injury prevention and performance enhancement are not competing objectives, but complementary components of an effective and practically applicable warm-up strategy.

From a scientific perspective, this dissertation contributes to the growing body of literature advocating for more ecologically valid and sport-specific approaches to IP. The findings support the notion that integrating performance-oriented elements into IPPs may not only maintain preventive efficacy but also improve player motivation, coach acceptance, adherence, and long-term implementation. This may be particularly relevant in amateur football environments, where limited training time frequently represents a major practical barrier.

Importantly, this dissertation also contributes valuable evidence within female football populations, a group that remains comparatively underrepresented in IP research despite demonstrating elevated susceptibility to severe lower-extremity injuries, particularly ACL injuries. The observed improvements in biomechanical risk factors, landing mechanics, and motor performance suggest that integrated neuromuscular and football-specific

interventions may represent a promising strategy for improving both player health and performance in women's football.

Overall, the Football+ appears to represent a promising next-generation IPP that more closely aligns with the real demands of football participation. Nevertheless, future large-scale randomized controlled trials incorporating prospective injury surveillance are still required to determine whether the observed biomechanical and performance-related adaptations ultimately translate into meaningful reductions in injury incidence and severity.

In conclusion, this dissertation demonstrates that the long-standing gap between scientific evidence and real-world implementation in football IP may be reduced by shifting from purely preventive models toward more integrated, football-specific, and performance-oriented approaches. The Football+ represents an important step in this direction and provides a foundation for future research and practical application in modern football.

# References


Åkerlund, I., Sonesson, S., Lindblom, H., Waldén, M., & Hägglund, M. (2023). Perceptions, facilitators, and barriers regarding use of the injury prevention exercise programme Knee Control among players and coaches in youth floorball: a cross-sectional survey study. *BMC sports science, medicine and rehabilitation, 15*(1), 56.

Al Attar, W. S. A. (2022a). The FIFA 11+ injury prevention program reduces the incidence of groin injury among soccer players: a systematic review and meta-analysis of randomized controlled trials. *Journal of science and medicine in sport, 25*, S2. doi:10.1016/j.jsams.2022.09.112

Al Attar, W. S. A. (2022b). The FIFA 11+ injury prevention program reduces the incidence of hamstring injury among soccer players: a systematic review and meta-analysis. *Journal of science and medicine in sport, 25*, S1-S2. doi:10.1016/j.jsams.2022.09.111

Al Attar, W. S. A. (2022c). The FIFA 11+ injury prevention program reduces the incidence of knee injury among soccer players: a systematic review and meta-analysis of randomized controlled trials. *Journal of science and medicine in sport, 25*, S2-S3. doi:10.1016/j.jsams.2022.09.113

Al Attar, W. S. A., Bizzini, M., Alkabkabi, F., Alshamrani, N., Alarifi, S., Alzahrani, H., . . . Sanders, R. H. (2021). Effectiveness of the FIFA 11+ Referees Injury Prevention Program in reducing injury rates in male amateur soccer referees. *Scandinavian journal of medicine & science in sports, 31*(9), 1774-1781.

Al Attar, W. S. A., Soomro, N., Pappas, E., Sinclair, P. J., & Sanders, R. H. (2016). How effective are F-MARC injury prevention programs for soccer players? A systematic review and meta-analysis. *Sports medicine, 46*(2), 205-217.

Al Attar, W. S. A., Soomro, N., Sinclair, P. J., Pappas, E., Muaidi, Q. I., & Sanders, R. H. (2017). Implementation of an evidence-based injury prevention program in professional and semi-professional soccer. *International Journal of Sports Science & Coaching, 13*(1), 113-121. doi:10.1177/1747954117707482

Arundale, A. J. H., Silvers-Granelli, H. J., Marmon, A., Zarzycki, R., Dix, C., & Snyder-Mackler, L. (2018). Changes in biomechanical knee injury risk factors across two collegiate soccer seasons using the 11+ prevention program. *Scandinavian journal of medicine & science in sports, 28*(12), 2592-2603.

Asgari, M., Alizadeh, M. H., Shahrbanian, S., Nolte, K., & Jaitner, T. (2022). Effects of the FIFA 11+ and a modified warm-up programme on injury prevention and performance improvement among youth male football players. *PloS one, 17*(10), e0275545.

Asgari, M., Hägglund, M., Terschluse, B., Sueck, M., Nolte, K., Schmidt, M., & Jaitner, T. (2026a). Alterations in knee biomechanics and motor performance following 3 months training with the Football+ and 11+ warm-up programs among amateur female players. A three-armed cluster allocated, non-randomized intervention study. *Journal of Exercise Science & Fitness*, 200463. doi:https://doi.org/10.1016/j.jesf.2026.200463

Asgari, M., Hägglund, M., Terschluse, B., Sueck, M., Nolte, K., Schmidt, M., & Jaitner, T. (2026b). Four Months Training with the Football+ and 11+ Improves the Landing Quality of Female Players. *International journal of sports medicine*.

Asgari, M., Nazari, B., Bizzini, M., & Jaitner, T. (2022). Effects of the FIFA 11+ program on performance, biomechanical measures, and physiological responses: A systematic review. *Journal of Sport and Health Science*. doi:https://doi.org/10.1016/j.jshs.2022.05.001

Asgari, M., Schmidt, M., Terschluse, B., Sueck, M., & Jaitner, T. (2023). Acute effects of the FIFA11+ and Football+ warm-ups on motor performance. A crossover randomized controlled trial. *PloS one, 18*(4), e0284702. doi:10.1371/journal.pone.0284702

Ayala, F., Calderón-López, A., Delgado-Gosálbez, J. C., Parra-Sánchez, S., Pomares-Noguera, C., Hernández-Sánchez, S., De Ste Croix, M. (2017). Acute effects of three neuromuscular warm-up strategies on several physical performance measures in football players. *PloS one, 12*(1), e0169660.

Babwah, T. J. (2014). The incidence of injury in a Caribbean amateur women's football league. *Research in Sports Medicine, 22*(4), 327-333.

Bathe, C., Fennen, L., Heering, T., Greif, A., & Dubbeldam, R. (2023). Training interventions to reduce the risk of injury to the lower extremity joints during landing movements in adult athletes: a systematic review and meta-analysis. *BMJ Open Sport & Exercise Medicine, 9*(2), e001508. doi:10.1136/bmjsem-2022-001508

Beck, N. A., Lawrence, J. T. R., Nordin, J. D., DeFor, T. A., & Tompkins, M. (2017). ACL Tears in School-Aged Children and Adolescents Over 20 Years. *Pediatrics, 139*(3). doi:10.1542/peds.2016-1877

Bizzini, M., & Dvorak, J. (2015). FIFA 11+: an effective programme to prevent football injuries in various player groups worldwide—a narrative review. *British journal of sports medicine, 49*(9), 577-579. doi:10.1136/bjsports-2015-094765

Bloch, H., Krutsch, W., Klein, C., Achenbach, L., & Reinsberger, C. (2025). ACL injuries in professional football (soccer): Women face higher risk, later surgical care and longer time loss compared to men. *Knee Surg Sports Traumatol Arthrosc*. doi:10.1002/ksa.70160

Dalen-Lorentsen, T., O'Brien, J., & Harøy, J. (2024). Real-world implementation of the Copenhagen Adduction Exercise: what do football teams modify and why? *BMJ Open Sport & Exercise Medicine, 10*(3), e001982. doi:10.1136/bmjsem-2024-001982

Dallmeyer, S., Steinfeldt, H., Hübers, T., Pietzonka, M., & Breuer, C. (2025). Monetising misfortune: the financial consequences of injuries in professional football teams. *BMJ open sport & exercise medicine, 11*(2), e002437. doi:10.1136/bmjsem-2024-002437

Daneshjoo, A., Mokhtar, A. H., Rahnama, N., & Yusof, A. (2013). The effects of injury prevention warm-up programmes on knee strength in male soccer players. *Biology of sport, 30*(4), 281.

Del Coso, J., Herrero, H., & Salinero, J. J. (2018). Injuries in Spanish female soccer players. *Journal of Sport and Health Science, 7*(2), 183-190.

Donaldson, A., Callaghan, A., Bizzini, M., Jowett, A., Keyzer, P., & Nicholson, M. (2019). A concept mapping approach to identifying the barriers to implementing an evidence-based sports injury prevention programme. *Injury Prevention, 25*(4), 244-251. doi:10.1136/injuryprev-2017-042639

Dunsky, A., Barzilay, I., & Fox, O. (2017). Effect of a specialized injury prevention program on static balance, dynamic balance and kicking accuracy of young soccer players. *World journal of orthopedics, 8*(4), 317.

Dvorak, J., Junge, A., Derman, W., & Schwellnus, M. (2011). Injuries and illnesses of football players during the 2010 FIFA World Cup. *British journal of sports medicine, 45*(8), 626-630.

Eirale, C., Tol, J., Farooq, A., Smiley, F., & Chalabi, H. (2013). Low injury rate strongly correlates with team success in Qatari professional football. *British journal of sports medicine, 47*(12), 807-808.

Ejnisman, B., Barbosa, G., Andreoli, C. V., de Castro Pochini, A., Lobo, T., Zogaib, R., . . . Dvorak, J. (2016). Shoulder injuries in soccer goalkeepers: review and development of a FIFA 11+ shoulder injury prevention program. *Open access journal of sports medicine*, 75-80.

Ekstrand, J., Bengtsson, H., Waldén, M., Davison, M., Khan, K. M., & Hägglund, M. (2023). Hamstring injury rates have increased during recent seasons and now constitute 24% of all injuries in men's professional football: the UEFA Elite Club Injury Study from 2001/02 to 2021/22. *British journal of sports medicine, 57*(5), 292-298. doi:10.1136/bjsports-2021-105407

Ekstrand, J., Gillquist, J., & Liljedahl, S.-O. (1983). Prevention of soccer injuries: supervision by doctor and physiotherapist. *The American journal of sports medicine, 11*(3), 116-120.

Ekstrand, J., Hägglund, M., & Fuller, C. (2011). Comparison of injuries sustained on artificial turf and grass by male and female elite football players. *Scandinavian journal of medicine & science in sports, 21*(6), 824-832.

Ekstrand, J., Spreco, A., Bengtsson, H., & Bahr, R. (2021). Injury rates decreased in men's professional football: an 18-year prospective cohort study of almost 12 000 injuries sustained during 1.8 million hours of play. *British journal of sports medicine, 55*(19), 1084-1092. doi:10.1136/bjsports-2020-103159

Eliakim, E., Morgulev, E., Lidor, R., & Meckel, Y. (2020). Estimation of injury costs: financial damage of English Premier League teams' underachievement due to injuries. *BMJ Open Sport Exerc Med, 6*(1), e000675. doi:10.1136/bmjsem-2019-000675

Emery, C. A., Owoeye, O. B. A., Räisänen, A. M., Befus, K., Hubkarao, T., Palacios-Derflingher, L., & Pasanen, K. (2022). The "SHRed Injuries Basketball" Neuromuscular Training Warm-up Program Reduces Ankle and Knee Injury Rates by 36% in Youth Basketball. *Journal of Orthopaedic & Sports Physical Therapy, 52*(1), 40-48. doi:10.2519/jospt.2022.10959

Engebretsen, L., Soligard, T., Steffen, K., Alonso, J. M., Aubry, M., Budgett, R., . . . Renström, P. A. (2013). Sports injuries and illnesses during the London Summer Olympic Games 2012. *British journal of sports medicine, 47*(7), 407-414. doi:10.1136/bjsports-2013-092380

Everhart, J. S., Du, A., Chalasani, R., Kirven, J. C., Magnussen, R. A., & Flanigan, D. C. (2018). Return to work or sport after multiligament knee injury: a systematic review of 21 studies and 524 patients. *Arthroscopy: The Journal of Arthroscopic & Related Surgery, 34*(5), 1708-1716.

Faude, O., Junge, A., Kindermann, W., & Dvorak, J. (2005). Injuries in female soccer players: a prospective study in the German national league. *The American journal of sports medicine, 33*(11), 1694-1700.

Faude, O., Rößler, R., & Junge, A. (2013). Football Injuries in Children and Adolescent Players: Are There Clues for Prevention? *Sports medicine, 43*(9), 819-837.doi:10.1007/s40279-013-0061-x

Finch, C. (2006). A new framework for research leading to sports injury prevention. *Journal of science and medicine in sport, 9*(1-2), 3-9.

Geertsema, C., Geertsema, L., Farooq, A., Harøy, J., Oester, C., Weber, A., & Bahr, R. (2021). Injury prevention knowledge, beliefs and strategies in elite female footballers at the FIFA Women's World Cup France 2019. *British journal of sports medicine, 55*(14), 801-806. doi:10.1136/bjsports-2020-103131

Ghareeb, D. M., McLaine, A. J., Wojcik, J. R., & Boyd, J. M. (2017). Effects of two warm-up programs on balance and isokinetic strength in male high school soccer players. *The Journal of Strength & Conditioning Research, 31*(2), 372-379.

Grappendorf, H. (2013). The "Year" of Women in Sports: Why Stop at One? *Journal of Physical Education, Recreation & Dance, 84*(5), 7-8.

Grooms, D. R., Bizzini, M., Silvers-Granelli, H., & Benjaminse, A. (2024). Neurocognitive & Ecological Motor Learning Considerations for the 11+ ACL Injury Prevention Program: A Commentary. *International journal of sports physical therapy, 19*(11), 1362.

Hägglund, M., Waldén, M., & Ekstrand, J. (2009). Injuries among male and female elite football players. *Scandinavian journal of medicine & science in sports, 19*(6), 819-827.

Hallén, A., Tomás, R., Ekstrand, J., Bengtsson, H., Van den Steen, E., Hägglund, M., & Waldén, M. (2024). UEFA Women's Elite Club Injury Study: a prospective study on 1527 injuries over four consecutive seasons 2018/2019 to 2021/2022 reveals thigh muscle injuries to be most common and ACL injuries most burdensome. *British journal of sports medicine, 58*(3), 128-136. doi:10.1136/bjsports-2023-107133

Hartmut, G., Becker, A., Walther, M., & Hess, H. (2010). Injuries in women's soccer: a 1-year all players prospective field study of the women's Bundesliga (German premier league). *Clinical Journal of Sport Medicine, 20*(4), 264-271.

Hewett, T. E., Myer, G. D., Ford, K. R., Heidt Jr, R. S., Colosimo, A. J., McLean, S. G., . . . Succop, P. (2005). Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study. *The American journal of sports medicine, 33*(4), 492-501.

Horan, D., Blake, C., Hägglund, M., Kelly, S., Roe, M., & Delahunt, E. (2022a). Injuries in elite-level women's football—a two-year prospective study in the Irish Women's National League. *Scandinavian journal of medicine & science in sports, 32*(1), 177-190. doi:https://doi.org/10.1111/sms.14062

Horan, D., Blake, C., Hägglund, M., Kelly, S., Roe, M., & Delahunt, E. (2022b). Injuries in elite-level women's football—a two-year prospective study in the Irish Women's National League. *Scandinavian journal of medicine & science in sports, 32*(1), 177-190.

Ibikunle, P. o., Efobi, K. C., Nwankwo, M. J., & Ani, K. U. (2019). UEFA model in identification of types, severity and mechanism of injuries among footballers in the Nigerian Women's Premier League. *BMJ Open Sport & Exercise Medicine, 5*(1), e000386. doi:10.1136/bmjsem-2018-000386

IOC mission Retrieved from https://olympics.com/ioc/mission

Jacobson, I., & Tegner, Y. (2007). Injuries among Swedish female elite football players: a prospective population study. *Scandinavian journal of medicine & science in sports, 17*(1), 84-91.

Junge, A., Chomiak, J., & Dvorak, J. (2000). Incidence of Football Injuries in Youth Players. *The American journal of sports medicine, 28*(5_suppl), 47-50. doi:10.1177/28.suppl_5.s-47

Junge, A., Lamprecht, M., Stamm, H., Hasler, H., Bizzini, M., Tschopp, M., . . . Dvorak, J. (2011). Countrywide campaign to prevent soccer injuries in Swiss amateur players. *The American journal of sports medicine, 39*(1), 57-63.

Kiani, A., Hellquist, E., Ahlqvist, K., Gedeborg, R., & Byberg, L. (2010). Prevention of Soccer-Related Knee Injuries in Teenaged Girls. *Archives of Internal Medicine, 170*(1), 43-49. doi:10.1001/archinternmed.2009.289

Kirkendall, D. T., & Krustrup, P. Studying professional and recreational female footballers: A bibliometric exercise. *Scandinavian journal of medicine & science in sports, n/a*(n/a). doi:https://doi.org/10.1111/sms.14019

Kunz, M. (2007). 265 million playing football. *FIFA magazine, 7*, 11-15.

LaBella, C. R., Huxford, M. R., Grissom, J., Kim, K.-Y., Peng, J., & Christoffel, K. K. (2011). Effect of Neuromuscular Warm-up on Injuries in Female Soccer and Basketball Athletes in Urban Public

High Schools: Cluster Randomized Controlled Trial. *Archives of Pediatrics & Adolescent Medicine, 165*(11), 1033-1040. doi:10.1001/archpediatrics.2011.168

Larruskain, J., Lekue, J. A., Diaz, N., Odriozola, A., & Gil, S. M. (2018). A comparison of injuries in elite male and female football players: A five-season prospective study. *Scandinavian journal of medicine & science in sports, 28*(1), 237-245. doi:https://doi.org/10.1111/sms.12860

Larruskain, J., Lekue, J. A., Diaz, N., Odriozola, A., & Gil, S. M. (2018). A comparison of injuries in elite male and female football players: A five-season prospective study. *Scandinavian journal of medicine & science in sports, 28*(1), 237-245.

Leppänen, M., Pasanen, K., Kujala, U. M., Vasankari, T., Kannus, P., Äyrämö, S., . . . Parkkari, J. (2017). Stiff Landings Are Associated With Increased ACL Injury Risk in Young Female Basketball and Floorball Players. *The American journal of sports medicine, 45*(2), 386-393. doi:10.1177/0363546516665810

Lindblom, H., Sonesson, S., Torvaldsson, K., Waldén, M., & Hägglund, M. (2023a). Extended Knee Control programme lowers weekly hamstring, knee and ankle injury prevalence compared with an adductor strength programme or self-selected injury prevention exercises in adolescent and adult amateur football players: a two-armed cluster-randomised trial with an additional comparison arm. *British journal of sports medicine, 57*(2), 83-90. doi:10.1136/bjsports-2022-105890

Lindblom, H., Sonesson, S., Torvaldsson, K., Waldén, M., & Hägglund, M. (2023b). Extended Knee Control programme lowers weekly hamstring, knee and ankle injury prevalence compared with an adductor strength programme or self-selected injury prevention exercises in adolescent and adult amateur football players: a two-armed cluster-randomised trial with an additional comparison arm. *British journal of sports medicine, 57*(2), 83-90.

Mandelbaum, B. R., Silvers, H. J., Watanabe, D. S., Knarr, J. F., Thomas, S. D., Griffin, L. Y., . . . Garrett, W. (2005). Effectiveness of a Neuromuscular and Proprioceptive Training Program in Preventing Anterior Cruciate Ligament Injuries in Female Athletes: 2-Year Follow-up. *The American journal of sports medicine, 33*(7), 1003-1010. doi:10.1177/0363546504272261

Mausehund, L., & Krosshaug, T. (2024). Knee Biomechanics During Cutting Maneuvers and Secondary ACL Injury Risk: A Prospective Cohort Study of Knee Biomechanics in 756 Female Elite Handball and Soccer Players. *The American journal of sports medicine, 52*(5), 1209-1219. doi:10.1177/03635465241234255

Meeuwisse, W. H., Tyreman, H., Hagel, B., & Emery, C. (2007). A dynamic model of etiology in sport injury: the recursive nature of risk and causation. *Clinical Journal of Sport Medicine, 17*(3), 215-219.

O'Brien, J., & Finch, C. F. (2016). Injury prevention exercise programmes in professional youth soccer: understanding the perceptions of programme deliverers. *BMJ open sport & exercise medicine, 2*(1), e000075.

O'Brien, J., Young, W., & Finch, C. (2017). The use and modification of injury prevention exercises by professional youth soccer teams. *Scandinavian journal of medicine & science in sports, 27*(11), 1337-1346.

O'Brien, J., Finch, C. F., Pruna, R., & McCall, A. (2019). A new model for injury prevention in team sports: the Team-sport Injury Prevention (TIP) cycle. *Science and Medicine in Football, 3*(1), 77-80.

O'Brien, J., Young, W., & Finch, C. F. (2017). The delivery of injury prevention exercise programmes in professional youth soccer: Comparison to the FIFA 11+. *Journal of science and medicine in sport, 20*(1), 26-31.

Obërtinca, R., Meha, R., Hoxha, I., Shabani, B., Meyer, T., & Aus der Fünten, K. (2024). Efficacy of a new injury prevention programme (FUNBALL) in young male football (soccer) players: a cluster-randomised controlled trial. *British journal of sports medicine, 58*(10), 548-555.

Pfeiffer, R. P., Shea, K. G., Roberts, D., Grandstrand, S., & Bond, L. (2006). Lack of effect of a knee ligament injury prevention program on the incidence of noncontact anterior cruciate ligament injury. *Journal of Bone and Joint Surgery, 88*(8), 1769-1774. doi:10.2106/JBJS.E.00616

Quintana-Cepedal, M., López-Aguado, I., Fernández-Somoano, A., Rodríguez, M. Á., Del Valle, M., & Olmedillas, H. (2024). Injury incidence and characteristics in adolescent female football players: A systematic review with meta-analysis of prospective studies. *Biology of sport, 41*(3), 137-151.

Ramachandran, A. K., Pedley, J. S., Moeskops, S., Oliver, J. L., Myer, G. D., Hsiao, H.-I., & Lloyd, R. S. (2025). Influence of Neuromuscular Training Interventions on Jump-Landing Biomechanics and Implications for ACL Injuries in Youth Females: A Systematic Review and Meta-analysis. *Sports medicine*. doi:10.1007/s40279-025-02190-w

Robles-Palazón, F. J., López-Valenciano, A., Croix, M. D. S., Oliver, J. L., García-Gómez, A., De Baranda, P. S., & Ayala, F. (2022). Epidemiology of injuries in male and female youth football players: A systematic review and meta-analysis. *Journal of Sport and Health Science, 11*(6), 681-695.

Robles-Palazón, F. J., López-Valenciano, A., De Ste Croix, M., Oliver, J. L., García-Gómez, A., Sainz de Baranda, P., & Ayala, F. (2022). Epidemiology of injuries in male and female youth football players: A systematic review and meta-analysis. *Journal of Sport and Health Science, 11*(6), 681-695. doi:https://doi.org/10.1016/j.jshs.2021.10.002

Rössler, R., Donath, L., Bizzini, M., & Faude, O. (2016). A new injury prevention programme for children's football – FIFA 11+ Kids – can improve motor performance: a cluster-randomised controlled trial. *Journal of Sports Sciences, 34*(6), 549-556. doi:10.1080/02640414.2015.1099715

Soligard, T., Myklebust, G., Steffen, K., Holme, I., Silvers, H., Bizzini, M., . . . Andersen, T. E. (2008). Comprehensive warm-up programme to prevent injuries in young female footballers: cluster randomised controlled trial. *Bmj, 337*.

Sople, D., & Wilcox, R. B. (2025). Dynamic Warm-ups Play Pivotal Role in Athletic Performance and Injury Prevention. *Arthroscopy, Sports Medicine, and Rehabilitation, 7*(2), 101023. doi:https://doi.org/10.1016/j.asmr.2024.101023

Steffen, K., Emery, C. A., Romiti, M., Kang, J., Bizzini, M., Dvorak, J., . . . Meeuwisse, W. H. (2013). High adherence to a neuromuscular injury prevention programme (FIFA 11+) improves functional balance and reduces injury risk in Canadian youth female football players: a cluster randomised trial. *British journal of sports medicine, 47*(12), 794-802.

Steffen, K., Myklebust, G., Olsen, O. E., Holme, I., & Bahr, R. (2008). Preventing injuries in female youth football – a cluster-randomized controlled trial. *Scandinavian journal of medicine & science in sports, 18*(5), 605-614. doi:https://doi.org/10.1111/j.1600-0838.2007.00703.x

Sugimoto, D., Howell, D. R., Tocci, N. X., & Meehan III, W. P. (2018). Risk factors associated with self-reported injury history in female youth soccer players. *The Physician and sportsmedicine, 46*(3), 312-318.

Tegnander, A., Olsen, O. E., Moholdt, T. T., Engebretsen, L., & Bahr, R. (2008). Injuries in Norwegian female elite soccer: a prospective one-season cohort study. *Knee Surgery, Sports Traumatology, Arthroscopy, 16*(2), 194-198.

Thorborg, K., Krommes, K. K., Esteve, E., Clausen, M. B., Bartels, E. M., & Rathleff, M. S. (2017). Effect of specific exercise-based football injury prevention programmes on the overall injury rate in football: a systematic review and meta-analysis of the FIFA 11 and 11+ programmes. *British journal of sports medicine, 51*(7), 562-571.

Valderrabano, V., Hintermann, B., Horisberger, M., & Fung, T. S. (2006). Ligamentous posttraumatic ankle osteoarthritis. *The American journal of sports medicine, 34*(4), 612-620.

Van Mechelen, W., Hlobil, H., & Kemper, H. C. (1992). Incidence, severity, aetiology and prevention of sports injuries. *Sports medicine, 14*(2), 82-99.

VBG.(2021).https://www.vbg.de/DE/3_Praevention_und_Arbeitshilfen/1_Branchen/11_Sport/Sportreport_2020/Sportreport_2020_node.html.

Wilke, J., Niederer, D., Vogt, L., & Banzer, W. (2018). Is the message getting through? Awareness and use of the 11+ injury prevention programme in amateur level football clubs. *PloS one, 13*(4), e0195998.

Windt, J., & Gabbett, T. J. (2017). How do training and competition workloads relate to injury? The workload—injury aetiology model. *British journal of sports medicine, 51*(5), 428-435.

Winstanley, C., Reid, D., & Fulcher, M. L. (2023). Suggested improvements to the 11+ as identified by coaches, players, strength and conditioning staff and medical staff in New Zealand Football. *BMJ open sport & exercise medicine, 9*(2), e001463.

Wright, R. W. (2009). Knee injury outcomes measures. *JAAOS-Journal of the American Academy of Orthopaedic Surgeons, 17*(1), 31-39.

Zarei, M., Abbasi, H., Daneshjoo, A., Barghi, T. S., Rommers, N., Faude, O., & Rössler, R. (2018). Long-term effects of the 11+ warm-up injury prevention programme on physical performance in adolescent male football players: a cluster-randomised controlled trial. *Journal of Sports Sciences, 36*(21), 2447-2454.

Zarei, M., Abbasi, H., Namazi, P., Asgari, M., Rommers, N., & Rössler, R. (2020). The 11+ Kids warm-up programme to prevent injuries in young Iranian male high-level football (soccer) players: A cluster-randomised controlled trial. *Journal of science and medicine in sport, 23*(5), 469-474.

# 11. Appendices

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# The Football+ program

## 1. RUNNING AND STRENGTH EXERCISES



1/4

### Running straight-forward/backward

- Make sure you keep your upper body straight.
- The hip, knee, and ankle should be aligned.
- Repetitions: 3-4x
- The pace increases at levels 2-3 to 50-60%.



2

### Crossover running

- The supporting leg's hip, knee, and ankle should be aligned.
- Gradually increase your pace as you become more comfortable with the movement.



3

### Running hip-in&out

- Make sure that you keep your pelvis horizontal
- The supporting leg's hip, knee, and ankle should be aligned.
- Repetition: 1x



5

### Hip-forward swing

- Make sure that you keep your upper trunk upright.
- Bend the knee of the supporting leg slightly for balance.



6/7

### Lateral lunge with hip stretch/Walking lunge

- Make sure that you keep your pelvis horizontal.
- Repetition: 10X for each side.



8

### The single-leg squat

- Keep your non-working leg extended in front of you for balance.
- In levels 2-3, Perform the exercise but aim to lower yourself deeper toward the ground, using a slower tempo.



9

### Hamstring walkout

- Focus on keeping your hips lifted, avoid letting your hips drop towards the ground.
- Move slowly and with control to maximize the stretch in the hamstrings.
- Repetitions: 10x back and forth.



10

### Nordic hamstring exercise

- Having a mat under the knees helps reduce discomfort and pressure on the kneecaps.
- Repetitions: 12x1



11

### Copenhagen plank

- The focus should be on using the adductor muscles to control movement.
- Avoid letting your hips sag or rotate.
- Repetitions: 12, 14, and 16 on each side in three levels, respectively.



12

### Super plank

- Breathe normally.
- Hold this position for 60 seconds in level two
- At level three, lift one arm off the ground, extending it forward until it is parallel to the floor. Lower your arm to the starting position. Alternate between sides, for 45-60 seconds.



13

### Mountain climbers

- Breathe normally.
- At level three, bring your right knee and left hand simultaneously toward your chest as near as you can.
- Push them back to their original position
- Alternate between sides, while holding a stable plank position for 45-60



14

### Dynamic plank

- Breathe normally.
- Extend the duration to 45 and 60 seconds in the second and third levels, respectively.

## 2. SMALL- SIDED GAMES



15

### Mirror dribbling drill

- Duration: 30, 40, and 50 seconds at the three levels.
- Repetitions: once each player



16

### One vs. one

- Start dribbling in different directions and make sudden changes in direction.
- At the next level, the defending player is allowed to take the ball.



17

### Active passing

- Place all players within the eighteen-yard box and assign each player a number from one upward.
- Players freely run within the penalty box, and upon receiving the ball, each player is responsible for passing it to the player with the next number.



18

### Directional Agility Ball Drill

- Run forward with the ball on the foot as fast as possible.
- Upon the trainer's signal quickly change direction.
- turn right if the command is 'right' and left if the command is 'left', and promptly 'stop', if the command is stop.

## 3. PLYOMETRIC & SPRINTING EXERCISES



19

### Hurdle hops

- Start by running at a moderate to fast pace toward the first hurdle.
- By approaching each hurdle, perform a jump to clear it with minimal ground contact time.
- Focus on maintaining proper jump-landing technique, including arm swing, foot placement, upright trunk, and stride length.



20

### Zigzag hops

- Perform continuous jumps over the rings, with 2-3 seconds of ground contact time during the first 3 repetitions, and minimal ground contact time during the last 3 repetitions.
- Repetitions: 6X

## ✖ INCORRECT





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PHOTO BY BORUSSIA DORTMUND

# THE FOOTBALL+

## A comprehensive warm-up to prevent injuries and improve performance

## MANUAL

Institute for Sport and Sport Science
TU Dortmund University

# The ***Football+*** Manual

*An evidence-based warm-up regime to mitigate injuries and improve performance.*
*Designed, developed, and Launched by the Movement and Training Science Group, Institute for Sport and Sport Science, TU Dortmund University in cooperation with Borussia Dortmund (BVB09).*

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Institute for Sport and Sports Science
TU Dortmund

## Introduction

Welcome to the Football+ manual, a comprehensive guide designed to instruct trainers, coaches, players, and scientists about the Football+ program. This manual is your key to understanding the program's principles, implementation, and the science that drives it. Before you dive into the program, take some time to familiarize yourself with this manual.

## Overview

The Football+ program has been developed through a thorough evaluation of studies conducted over the past two decades. These studies have provided insights from various angles, including injury incidences, biomechanical risk factors, physiological measures, training interventions, adherence to programs in real football-world football, and the challenges encountered during implementation.

Tailoring a well-accepted and practical injury prevention program in a form of a warm-up modality requires careful consideration. Serving as the final phase of athlete preparation, the warm-up regimen aims to reduce injury risk and optimize performance. The Football+ program integrates a set of key elements essential for addressing these aims, which are specifically tailored for football players. It encompasses a range of football-specific exercises meticulously crafted to enhance motor performance while also targeting injury risk factors.

## The Football+ effects on motor performance and biomechanical risk factors

The primary studies strongly emphasize that the Football+ optimizes both acute and long-term performance, compared to other injury prevention programs and traditional warm-ups. Its effects on biomechanical risk factors have been validated against other programs and traditional warm-ups. While further studies are needed to explore all aspects of the program comprehensively, initial findings show promising efficacy for the Football+.

## Field Set-Up

The layout and equipment of the field were strategically organized to ensure seamless execution of the exercises. The Football+ requires no additional equipment and can be easily implemented in any circumstances. To set up the field for running exercises, strength exercises, and dynamic stretches, all you need is eight to ten pairs of disc cones spaced approximately four to five meters apart in length and width. For plyometric exercises, you'll require five to seven pairs of hurdles with a height of 30-50 cm, depending on the players' level and progression."

## Implementation and progression to the next level

The Football+ adopts a 3-level difficulty system to facilitate progression. As players undergo training and enhance their abilities, they advance to more challenging exercises and intensities, ensuring a gradual and safe journey toward peak performance. The progression is designed to adapt every 4-6 weeks based on player feedback, allowing continual enhancement of skills and readiness for the main training body. While implementing the program twice a week offers advantages, optimal efficiency is achieved by following the program thrice weekly.

## We Value Your Feedback

We want this manual to be as informative and user friendly as possible. After you've had a chance to review it, please provide your feedback and suggestions. Your insights helps us enhance this resource and ensure that it meets your needs and expectations. Thank you for choosing the Football+ program, and we look forward to your success and safety as you embark on this exciting training journey.

Best regards,
The Football+ Team
Mojtaba.asgari@tu-dortmund.de

# The Football+ Exercises

## Part 1. Foundation Building: Running and Strength Exercises

1. Running straight
2. Crossover running
3. Running hip-in&out
4. Running forward/backward
5. Dynamic hip swing
6. Lateral lunge with hip stretch
7. Walking lunge
8. Single leg squat **(beginner-intermediate-advanced)**
9. Hamstring walkout
10. Modified Nordic hamstring exercise **(beginner-intermediate-advanced)**
11. Copenhagen plank **(beginner-intermediate-advanced)**
12. Super plank **(beginner-intermediate-advanced)**
13. Mountain climbers plank **(beginner-intermediate-advanced)**
14. Dynamic plank **(beginner-intermediate-advanced)**

## Part 2. Ball-Based Training: Small-Sided Games

15. Mirror dribbling drill
16. One vs. one
17. Active passing
18. Directional agility ball drill

## Part 3. Explosive Performance: Plyometric, Agility, and Sprinting Drills

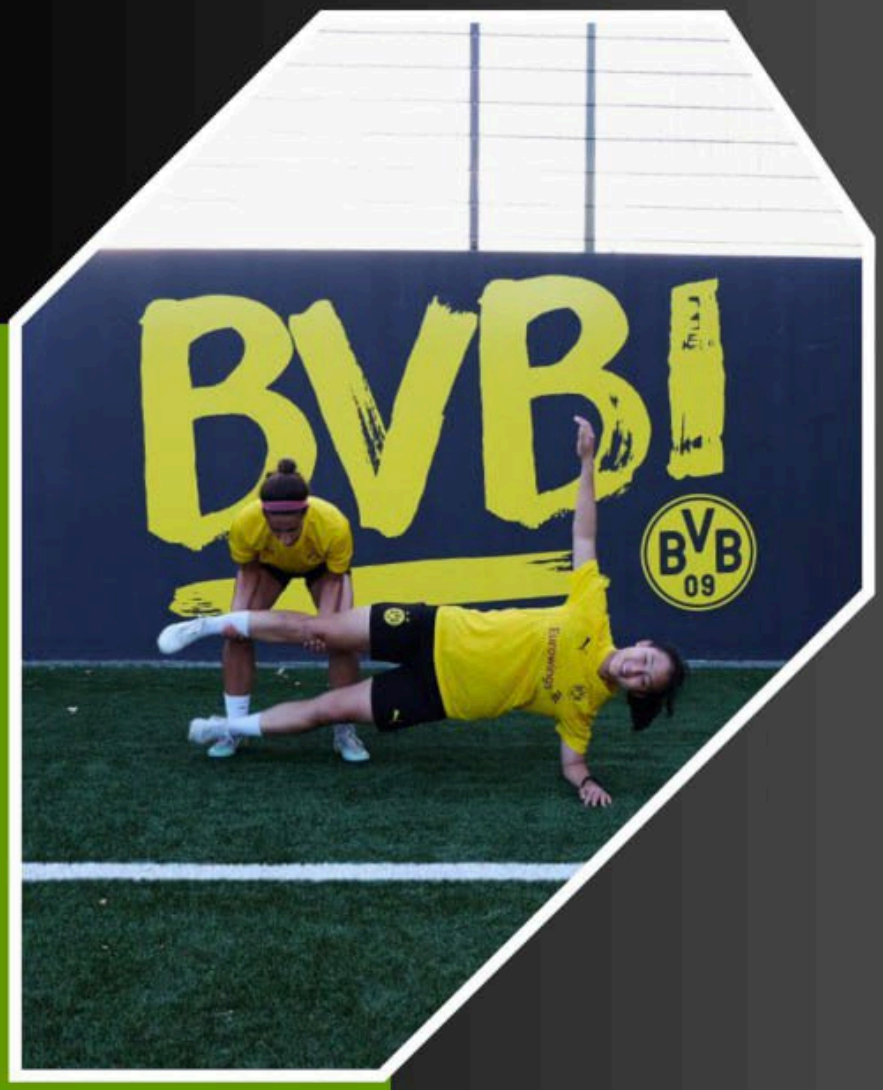
19. Hurdle hops
20. Zigzag hops

**Duration in practice: 25±2 minutes*

**How to cite this manual:**
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# PART 1

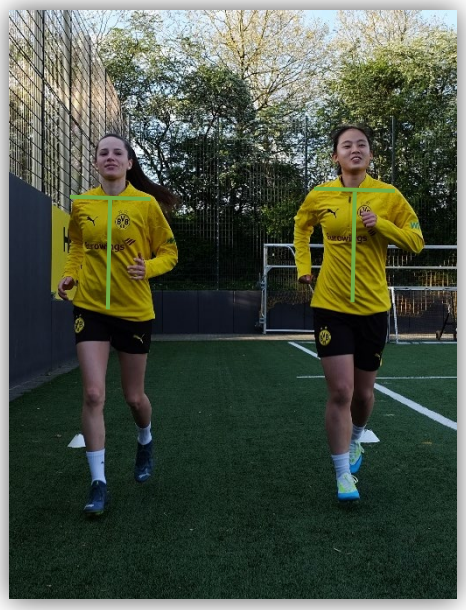
## RUNNING & STRENGTH EXERCISES



## Part1. Foundation Building: Running and Strength Exercises

The Football+ program comprises a well-structured warm-up routine that sets the stage for an effective and safe training session. In this part, we delve into the exercises that make up the initial phase of the program, preparing players for the challenges of the football pitch.

Exercise 1. Running straight: The program kicks off with a 2-minute self-estimated run across the pitch at approximately 40% of the maximal pace. Run slightly more quickly (approximately 50%*) on the way back.

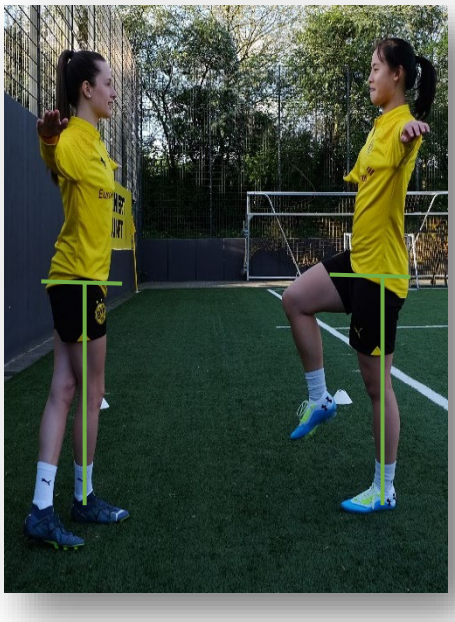


Tips:

- Make sure you keep your upper body straight.
- The hip, knee, and ankle should be aligned.
- Repetitions: 3-4x
- The pace increases at levels 2-3 to 50-60%.

****Running at 50% intensity means jogging at a pace that is halfway between walking and sprinting. To estimate this pace, players should focus on their perceived effort level rather than exact speed measurements. At 50% intensity, players should be able to maintain a conversation while running without feeling overly breathless or fatigued. Additionally, they should feel that they are exerting moderate effort without pushing themselves to the point of discomfort.*

Exercise 2. Crossover running: Start with a slight side jog, maintaining the arms parallel to the shoulders and the elbows fully extended. As you run, consciously lift your knee up and cross the leg in front of the other with each step. The crossover should be deliberate and controlled without overreaching. Continue this pattern half of the way, change your direction and do the next side. Run smoothly on the way back.



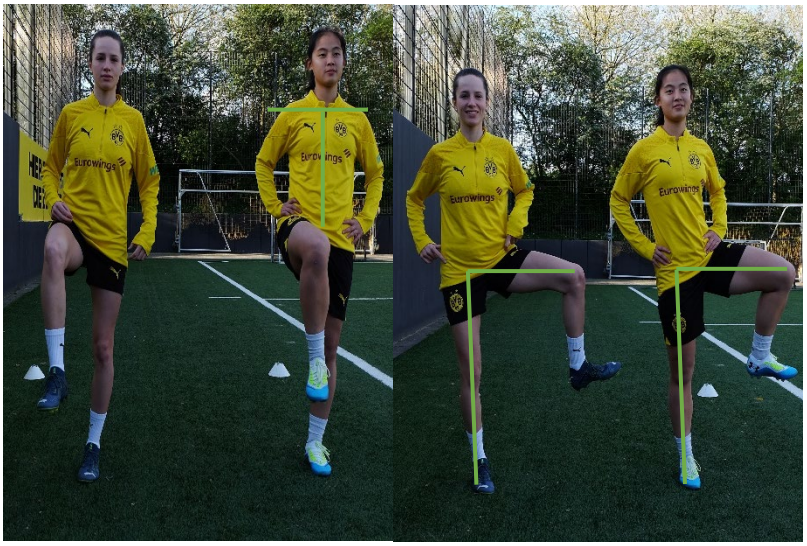
Tips:

- The hip, knee, and ankle of the supporting leg should be aligned.
- Gradually increase your pace as you become more comfortable with the movement.
- Repetitions: 1x

Exercise 3. Running hip-in&out: Jog through the cones while alternatively performing hip-in movement through the right and left legs. Lift your knee to the side, rotate it forward and put your foot down. Perform the hip-out exercise on the way back.

Tips:

- Make sure that you keep your pelvis horizontal
- The hip, knee, and ankle of the supporting leg should be aligned.
- Repetition: 1x



Exercise 4. Running forward/backward: Begin by running forward at a moderate pace towards the next cone, ensuring proper technique is maintained. Once the forward running segment is completed, transition to running backward toward the previous cone. Continue through the pathway following the algorithm of two cones forward, one cone backward.

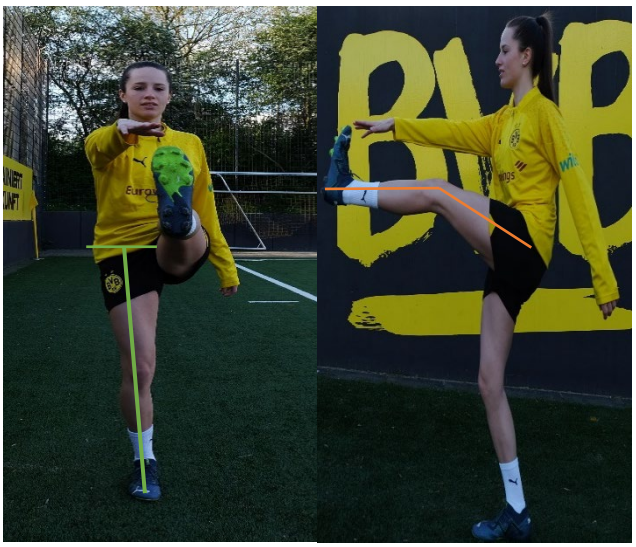
Tips:

- Safety precautions should be taken during this exercise to maintain proper footing and encourage players to be mindful of their surroundings to avoid collisions or injuries.
- Focus on maintaining good posture and keeping the upper body stable while running.
- Incorporate variations such as changing the pace, and adding directional changes in levels 2-3.

Exercise 5. Hip-forward swing: Jog through the cones while alternatively performing hip-forward swing in a controlled and dynamic motion. As you swing the leg forward, allow it to reach a position parallel to the ground, engaging the hip flexors. Maintain a smooth and natural rhythm, focusing on the continuous swinging motion. Run smoothly on the way back.

Tips:

- Make sure that you keep your upper trunk upright.
- Bend the knee of supporting leg slightly for balance.
- The hip, knee, and ankle of the supporting leg should be aligned.
- Repetition: 10X for each side.



*Correct* *Incorrect*

Exercise 6. Lateral lunge with hip stretch: Starting by standing with your feet together and maintaining an upright posture. Take a step to the side, leading with one leg, and lower your body into a lunge position, keeping the other leg straight. While in the lunge, gently push your hip outward to the side to create a stretch in the hip area. Stand up; repeat the movement by taking a step to the side with the same leg. Continue this pattern halfway, switch to the other side, and repeat the exercise. Run smoothly backward on the way back.




Tips:

- Repetition: 10X for each side.
- Make sure that you keep your pelvis horizontal.

Exercise 7. Walking lunge: Starting by standing with your feet together and maintaining an upright posture. Take a step forward with one leg, ensuring a comfortable stride length. Lower your body into a lunge position, with both knees bending at approximately 90 degree angles. As you lunge forward, keep your back straight and chest up. After reaching the lunge position, push through the heel of the leading leg to return to a standing position. Immediately step forward with the opposite leg and repeat the lunge. Run slowly on the way back.




Tips:

- Make sure that you keep your upper trunk upright.
- Make sure that you keep your pelvis horizontal.
- Repetition: 1X

Exercise 8. The single-leg squat: Stand with your feet shoulder-width apart. Shift your weight onto one leg while keeping the other foot slightly lifted off the ground. Begin the movement by bending your knee and lowering your body down as if sitting back into a chair, while maintaining a proper alignment through the ankle, knee and hip. Keep your chest up and your back straight as you descend. Lower yourself as far as you can comfortably go while maintaining balance and control. Push through your heel to return to the starting position.

Tips:

- Keep your non-working leg extended in front of you for balance.
- Level 2: Perform the single-leg squat as described above, but aim to lower yourself deeper toward the ground, using a slower tempo to challenge your muscles further.
- Level 3: Aim to lower yourself as close to the ground as possible while maintaining proper form.
- Do not allow the knees to buckle in (Valgus position)



*Correct* *Incorrect*

Exercise 9. Hamstring walkout: Begin by lying on your back with your knees bent and feet flat on the ground, hip-width apart. Lift your hips off the ground, coming into a shoulder bridge position with your body forming a straight line from shoulders to knees. Slowly extend your legs out in front of you, walking your feet away from your body until your heels touch the ground, feeling a stretch in your hamstrings. Return to the starting position by walking your feet back towards your body, lifting your hips high in the bridge position.



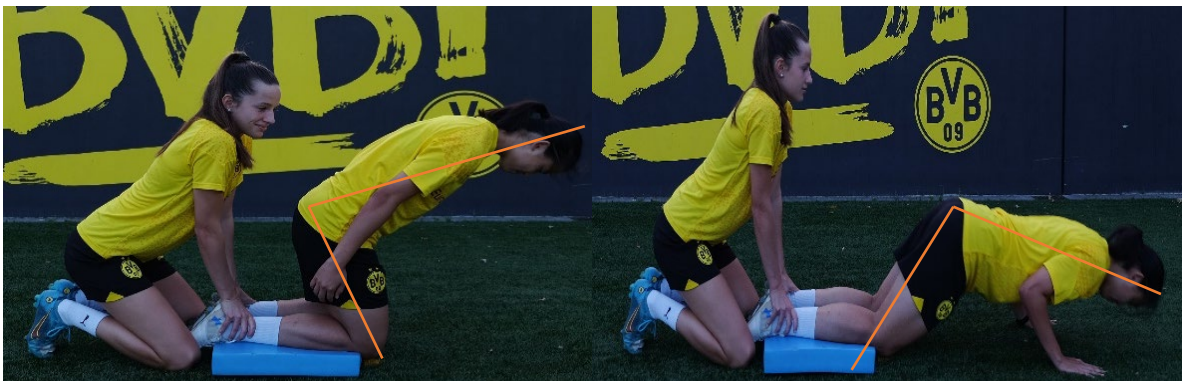
Tips:

- Focus on keeping your hips lifted, avoid overarching your lower back or letting your hips drop towards the ground.
- Move slowly and with control to maximize the stretch in the hamstrings.
- Repetitions: 10x back and forth.

Exercise 10. Nordic hamstring exercise (NHE): Kneel on the floor on a padded mat. Ask your partner to hold your feet down, securing them firmly. Maintain a straight line from your knees to your head throughout the exercise. Slowly lean forward from your knees, maintaining control and keeping your body in a straight alignment. Gradually lower your upper body toward the ground while controlling the movement with your hamstrings. The aim is to descend as far as possible while using the hamstrings to resist the lowering motion. Once you've reached your maximum range of motion or cannot control the descent any longer, put your hands on the floor to support your body and continue descending until the knees are fully extended. Then return to the starting kneeling position.



*Correct*



*Incorrect*

Tips:

- Performing the NHE with a mat under the knees helps reduce discomfort and pressure on the kneecaps.
- In level 3, aim to reach the fully extended knee position without using your hands' support.
- Repetitions: 12x

## Plank variations

Exercise 11. Copenhagen plank: Strengthens the adductor muscles that often do not receive the attention they deserve. Begin by lying on your side ensure that your body is in a straight line from your head to heels, with your legs stacked on top of each other. Prop yourself up on your forearm, ensuring that your elbow is directly below your shoulder for support. Ask your partner to hold your upper leg at hip height and support the ankle and knee joints. While maintaining the side plank position, slowly lower your opposite foot toward the ground.

Tips:

- The focus should be on using the adductor muscles of the inner thigh to control movement.
- Avoid letting your hips sag or rotate during this motion.
- Repetitions: 12,14,16, each side in three levels, respectively.



*Correct*



*Incorrect*

Exercise 12. Super plank: Begin in a traditional plank position, supporting your body on your forearms and toes, maintaining a straight line from your head to heels. Now move both arms forward, increasing the angle generated by the arms and the floor. Engage your core muscles, glutes, and legs to stabilize your body and maintain the plank position. Hold this extended position for 30-45 seconds, focusing on balance and stability without allowing your body to rotate or lose alignment.

Tips:

- Breathe normally.
- Hold this position for one minute in level two
- At level three, lift one arm off the ground, extending it forward until it is parallel to the floor. Lower your arm to the starting position. Repeat the movement on the opposite side. Alternate between sides, maintaining the plank position for 45-60 seconds.



*Correct (advanced)*



*Correct*



*Incorrect*



*Incorrect*

Exercise 13. Mountain climbers: Begin in a traditional plank position. Make sure your arms are shoulder-width apart, and the spine is straight. Bring your right knee toward your chest as near as you can. Push it back to its original position while bringing the left knee toward your chest. The exercise looks as if you are climbing a mountain and hence the name. Alternate between sides, maintaining a controlled and stable plank position for 30-45 and 45-60 seconds at beginner and intermediate levels.

Tips:

- Breathe normally.
- At level three, bring your right knee and left hand simultaneously toward your chest as near as you can.
- Push them back to their original position while bringing the left knee and right hand toward your chest.
- Alternate between sides, maintaining a controlled and stable plank position for 45-60



*Correct*



*Incorrect*

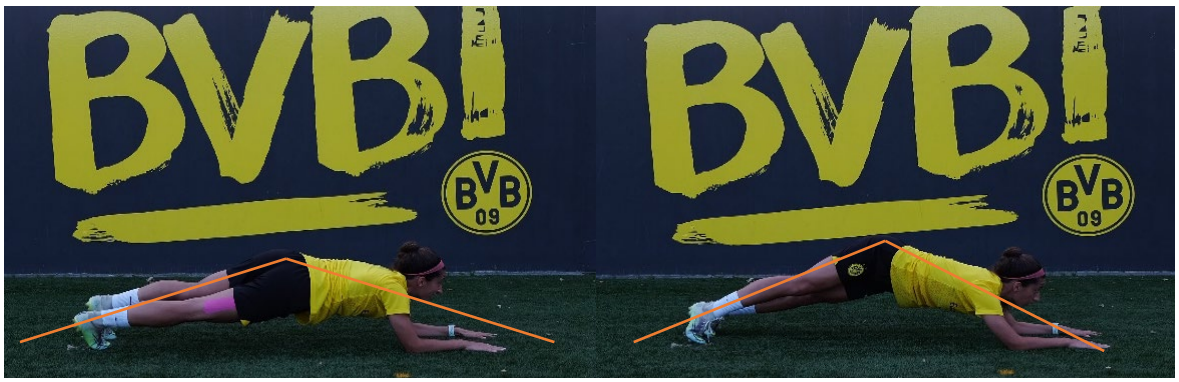
Exercise 14. Dynamic plank: Begin in a traditional plank position, supporting your body on your forearms and toes, maintaining a straight line from your head to heels. Now move both arms forward, increasing the angle generated by the arms and the floor. While maintaining the plank position, initiate a controlled rotation of your pelvis to the right, tilting it downward. Return to the center, align your pelvis back to the starting position and repeat the rotation, this time tilting your pelvis to the left while maintaining the plank posture. Continue alternating rotations from right to left for 30 seconds, focusing on controlled and deliberate movements without excessively swaying or shifting your body weight. Maintain a stable and engaged core throughout the exercise to support the rotational movements.

Tips:

- Extend the duration to 45 and 60 seconds in the second and third levels, respectively.



*Correct*



*Incorrect*

# PART 2

## SMALL-SIDED GAMES



## Part 2. Ball-Based Training: Small-Sided Games.

****In each session, perform three out of the following four exercises!*

Exercise 15. Mirror dribbling drill: Divide into pairs. While each player has a ball, the first player begins dribbling and performing various maneuvers with the ball. The second player, positioned behind the first player, must precisely replicate the same maneuvers and dribbles, mimicking the movements of the first player. Switch the positions of the first and second players, and repeat the exercise.

Tips:

- Duration: 30, 40, and 50 seconds at the three levels.
- Repetitions: once each player




Exercise 16. One vs. one: Do the following steps to perform this exercise:

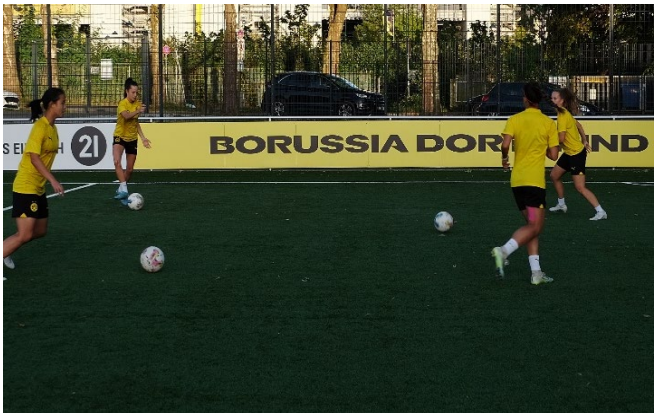
- The player with the ball starts dribbling in different directions and makes sudden changes in direction.
- The defending player is required to maintain a proper defensive posture, shadow the attacking player, and apply pressure (initially without taking the ball).
- Switch positions and repeat the exercise.
- At the next level, the defending player is allowed to take the ball, and the positions of the defender and attacker switch.
- In the third level, while dribbling, the attacking player begins a countdown from 100 downward in threes, such as 100, 97, 94, 91, and so on, until the end.




****The countdown provides cognitive distraction and an external focus for the player performing the dribbling exercise. This external focus helps the player maintain concentration, enhance decision-making abilities, and improve performance under pressure by engaging the mind with a specific task, thereby potentially simulating game-like situations where players need to perform technical skills while multitasking or dealing with distractions.*

## Exercise 17. Active passing: Do the following steps to perform this exercise:

- Place all players within the eighteen-yard box and assign each player a number from one upward.
- Players freely run within the penalty box, and upon receiving the ball, each player is responsible for passing it to the player with the next number.
- During the exercise, advise players to establish clear verbal and visual communication, assume correct positions, and maintain logical distances from the players before and after them.
- Initiate the exercise with three balls; gradually increasing the number of balls up to a maximum of half the number of players participating.



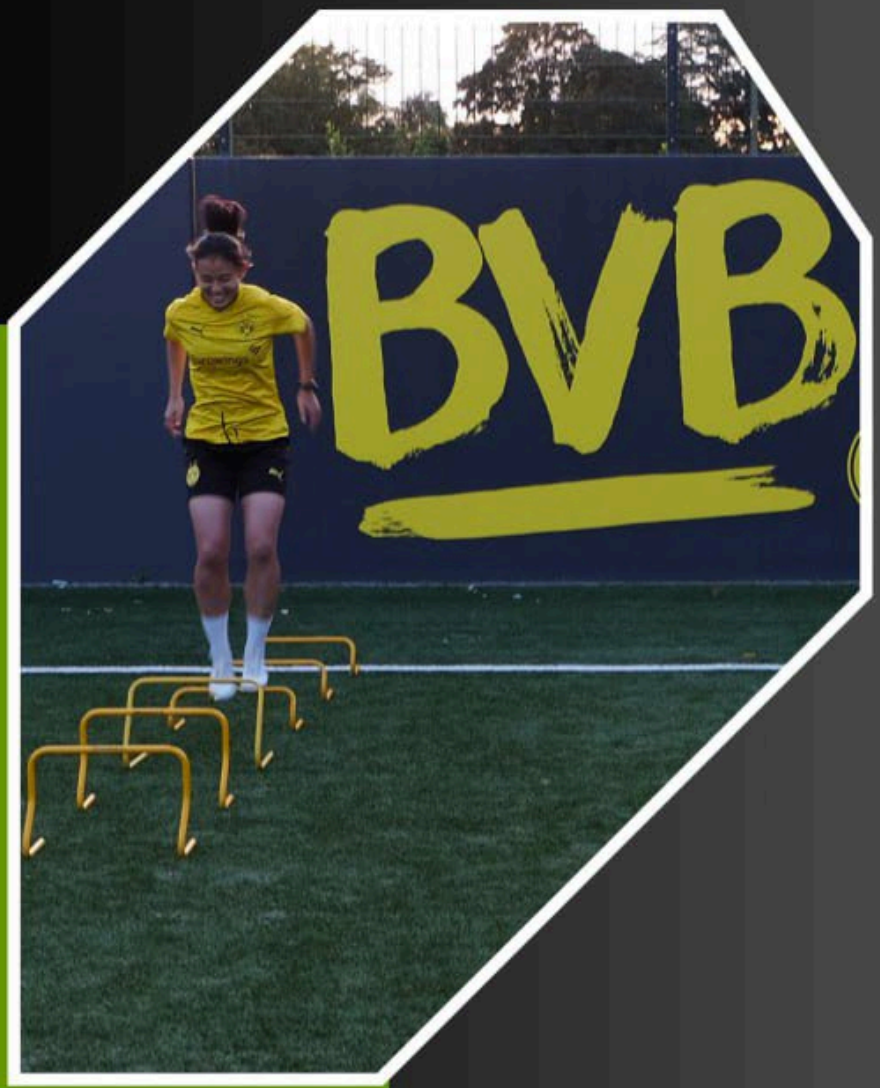

## Exercise 18. Directional Agility Ball Drill:

The players stand on the penalty box line, spaced 3-4 meters apart. Upon the trainer's signal, they begin running forward with the ball on their foot as fast as possible. When instructed by the trainer, they must quickly change direction. They should turn right if the command is 'right' and left if the command is 'left', and then continue running in that direction until given a new instruction. If the command is 'stop,' they must promptly come to a halt and place their foot on the ball.



# PART 3

## PLYOMETRIC& SPRINTING EXERCISES



## Part 3. Plyometric, Agility, and Sprinting Drills

Incorporate agility drills and sprints with plyometric exercises to enhance the ability to change direction quickly and accelerate, while also maximizing speed and explosiveness. This part involves a series of plyometric exercises that gradually increase in intensity and complexity.

Exercise 19. Hurdle hops: Set up hurdles in a straight line, spaced evenly apart to create a series of hurdles to jump over, and at a height appropriate for participants' abilities. The distance between the hurdles can vary based on the desired challenge level and the available space.

Tips:

- Players begin at one end of the course, starting by running at a moderate to fast pace toward the first hurdle.
- As players approach each hurdle, they perform a jump to clear it with minimal ground contact time while continuing to run.
- Throughout the exercise, participants focus on maintaining proper jump-landing technique, including arm swing, foot placement, upright trunk and stride length.
- When jumping over the hurdles, aim to land softly with bent knees to absorb the impact and minimize stress on the joints. Do not allow the knees to buckle.
- Jump over the last hurdle and immediately do a zigzag sprint through a pair of marker cones spaced 5 meters apart and designed in a zigzag form.
- To increase the challenge and intensity of the exercise, participants can increase the height or width of the hurdles, or the number of repetitions performed.




*Correct*




*Incorrect*

****Perform the following variations: a two-footed jump, a single-leg jump, and a lateral jump.*

Exercise 20. Zigzag hops: Set up exercise rings in a zigzag pattern, spaced evenly apart to create a series of rings to jump in.

Tips:

- Perform continuous jumps over the rings, focusing on clearing each ring with 2-3 seconds ground contact time during the first 3 repetitions, and minimal ground contact time during the last 3 repetitions.
- Maintain an upright posture, drive the knees upward to generate height and power, and ensure that your knees do not buckle in and your ankles do not pronate upon landing.
- Emphasize quick and explosive movements to navigate through the cones efficiently.
- Progression can be achieved by increasing the distance covered or increasing the width of the rings. Perform a 10-meter linear sprinting immediately after last hop.
- Repetitions: 6X



*Correct*



*Incorrect*

****Throughout the plyometric exercises, constantly remind participants to perform each exercise as quickly and explosively as possible while maintaining proper landing form and technique. Emphasize the importance of maximizing the stretch-shortening cycle, which involves rapidly stretching the muscles (eccentric phase) followed by an immediate contraction (concentric phase) to generate explosive power. Encourage participants to push their limits while prioritizing the safety and proper execution of each plyometric exercise.*