DOCTORAL THESIS

UCAM
UNIVERSIDAD CATÓLICA DE MURCIA

INTERNATIONAL DOCTORAL SCHOOL

Doctoral Programme in Sports Science

EFFECTS OF DIFFERENT STRENGTH AND CONDITIONING PROGRAMS VARIATIONS ON PERFORMANCE VARIABLES IN PROFESSIONAL FEMALE SOCCER PLAYERS

Author:
Sefika Pelin Bal

Supervisors:
Dr. Luis Manuel Martínez Aranda
Dr. Javier Raya González

Murcia, September 2025

DOCTORAL THESIS

UCAM
UNIVERSIDAD CATÓLICA DE MURCIA

ESCUELA INTERNACIONAL DE DOCTORADO

Programa de Doctorado en Ciencias del Deporte

EFFECTS OF DIFFERENT STRENGTH AND CONDITIONING PROGRAMS VARIATIONS ON PERFORMANCE VARIABLES IN PROFESSIONAL FEMALE SOCCER PLAYERS

Autor:

Sefika Pelin Bal

Directores:

Dr. Luis Manuel Martínez Aranda

Dr. Javier Raya González

Murcia, septiembre de 2025

THESIS SUPERVISORS' AUTHORISATION
FOR THESIS SUBMISSION

Prof. Dr. Luis Manuel Martínez Aranda and Prof. Dr. Javier Raya González, as Supervisors(1) of the Doctoral Thesis 'Effects of Different Strength and Conditioning Programs Variations on Performance in Professional Female Soccer Players' by Sefika Pelin Bal in the Doctorate Programme Sports Science, **authorise(s) its submission**, given that it meets the required conditions for its defence.

Which I hereby sign in compliance with Spanish Royal Decree 99/2011, of 28 January, in Murcia, on 29 September, 2025.

Dr. Luis Manuel Martínez Aranda

Dr. Javier Raya González

(1) If the Thesis is supervised by more than one Supervisor, both must be mentioned and both must sign.

ABSTRACT

Soccer is the world's most popular sport, and women's participation has grown rapidly in recent decades, reaching new levels of professionalization and global visibility. Despite this progress, research on female players remains limited compared to their male counterparts, particularly regarding evidence-based training approaches. This doctoral thesis investigates the effects of strength and sprint-based training interventions on the physical fitness and match performance of female soccer players. Although women's soccer has gained remarkable popularity and professionalization in recent decades, research remains disproportionately focused on male athletes, leaving significant gaps in evidence-based training guidelines tailored to women.

Through three complementary studies, this work evaluates (i) the short-term impact of in-season strength training in adolescent players, (ii) the comparison between traditional and integrated sprint training in professional players, and (iii) the long-term effects of structured strength training across two competitive seasons in youth female athletes. All three studies followed an experimental intervention design, applying specific training programs over defined periods and assessing pre- and post-intervention changes in performance. The research employs physical fitness tests (e.g., countermovement jump, aerobic capacity, sprint performance) and GPS-based match external load metrics (e.g., total distance, very-high-speed running, number of sprints, and maximum velocity).

The results indicate that short-term strength training enhanced fitness and match outputs in youth players, specific sprint training method led to higher benefits in professional players, and long-term strength training promoted consistent and lasting improvements. Collectively, this thesis advances current knowledge in sports science by providing evidence-based recommendations to optimize periodization, conditioning, and injury prevention strategies in women's soccer.

Keywords: Women's soccer; strength training; sprint training; physical fitness; match performance; GPS.

RESUMEN

El fútbol es el deporte más popular del mundo, y la participación femenina ha crecido rápidamente en las últimas décadas, alcanzando nuevos niveles de profesionalización y visibilidad global. A pesar de este progreso, la investigación sobre jugadoras sigue siendo limitada en comparación con sus homólogos masculinos, especialmente en lo que respecta a enfoques de entrenamiento basados en la evidencia. Esta tesis doctoral investiga los efectos de las intervenciones de entrenamiento de fuerza y de velocidad sobre la condición física y el rendimiento en competición de futbolistas femeninas. Aunque el fútbol femenino ha experimentado una notable popularidad y profesionalización en los últimos años, la investigación sigue centrada de manera desproporcionada en los hombres, lo que genera vacíos importantes en las directrices de entrenamiento específicas para mujeres basadas en la evidencia.

A través de tres estudios complementarios, este trabajo evalúa (i) el impacto a corto plazo de un programa de fuerza realizado durante la temporada en jugadoras adolescentes, (ii) la comparación entre el entrenamiento de velocidad tradicional y el entrenamiento integrado en jugadoras profesionales, y (iii) los efectos a largo plazo de un programa estructurado de fuerza a lo largo de dos temporadas competitivas en futbolistas juveniles. Los tres estudios siguieron un diseño experimental de intervención, aplicando programas de entrenamiento específicos durante periodos definidos y evaluando los cambios en el rendimiento antes y después de la intervención. La investigación incluye pruebas de condición física (p. ej., salto con contramovimiento, capacidad aeróbica, rendimiento en sprint) y métricas de carga externa en competición obtenidas mediante GPS (p. ej., distancia total, carrera a muy alta velocidad, número de esprints y velocidad máxima).

Los resultados indican que el entrenamiento de fuerza a corto plazo mejoró la condición física y el rendimiento en competición de las jugadoras juveniles, los métodos específicos de entrenamiento de velocidad generaron beneficios diferenciados en las jugadoras profesionales, y el entrenamiento de fuerza a largo plazo promovió mejoras consistentes y duraderas. En conjunto, esta tesis amplía el conocimiento actual en ciencias del deporte al proporcionar recomendaciones

basadas en la evidencia para optimizar la periodización, la preparación física y la prevención de lesiones en el fútbol femenino.

Palabras clave: Fútbol femenino; entrenamiento de fuerza; entrenamiento de velocidad; condición física; rendimiento competitivo; GPS.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to my supervisors, whose guidance, encouragement, and expertise have been invaluable throughout this PhD journey. I am also thankful to my colleagues and collaborators for their insightful discussions and support during data collection and analysis. Special thanks go to the players, coaches, and clubs who kindly agreed to participate in this research. Without their commitment, this work would not have been possible.

I owe my heartfelt appreciation to my family and friends, who have provided unconditional love, patience, and motivation during the demanding years of this doctorate. Finally, I dedicate this thesis to all women athletes whose passion and perseverance continue to inspire progress in sports science and beyond.

‘It's hard to beat a person who never gives up.’

Babe Ruth

‘Originality consists in returning to the origin, so original is that it returns to the simplicity of the first solutions.’ Antoni Gaudi (1852-1926).

GENERAL TABLE OF CONTENTS

ABSTRACT **9**

I - INTRODUCTION **24**

1.1. Contextual Approach to Soccer **25**

1.2. Match Running Demands in Female Soccer **28**

1.2.1. Total Distance and High-Intensity Running 29

1.2.2. Sprinting and Acceleration Demands 31

1.2.3. Repeated-Sprint Ability (RSA) 32

1.2.4. Season Program and Fatigue-Related Variations 32

1.3. Physical fitness in female soccer players **33**

1.3.1. Aerobic Capacity 34

1.3.2. Anaerobic Capacity and Power 35

1.3.3. Muscular Strength and Explosive Power 37

1.3.4. Relationship Between Physical Fitness and Match Running Demands. 38

1.4. Strength Training Methods for Improving Physical Fitness Performance **41**

1.5. Effects of Strength Training Programs on Female Soccer Players **45**

1.5.1. Effects on Physical Fitness Tests 45

1.5.2. Effects on Match Running Demands and Outcomes 48

II - OBJECTIVES AND HYPOTHESES **52**

2.1. General Objective **52**

2.2. Specific Objectives and Hypotheses **52**

2.2.1. Study 1: Young elite female players: In-season strength training (10 weeks) 52

2.2.2. Study 2: Professional female players: Traditional vs. Modified Integrated Sprint Training (12 weeks) 53

2.2.3. Study 3: Young elite female players: Long-term traditional strength training (two seasons) ... 53
2.2.4. Integrated Thesis Perspective ... 54
III - Impact of a 10-Week Strength Training Program on Physical Performance and Match External Load in Young Elite Female Soccer Players ... 56
3.1. Abstract ... 56
3.2. Introduction ... 57
3.3. Materials and Methods ... 59
3.3.1. Study Design ... 59
3.3.2. Participants ... 60
3.3.3. Procedures ... 61
3.3.4. Test ... 62
3.3.5. Match Running Demands ... 63
3.3.6. Strength Training Program ... 63
3.3.7. Statistical Analysis ... 68
3.4. Results ... 68
3.5. Discussion ... 71
3.6. Conclusions ... 73
IV - The Differential Effects of Two Complementary Sprint-Based Training Programs on Sprint Performance in Professional Female Soccer Players ... 76
4.1. Abstract ... 76
4.2. Introduction ... 77
4.3. Method ... 79
4.3.1. Study Design ... 79
4.3.2. Participants ... 79
4.3.3. Procedures ... 80
4.3.4. Test ... 81

4.3.5. Statistical Analysis 83
4.4. Results 83
4.5. Discussion 84
4.6. Conclusion 87
V - Implementing a Two-Season Traditional Strength Training Intervention: Chronic Adaptations in Physical Fitness and External Match Demands of Elite Young Female Soccer Players. 90
5.1. Abstract 90
5.2. Introduction 91
5.3. Method 92
5.3.1. Study Design 92
5.3.2. Participants 93
5.3.3. Procedures 94
5.3.4. Test 94
5.3.5. Intervention Program 95
5.3.6. Statistical Analysis 97
5.4. Results 97
5.5. Discussion 101
5.6. Conclusions 104
VI - CONCLUSIONS AND PRACTICAL APPLICATIONS 106
6.1. Conclusions 106
6.1.1. General Conclusion 106
6.1.2. Specific Conclusions 106
6.2. Practical Applications 107
VII - LIMITATIONS AND FUTURE WORK 110
7.1. Limitations 110
7.2. Future Work 111

VIII - BIBLIOGRAPHICAL REFERENCES 114

IX - APPENDICES 144

Appendix 1. Study 1: Impact of a 10-week Strength Training Program on Performance and match External Load in Young Elite Female Soccer Players **... 144**

Appendix 2. The Informed Consent **..... 159**

Appendix 3. The Ethical Committee Approval **..... 161**

ACRONYMS AND ABBREVIATIONS

The abbreviations of the units from the International System Units are not included in the following list as there are internationally accepted standards for their use. In addition, no abbreviations universally used in statistics are presented in this section.

1RM, One Repetition Maximum
ACL, Anterior Cruciate Ligament
CG, Control Group
CMJ, Countermovement Jump
CSTT, Complementary Strength Training Program
EG, Experimental Group
ES, Effect Size
GPS, Global Positioning System
HIR, High-Intensity Running
HSR, High-Speed Running
MIST, Modified Integrated Sprint Training
ROM, Range of Motion
RSA, Repeated-Sprint Ability
S1, Season 1
S2, Season 2
SD, Standard Deviation
ST, Strength Training
TD, Total Distance
TST, Traditional Sprint Training
VHSR, Very-High-Speed Running
Vmax, Maximum Velocity
VO_2max, Maximal Oxygen Uptake
WSL, Women's Super League
Δ (%), Percentage of Change

LIST OF FIGURES, TABLES AND APPENDIXES

LIST OF FIGURES

Figure 1. CONSORT diagram of participant's recruitment, allocation, follow-up, and analysis..... 61

Figure 2. Individual changes in physical performance and match load variables before (baseline) and after (post training) the 10-week intervention period. Abbreviations: CG = control group; EG = experimental group 70

Figure 3. Within-group changes in CMJ and VO_2max..... 99

Figure 4. Within-group changes in TD, VHSR and Vmax 100

LIST OF TABLES

Table 1. Year-on-year growth in soccer publications 26

Table 2. Session 1 for the complementary strength training program. 64

Table 3. Session 2 for the complementary strength training program. 66

Table 4. Changes in physical performance and match load variables before (baseline) and after (post-training) the 10-week intervention period 69

Table 5. Modified Integrated Sprint Training (MIST) 82

Table 6. Traditional Sprint Training (TST) 83

Table 7. Changes in physical fitness and match load variables before (baseline) and after (post-training) the application of the sprint-based training programs. 84

Table 8. Session-1 for the Traditional Strength Training Program. 96

Table 9. Session-2 for the Complementary Strength Training Program. 96

Table 10a. Descriptive data related to physical fitness and match load variables across the 2-years follow-up 97

Table 10b. Descriptive data related to physical fitness and match load variables across the 2-years follow-up 98

Table 11. Between-groups differences in physical fitness and match load variables across the 2-years follow-up 101

APPENDIXES

Appendix 1. Study 1: Impact of a 10-week Strength Training Program on Performance and match External Load in Young Elite Female Soccer Players ... 144

Appendix 2. The Informed Consent ... 159

Appendix 3. The Ethical Committee Approval ... 161

I – INTRODUCTION

I - INTRODUCTION

Soccer is widely regarded as the most popular sport in the world, with more than 265 million active participants across continents (Fédération Internationale de Football Association [FIFA], 2007). Beyond its role as a global cultural phenomenon, soccer has become an important focus of scientific inquiry, particularly in the areas of performance optimization, health promotion, and social development. Over the last three decades, women's soccer has grown significantly in participation, visibility, and professionalization, with milestones such as the establishment of the FIFA Women's World Cup in 1991 and the expansion of elite domestic leagues (FIFA, 2023a; FIFA, 2024).

Despite this progress, research on female players continues to lag behind that on male athletes, resulting in knowledge gaps that limit the development of evidence-based training practices (Kirkendall & Krustrup, 2022). Historically, much of the literature on soccer performance has been extrapolated from studies in men, overlooking the physiological, biomechanical, and sociocultural particularities of women athletes (Fink, 2015). Addressing these disparities is essential, not only to improve performance but also to enhance player welfare and long-term development.

In contemporary soccer, performance is strongly linked to the ability to execute high-intensity actions, including sprints, accelerations, and repeated changes of direction, while sustaining overall endurance demands throughout competition (Beato et al., 2023). Female players encounter additional considerations such as hormonal fluctuations, lower absolute muscle mass, and higher susceptibility to injuries such as anterior cruciate ligament (ACL) tears (Herzberg et al., 2017; Hewett et al., 2006b; Randell et al., 2021). These factors highlight the importance of developing training interventions that are both context-specific and scientifically validated.

The purpose of this thesis is to examine the effects of structured strength and sprint-based training interventions on the physical fitness and match performance of female soccer players. By integrating controlled physical testing with applied match data, this work aims to provide new insights into how targeted conditioning strategies can improve athletic performance, reduce injury risk, and contribute to the ongoing professionalization of women's soccer.

1.1. CONTEXTUAL APPROACH TO SOCCER

Soccer is the most popular sport globally, with over 265 million participants, showcasing its universal appeal and cultural significance (FIFA, 2007). This global reach further underscores the game's ability to unite diverse communities, promote social inclusion, and act as a platform for cultural exchange. Despite its role as a unifying force, the sport has historically been male dominated in participation and representation. While professionalization has advanced rapidly in men's soccer, women's soccer has traditionally lagged behind due to systemic inequities, including uneven access to funding and limited media exposure. These disparities have resulted in a gender imbalance in the development and visibility of women's soccer, emphasizing the need for structural changes.

The first recorded international women's football match was in Edinburgh in 1881, featuring Scotland and England. Women's football developed gradually, gaining traction during World War I as women took over roles in factories and on the pitch. However, a significant setback occurred in 1921 when the Football Association in England banned women from playing, followed by similar bans in France (1932), Germany (1955), and Brazil (until 1979). While the first men's FIFA World Cup was held in 1930, the women's equivalent did not begin until 1991 (Nassis et al., 2021). Since then, the sport has seen steady growth, with the 2023 Women's World Cup attracting a record 2 billion viewers (FIFA, 2023a). This rising popularity has also contributed to an increase in scientific research, as shown on the table below which is extrapolated from Figure 1 from Kirkendall & Krustrup, 2022.

Table 1. *Year-on-year growth in soccer publications*

	Female Soccer	Male Soccer	Female Professional	Male Professional
2000	30	270	2	18
2019	380	1170	12	348
2000–2019 % Increase	1 167%	333%	500%	1 833%

As the table highlights, even though there has been a welcome increase in research in the number of articles on women's soccer, based on the output of articles it can be inferred that research on especially on professional women's soccer is still lagging behind compared to men's soccer.

Nonetheless, women's soccer has seen remarkable growth, highlighted by key events and initiatives addressing inequalities. The number of women and girls participating in organized football has increased by nearly a quarter since 2019, reaching 16.6 million in 2023 (FIFA 2023b). The establishment of the FIFA Women's World Cup in 1991 marked a crucial milestone, providing a platform for female athletes to show their talents on a global stage. This, along with the growing visibility of professional leagues like the National Women's Soccer League (NWSL) in the United States and the Women's Super League (WSL) in England, has elevated the status of women's soccer, inspiring millions of young athletes worldwide.

Furthermore, global movements advocating for gender equality in sports have further propelled the growth of women's soccer, with organizations like Equal Playing Field and campaigns such as #ChangeTheGame supporting the cause. In 2018, FIFA introduced its first-ever global women's football strategy, outlining how it would collaborate with its stakeholders. At the forefront of women's football is the FIFA Women's World Cup™—the greatest catalyst driving the game's growth

every four years. The 2015 edition in Canada drew unprecedented interest, with over 750 million fans tuning in worldwide. In France in 2019, the tournament reached new heights, with 1.12 billion viewers experiencing the magic of the competition across more than 200 territories. Then, in 2023, the FIFA Women's World Cup in Australia and Aotearoa, New Zealand, went #BeyondGreatness, attracting a global audience of over 2 billion supporters and filling stadiums with almost 2 million spectators (FIFA, 2024).

Despite these advancements, significant challenges remain. Women's soccer players encounter unique physiological and biomechanical factors that affect their performance and training needs. Hormonal fluctuations, such as those related to the menstrual cycle, can influence energy levels, recovery, and injury risk (Herzberg et al., 2017; Randell et al., 2021). Moreover, variations in muscle mass and neuromuscular coordination lead to a higher vulnerability to anterior cruciate ligament (ACL) injuries in women athletes, a critical concern widely documented in sports science literature as women have a higher risk than men (Herzberg et al., 2017; Hewett et al., 2006b; Randell et al., 2021). These factors highlight the importance of customized training programs that cater to the specific requirements of women players to improve performance and reduce injury risks.

The evolution of modern women's soccer has introduced new physical and tactical demands, emphasizing speed, power, and endurance. Players are now expected to perform at levels comparable to their male counterparts, focusing more on high-intensity actions such as sprints, accelerations, and decelerations (Beato et al., 2023). This shift highlights the importance of developing targeted strength and conditioning interventions, which are crucial for meeting the increasing physical demands of the game (McQuilliam et al., 2022). Such interventions must enhance performance while accounting for the physiological differences unique to women athletes, ensuring training programs are both effective and appropriate for long-term development.

Furthermore, a bibliometric review of research in women's soccer reveals a persistent knowledge gap, with much of the existing literature based on studies of

male players (Kirkendall & Krustrup, 2022). While research focused on men provides a foundational understanding of soccer performance, it often overlooks the physiological, psychological, and social contexts unique to women athletes. For instance, factors such as hormonal influences, differences in energy metabolism, and the social pressures tied to gender roles in sports remain underexplored in women's soccer (Chalabaev et al., 2013; Herzberg et al., 2017). Addressing these gaps is crucial for advancing evidence-based practices tailored to women players.

Professionalizing women's soccer has also sparked discussions about broader societal issues, including gender equity, media representation, and the commercialization of women's sports (Fink, 2015). While media coverage of women's soccer has improved, it remains disproportionately low compared to men's soccer, limiting the sport's commercial potential and ability to attract sponsorships and investments. This lack of visibility affects the financial sustainability of women's soccer leagues and the aspirations of young girls seeking role models in the sport. Bridging this gap requires collaborative efforts between governing bodies, media organizations, and sponsors to ensure equitable representation and support for women athletes.

In conclusion, while women's soccer has made remarkable progress in recent decades, it remains a work in progress with numerous challenges that must be addressed to achieve full equity with male soccer. Advancing research tailored to women athletes, improving access to resources, and fostering a culture of inclusivity within the sport are critical steps toward realizing the full potential of women's soccer. As the sport continues to grow, it promises to transform the landscape of soccer and serve as a powerful catalyst for gender equality and social change in the broader sports industry.

1.2. Match Running Demands in Female Soccer

Soccer is a physically demanding sport that requires players to engage in a combination of aerobic endurance and high-intensity anaerobic actions, such as sprints, accelerations, decelerations, and directional changes. These physical demands are particularly crucial in modern women's soccer, where the pace of the

game and the frequency of high-intensity actions have significantly increased in recent years assuming trends are similar to men's soccer (Bush et al. 2015). Understanding these demands becomes essential for designing training programs that optimize player performance, minimize injury risk, and maintain high-performance levels throughout a match as the sport evolves.

1.2.1. Total Distance and High-Intensity Running

The physical demands of elite women's soccer involve significant locomotor activity, as players cover extensive total distances (TD) and frequently execute high-intensity efforts throughout a match. These demands can vary by playing position, leading to distinct external match loads and noticeable individual differences within each position (Winther et al., 2021). For example, during a full match, the average total distance (TD) recorded for various positions highlights this individual variability: center backs (CBs) generally cover approximately 8,934±264 m, while full backs (FBs) average 9590±255 m. Central midfielders (CMs) typically cover 9,982±229 m, and wide midfielders (WMs) cover an average of 10,131±284 m. Forwards (FWs) also show a notable TD of 9,376±311 m. These figures consistently indicate that wide players (FBs and WMs) and central midfielders cover more total distance during a full match than CBs (Winther et al., 2021).

A significant proportion of this total distance is achieved at high-intensity speeds, with approximately 17% of the total distance covered at speeds exceeding 18 km/h (Andersson et al., 2010; Datson et al., 2014; Mohr et al., 2008; Pérez Armendáriz et al., 2024). High-intensity running (HIR) is one of the most crucial factors determining match outcomes, as it is frequently linked to key moments such as counterattacks, defensive recoveries, and set-piece plays. Research indicates that top-class soccer players performed more high-intensity running during a match compared to moderate professional players, underscoring the significance of this metric in player performance. While specific speed thresholds for high-intensity running (HIR), high-speed running (HSR), and very high-speed running (VHSR) can vary across studies, a systematic review highlights considerable variability in HSR thresholds (ranging from 11.1 to 21.6 km/h) and sprinting (from 15.0 to 30.0 km/h) (Nieto-Acevedo et al., 2025). The mean velocity for the HSR threshold is 16

km/h, with 18.0 km/h being the most frequently used, while sprint thresholds average around 21 km/h (Nieto-Acevedo et al., 2025). Official UEFA and FIFA reference thresholds for women's soccer include 19 km/h for HSR and 23 km/h for sprinting (Nieto-Acevedo et al., 2025). Common definitions in research include HIR at 15 km/h and HSR at 18 km/h (Winther et al., 2021). VHSR is frequently defined at thresholds such as 19 km/h (Olaizola et al., 2024). Positional analysis further reveals notable differences in these high-intensity efforts; for example, WMs demonstrate the highest HIR distances (2143±109 m at 15 km/h) and HSR distances (805±62 m at 18 km/h), significantly surpassing CBs who cover 1313±99 m and 340±38 m, respectively (Winther et al., 2021). Similarly, CMs and FBs also exhibit greater high-intensity running volumes compared to CBs and FWs (Winther et al., 2021). Mohr et al. (2008) also specify that HIR accounts for about 1.31 km (range: 0.71−1.70 km) of the total distance, performed through roughly 125 efforts (range: 72−159) lasting 2.3 seconds on average (Mohr et al., 2008). Furthermore, professional female players in domestic leagues typically cover around 500 m at speeds above 19 km/h and 125 m at over 22.5 km/h (Olaizola et al., 2024). The comprehensive body of evidence underscores the highly variable and position-specific nature of total distance and high-intensity running demands in elite women's soccer, emphasizing the critical need for tailored training interventions to optimize performance and manage fatigue effectively across different playing roles and competitive standards.

In addition, research on female soccer matches shows that players vary the activity intensity approximately 1350 times during the 90 minutes (Mohr et al., 2008), with anaerobic variables such as the number of sprints and high-intensity bouts approximately 24 and 140 times respectively (Andersson et al., 2010; Mohr et al., 2008). These variables highlight the need for targeted interventions, particularly strength and conditioning programs to improve high-intensity running abilities and sprinting performance in women’s soccer players.

Lastly, recent advancements in performance analysis, particularly through the utilization of GPS technology, have significantly enhanced the tracking of high-intensity metrics, such as peak velocities, high-intensity running distances, and recovery times between sprints (Ferraz et al., 2023). These developments furnish

coaches with actionable insights, enabling the effective customization of training programs. The integration of GPS tracking and video analytics into training routines can further augment the evaluation of player performance in high-intensity actions, thereby aiding in the optimization of match readiness.

1.2.2. Sprinting and Acceleration Demands

Sprinting and accelerations are among soccer's most critical high-intensity actions, as they allow players to create space, recover defensively, and seize goal-scoring opportunities. Depending on their positional roles, women soccer players perform approximately 20 sprints per match, with the mean sprint distance being approximately 13 meters (Andersson et al., 2010). Baumgart et al. (2018) compared the sprint mechanical properties of female and male top-level soccer players. The study found that elite male players reached a peak sprint velocity of approximately 8.9 m/s. In contrast, female players achieved a peak speed of approximately 7.4 m/s. For power outputs, the study found a peak of approximately 1440 W for the top-level males and approximately 820 W for the top-level females (Baumgart et al., 2018). As is evident, overall, the sprint mechanical properties were found to be lower for female top-level soccer players, however this does not diminish the need for tailored interventions to enhance sprint mechanics and by monitoring player progress by measuring metrics such as maximum speed, and power outputs, tailored training interventions can be provided in order for female players to reach their full potential.

Accelerations and decelerations are equally demanding for players, the meta-analysis by Pérez Armendáriz et al. (2024) summarized that female players completed a total of 165 ± 129 acceleration and 146 ± 141 deceleration actions during the match. These movements can place significant stress on the neuromuscular and skeletal systems, which could increase the risk of injuries such as muscle strains and ligament tears. Effective training programs that emphasize eccentric strength, lower-limb stability, and deceleration mechanics are essential for reducing the risk of injury while enhancing acceleration performance. For example, exercises targeting the posterior chain, such as Nordic hamstring curls, single-leg squats, and resisted accelerations, have been shown to improve strength, sprint performance

and lower injury rates in athletes (Ishøi et al., 2018; Mendiguchia et al., 2020; Mjølsnes et al., 2004; Petersen et al., 2011).

1.2.3. Repeated-Sprint Ability (RSA)

Repeated-sprint ability (RSA) reflects a player's capacity to perform multiple sprints with minimal recovery and is particularly critical during the latter stages of matches, where fatigue often impairs performance. Women soccer players with higher RSA are better equipped to sustain high-intensity efforts throughout a match, providing a competitive advantage during periods of fatigue (Armada-Cortés et al. 2022; Torreblanca-Martínez et al. 2020). RSA is essential for players in positions that require frequent sprints and recovery, such as forwards and wingers (Çetin & Koçak, 2022).

A meta-analysis conducted by Liu et al. 2024 found that combined training that includes both plyometric and sprint exercises significantly improves repeated sprint ability in team-sport athletes when compared to single-method or traditional training. These results emphasize the importance of using comprehensive training programs to enhance key performance indicators in team sports. In addition, the direct impact of RSA improvements on match performance metrics, such as sprint frequency, recovery time, and total high-intensity distance, remains underexplored particularly for women's soccer.

1.2.4. Season Program and Fatigue-Related Variations

Match running demands vary throughout the in-season mesocycle based on fluctuations in match frequency, recovery time, and cumulative fatigue. Performance decrements and injury risks are expected to be more pronounced during critical season periods (Dellal et al., 2013). Fatigue disproportionately impacts high-intensity actions, with significant declines observed in sprint frequency, high-intensity running distances, and RSA during the toward the end of elite female soccer matches (Krustrup et al., 2010) or by extension during the second half (Harkness-Armstrong et al., 2022).

To reduce the performance declines mentioned earlier, it is essential to use training methods that boost fitness results without causing excessive fatigue. González-Badillo et al. (2016) recommended completing only half of the maximum possible repetitions during strength training sessions. Their findings indicated that this strategy led to a greater mean repetition velocity, reduced neuromuscular fatigue, quicker recovery, and lower hormonal stress and muscle damage compared to training to failure. Despite these promising results, this approach has not yet been examined in female youth athletes to determine its potential impact on physical fitness measures.

Additionally, incorporating recovery protocols such as active recovery, foam rolling (i.e., Self-Myofascial Release), and cold-water immersion will enhance recovery rates and reduce performance loss due to fatigue throughout the season (Haller et al., 2022; Versey et al., 2013). However, research on the impact of strength and conditioning programs on match performance outcomes for women's soccer players remains insufficient. This further underscores the need for further research to gain insight into optimizing training loads alongside recovery strategies and sustaining consistently high performance over competitive seasons.

The demands of running in women's soccer are complex and multifaceted, necessitating a comprehensive training and performance optimization approach. Addressing the needs for high-intensity running, sprinting, accelerations and decelerations —along with RSA and positional roles—requires coaches and sports scientists to develop evidence-based training programs that target the specific requirements of women's soccer players. As the game evolves, investing in research becomes crucial to helping players perform at the highest competitive levels while reducing injury risks.

1.3. PHYSICAL FITNESS IN FEMALE SOCCER PLAYERS

Physical fitness is crucial for soccer performance. It enhances the players' ability to meet the demands of the soccer game, both physically, tactically, and technically. In women's soccer, the physical demands of the game have increased

significantly over the past decade due to the professionalization of the sport, resulting in faster game speeds, more frequent high-intensity actions, and more incredible overall physicality (Datson et al., 2014). Women's soccer players rely on aerobic capacity, anaerobic power, muscular strength, explosive power, speed, agility, and flexibility to perform these actions efficiently and sustain performance across 90 minutes of match play (Stølen et al., 2005).

While these components collectively influence performance, their development must align with women athletes' unique physiological and biomechanical characteristics. This includes hormonal variations (menstrual cycle), lower muscle mass, differences in neuromuscular control, and a greater risk of injuries, such as anterior cruciate ligament (ACL) tears (Herzberg et al., 2017; Hewett et al., 2006b; Randell et al., 2021). Despite the growing body of research in this area, significant gaps remain in understanding the specific needs of women soccer players, as much of the existing literature is still extrapolated from studies on male athletes.

1.3.1. Aerobic Capacity

Aerobic capacity provides the physiological foundation for soccer-specific fitness, enabling players to maintain high work rates throughout a match and recover efficiently between repeated high-intensity efforts. VO_2max, a widely used measure of aerobic fitness, typically ranges between 55 and 60 mL/kg/min in elite women soccer players, although some studies have reported higher values among top-performing athletes (Haugen et al., 2014; Xing et al., 2023). Studies have shown that players with higher aerobic capacity, as measured by VO_2max or the Yo-Yo Intermittent Recovery Test Level 1 (YYIRL1), cover greater distances during matches and maintain higher work rates (Bangsbo et al. 2008; Krustrup et al. 2005). Additionally, other research suggests that players with greater aerobic capacity are better equipped to cover longer distances during matches, sustain high-intensity running, and recover more effectively during periods of fatigue (Mohr et al., 2008; Andersson et al., 2010).

As mentioned, midfielders, who often cover the most ground (10–12 kilometers per match), rely heavily on aerobic endurance to transition effectively between offensive and defensive phases (Winther et al., 2022). However, aerobic capacity benefits all positions by delaying fatigue, maintaining work rates, and supporting recovery during critical moments, such as counterattacks or defensive recoveries.

Aerobic capacity alone cannot meet soccer's dynamic demands despite its importance. Instead, it must complement anaerobic capacity. In addition, strength-focused training is crucial in order to optimize high-intensity running capacity and recovery capabilities (Bangsbo et al., 2006, 2008).

1.3.2. Anaerobic Capacity and Power

Anaerobic power is critical for executing short bursts of high-intensity activity, such as sprints, accelerations, and decelerations. These actions often determine the outcome of critical match moments, such as counterattacks, set pieces, and defensive recoveries. Anaerobic power also underpins RSA, which reflects a player's capacity to perform multiple high-intensity sprints with minimal recovery (García-Calvo et al., 2025; Xing et al., 2023). Female soccer players typically perform between 1000 to 1400 short-duration of maximal or near-maximal intensity per match, relying heavily on the phosphagen and glycolytic energy systems to fuel these efforts (Arazi et al., 2017; Haugen et al., 2014; Sporiš et al., 2011). However, women's soccer players generally exhibit lower anaerobic power than their male counterparts due to reduced muscle mass and differences in type II (fast-twitch) muscle fiber composition (Krustrup et al., 2022). Despite these physiological differences, a few studies have shown that specific training interventions can significantly improve anaerobic power, thus enabling women to narrow the gap in performance for critical components (Buchheit et al., 2010; Rey et al., 2024).

Quantitative assessments of anaerobic power in women's soccer often include short sprint tests (e.g., 10 m, 20 m, 40 m), vertical and horizontal jump tests,

and repeated sprint ability (RSA) evaluations such as the Repeated Anaerobic Sprint Test (RAST) (Arazi et al., 2017; Osses-Rivera et al., 2024). Haugen et al. (2014) reported that national-level female players were significantly faster over 20 meters and exhibited superior countermovement jump (CMJ) performance than their lower-division counterparts, suggesting a strong relationship between anaerobic power and playing level. Similarly, Emmonds et al. (2019) found that reactive strength, particularly measured through drop jump (DJ) and CMJ height, was highly predictive of sprint speed and change-of-direction (CoD) ability, indicating that anaerobic qualities are key to effective movement in match situations.

Perroni et al. (2019) analyzed energy system contributions during RSA testing in an elite female soccer player and found that although the aerobic system provided the majority (~80%) of the total energy, the anaerobic systems were critical in delivering the peak outputs required for sprint performance, particularly in the initial repetitions. This underscores the dual role of energy systems but confirms the centrality of anaerobic power in high-quality efforts. Arazi et al. (2017) further demonstrated that speed-based high-intensity interval training (HIIT) elicited greater improvements in anaerobic power and fatigue resistance than heart rate-based HIIT, supporting the idea that the nature of training stimuli influences the development of anaerobic performance. Additionally, biomechanical asymmetries, such as those observed in unilateral horizontal jumps, have been linked to reduced vertical jump height and CoD performance, as shown by Roso-Moliner et al. (2023), implying that physical imbalances may impair anaerobic efficiency and athletic performance.

In conclusion, anaerobic power is a crucial element of physical fitness in female soccer players, directly contributing to the performance of key actions such as sprints, jumps, and repeated high-intensity efforts. The literature consistently supports the relationship between anaerobic power and game-specific performance, emphasizing the need for regular assessment and targeted development of these physical qualities to enhance athletic outcomes and reduce injury risk in elite female soccer populations.

While some articles focus on anaerobic power, still more research is needed to understand how these adaptations translate to match-specific metrics, such as sprint frequency, total high-intensity distance, and recovery efficiency in women's soccer players.

1.3.3. Muscular Strength and Explosive Power

Muscular strength and explosive power are essential for nearly all soccer-specific actions, including sprinting, speed, agility, jumping, tackling, and rapid directional changes. Strength provides the base for force production, while explosive power determines the speed at which this force can be applied. Both are critical in modern soccer, where the frequency and intensity of sprints and aerial duels have increased significantly (Suchomel et al., 2016). Furthermore, those allow players to generate chances at goal, regain possession defensively, and avoid being challenged by an opponent (Andersson et al., 2010). Speed includes sprinting attributes, such as acceleration, top speed reached, and deceleration, while agility refers to the capacity to change direction quickly. As mentioned previously, women's soccer players perform an average of 20 sprints per match, typically over distances of 13 meters (Andersson et al., 2010).

Nimphius et al. (2010) examined the relationships between strength, speed, and COD performance in female athletes, revealing that relative strength exhibited stronger correlations with sprint and COD performance than absolute strength. This finding suggests that strength relative to body mass serves as a more accurate predictor of physical performance in females. Pedersen et al. (2022) investigated high-level female football players and reported no correlation between 1RM half squat and match-play performance. However, they identified significant associations between sprint times and CMJ height, both of which are influenced by muscle strength, and peak match speed, indicating a partial role of strength in determining physical match performance. Wing et al. (2020) found a strong correlation between predicted 1RM back squat strength and tackling success ($r = 0.61$), and noted that CMJ and squat jump heights were linked to heading success. These findings support the conclusion that lower-body muscle strength plays a crucial role in physical actions essential for performance in female soccer. Sporis et

al. (2011) confirmed that in female soccer players, strength measures were positively associated with both aerobic and anaerobic power, demonstrating that muscular strength contributes to broader components of physical fitness, including energy system performance. Pecci et al. (2023) identified sprinting, COD, and CMJ height as discriminatory factors of competitive level in professional female soccer players, emphasizing lower-limb strength as a key contributor to these physical fitness variables. Fristrup et al. (2024) evaluated strength tests in elite female athletes and found excellent test-retest reliability in knee extensor and flexor strength, indicating that these reliable strength indicators are useful for assessing and tracking physical fitness in female team sports. Nasiss et al. (2021) highlighted the increasing focus on elite women's football and stressed the importance of understanding physiological demands specific to female athletes, identifying strength as central to physical performance and resilience in female soccer, as recognized by both players and coaches. Darragi et al. (2024) reported that higher strength levels in elite young female soccer players were associated with improved performance in physical fitness indicators such as countermovement jump, sprint speed, and repeated shuttle runs. Additionally, players with higher strength had lower injury incidence, indicating a dual role of strength in enhancing fitness and reducing injury risk. Liu et al. (2024) demonstrated through a meta-analysis that repeated sprint ability, a key component of physical fitness in soccer, is significantly influenced by muscle strength and neuromuscular capacity. The findings emphasized that stronger muscles enable better performance and recovery in repeated high-intensity efforts.

1.3.4. Relationship Between Physical Fitness and Match Running Demands

The physical demands that occur while playing soccer (referred to as "match running demands", such as sprinting, jogging, or covering long distances during a match), are closely related to specific components of physical fitness (like endurance, strength, speed, and agility). This relationship shows that different aspects of a player's physical fitness each play a role in how well they perform in soccer. Aerobic capacity is the foundation of soccer-specific fitness, enabling players to sustain high work rates over prolonged periods and recover efficiently between bouts of high-intensity actions (Slimani et al., 2019). Studies have consistently shown that players with higher aerobic capacity, as measured by

VO_2max or the Yo-Yo Intermittent Recovery Test Level 1 (YYIRL1), cover greater distances during matches and maintain superior work rates (Bangsbo et al. 2008; Krustrup et al. 2005). For example, midfielders, who usually run 10–12 kilometers during a match, depend largely on aerobic stamina to sustain their ongoing movement and help quick switches from attacking to defending roles (Winther et al., 2022).

While aerobic capacity underpins total distance covered and recovery, anaerobic power and muscular strength play pivotal roles in HIR, sprinting performance, and RSA. HIR is crucial in decisive match scenarios, such as counterattacks, defensive recoveries, and goal-scoring opportunities. Elite women's soccer players typically cover 8–15% of their total match distance at high-intensity speeds (>18 km/h), underscoring the importance of anaerobic power in modern soccer (Andersson et al., 2010; Datson et al., 2014; Mohr et al., 2008; Pérez Armendáriz et al., 2024). The players' improved strength and power enhance their ability to perform more sprints, accelerate more quickly, and sustain greater distances at high intensity, thereby increasing their chances of winning critical phases of the game (Stølen et al., 2005).

Repeated sprint ability is an important factor for match performance; it indicates the player's ability to perform sprints several times with short recovery periods. Some studies show significant correlations between RSA, total distance covered, and high-intensity actions during matches. It can be genuinely interpreted that it contributes massively to effective soccer competition (Buchheit et al., 2010; Mujika et al., 2009; Rampinini et al., 2007). Athletes with better RSA maintain high-intensity efforts toward the end of a match; hence, it is a critical player quality in a game situation when fatigue has usually set in and can be expected to diminish performance. Training interventions such as repeated sprints and high-intensity interval training have drastically improved RSA, subsequently improved sprint frequency and recovery time, and increased match performance metrics (Armada-Cortés et al., 2022; Buchheit et al., 2010; Torreblanca-Martínez et al., 2020).

The neuromuscular fitness attributes, sprint speed, and explosive power will further complement a player's ability to meet match-play demands. For instance, it has been previously established that faster sprint times (10-meter sprint) will likely cause more acceleration during a match. In contrast, greater lower-body power, as defined by countermovement jump performance, does relate to the better execution of high-intensity movements (Papla et al., 2020). These findings highlight that strength and power development are key in supporting offensive and defensive actions and sustaining repeated high-intensity activities in a match.

The diversity in physical fitness demands of the different roles thus reinforces the need to adopt a specific training approach for each role. Midfielders typically rely heavily on aerobic capacity in support of their high work rates and repeated high-intensity actions over considerable distances. Forwards derive more from anaerobic power and speed, less from aerobic capacity, and more from sprinting to exploit scoring opportunities (Sánchez-Abselam et al., 2024). Defenders emphasize strength, power, and agility to make quick changes of direction and effective defensive actions. Goalkeepers, who have less distance covered in terms of overall running, depend upon explosive strength and reaction time for the execution of high-intensity movements like diving and saving (Sánchez-Abselam et al., 2024).

Another important factor is injury prevention. Match demands combined with physical fitness play a key role in this regard. Aerobic capacity enables recovery between high-intensity actions more quickly, while strength training improves stability at the joints and control by the neuromuscular system, which reduces fatigue-related injuries (Slimani et al., 2019). Other components, like flexibility and mobility, do not get the recognition they deserve but are also very important in reducing injury risk such as ACL during high-intensity play (Hewett et al., 2006a; Hewett et al., 2006b). Training programs that include flexibility can increase the quality of movement and injury robustness.

The research gaps are still profound in women’s soccer. Most of the available evidence comes from research conducted on male soccer players; as such, it cannot be directly applied to women athletes. Few longitudinal studies have been

conducted to assess the impact of training interventions on parameters specific to women, such as sprint frequency, recovery efficiency, and injury resilience. Also, research on the interaction between different fitness components—strength, aerobic capacity, and flexibility—in women's soccer is limited. Such gaps must be addressed so that football-specific, evidence-based training regimes can be constructed for women that enhance performance while reducing injury potential.

1.4. STRENGTH TRAINING METHODS FOR IMPROVING PHYSICAL FITNESS PERFORMANCE

Strength training is an essential part of soccer physical preparation as muscular strength plays a pivotal role in athletic performance. Evidence supports its role in building muscular strength, power, and neuromuscular coordination, enhancing athletic performance (Stone et al., 2022) and decreasing the potential injuries (Suchomel et al., 2016). Muscle training plays a crucial role for soccer players in bridging performance gaps caused by physical differences, thereby helping them meet the demands of modern soccer, including intense acts, quick runs, and powerful moves (Suchomel et al., 2016; Turner et al., 2013). It is anticipated that increased strength is associated with improved sprint performance, as concluded in a literature review by Suchomel et al. (2016).

Recent evidence from elite female soccer has also shown that targeted strength interventions implemented during the competitive season can improve both physical fitness and match-running performance. For example, in adolescent elite female players, a 12-week in-season ST program with two weekly sessions improved anthropometric and body composition characteristics, as well as measures of physical fitness such as countermovement jump (CMJ) and repeated shuttle sprint ability (RSSA), while reducing non-contact injury incidence compared to a control group (Darragi et al., 2024).

Resistance training focuses on improving maximal strength and muscular endurance through progressive overload. Exercises such as squats, deadlifts, and lunges are widely used to target lower-body strength, which directly impacts sprint

acceleration, jumping ability, and deceleration control (Wing et al., 2020). Resistance training also contributes to injury prevention by strengthening muscles and stabilizing joints (Darragi et al., 2024). A study has shown that strength and resistance training enhance speed and change of direction performance (Liu et al., 2024). Lower limb resistance exercise (RE) is also effective for improving running economy and performance, and a combination of strength and plyometric training is recommended to improve running economy. Lower limb RE may also change some aspects of joint kinematics during running and help minimize the risk of running-related injuries (Šuc et al., 2022).

Regarding repeated sprint ability (RSA), which is crucial for team sports, studies indicate that resistance training (RT) can improve RSA by enhancing neuromuscular function, such as muscle strength and motor unit recruitment, and boosting running economy. Combined training (CT) that integrates different training methods, such as RT, plyometric training (PT), and sprint training (ST), can efficiently enhance multiple physical qualities. Specifically, PT + RT has proven effective in increasing neuromuscular performance, including 20-m sprint, squat jump (power, velocity, force, and height). Additionally, PT + RT + ST can improve repeated sprint mean and best time (Liu et al., 2024). Furthermore, a systematic review indicates that resistance training (RT), or RT combined with other strength-based exercises, performed for 4-12 weeks significantly enhances muscle power, strength, speed, and jump performance in elite female athletes (Zouita et al., 2023). Nonetheless, the optimal dosage of programming elements, including training intensity and duration, required to achieve substantial improvements in muscular fitness and its physiological adaptations, remains unclear for female elite athletes. In a study examining resistance training effects during the menstrual cycle in females, 12 weeks of submaximal resistance training (3 sets of 8-12 repetitions) significantly increased maximum isometric force in all groups (BMI under, normal BMI, and over BMI) (Sung & Kim, 2019).

Plyometric training emphasizes explosive, high-velocity movements that compose the stretch-shortening cycle. Exercises such as bounding, depth jumps, and box jumps improve power output, sprinting speed, and agility (Ramírez-Campillo et al., 2021; Sánchez-Sánchez et al., 2024). For instance, Ozbar et al. (2014)

conducted a study demonstrating that an 8-week plyometric training program led to significant improvements in triple hop distance, countermovement jump, standing broad jump, peak power, and 20-meter sprint performance among female soccer players. In addition, Nonnato et al. (2022) studied the effectiveness of 12 weeks of plyometric (PLY) training on physical performance in professional female soccer players during the season. A meta-analysis study by Pardos-Mainer et al. (2021) found that plyometric training was better in enhancing the time of linear sprint in female soccer players. They concluded that plyometric exercises significantly improved sport-specific fitness parameters in professional female soccer players during the season.

Eccentric training involves muscle lengthening under tension when the external force exceeds the muscle's capacity to produce force. It is a powerful method for enhancing critical attributes such as strength, power, and stretch-shortening cycle efficiency due to its ability to generate high force at a lower metabolic cost (Douglas et al., 2017). Eccentric training directly enhances components vital for soccer, improving rapid strength, explosive power, and sprint performance by enhancing motor unit recruitment and increasing muscle cross-sectional area (Zhang et al., 2024). It also significantly increases jump height through enhanced braking force and stretch-shortening cycle efficiency (Zhang et al., 2024). Importantly, eccentric training enhances deceleration and COD speed, directly conditioning muscles to handle the high forces involved in these agile movements (Zhang et al., 2024). Beyond enhancing performance, a key benefit is the prevention of injuries, particularly hamstring strains. Exercises like the Nordic Hamstring Exercise (NHE) have consistently reduced the incidence of hamstring injuries by 65%–70% (Petersen et al., 2011), with systematic reviews confirming a decrease in overall lower extremity injuries, including those common in soccer (Hu et al., 2023). These protective effects arise from adaptations in muscle structure and increased fascicle length.

High-intensity interval training (HIIT) combines aerobic and anaerobic conditioning to simulate match-specific demands. HIIT improves players' RSA, fatigue resistance, and high-intensity running capacity by integrating short, high-

intensity bouts of activity with brief recovery periods. It also supports overall endurance and complements strength training interventions by targeting both energy systems (Buchheit et al., 2010). Sprint-specific drills such as small-sided games (SSGs) and HIIT can close the gap between training and match performance by improving acceleration, speed, decision-making, and tactical awareness under match-like conditions (Arslan et al., 2020; Eniseler et al., 2017; Wen et al., 2023). HIIT has also been shown to be a valuable, time-efficient complement to conventional training methods for improving strength, power, and neuromuscular efficiency (Hung et al., 2025).

Isometric exercises involve holding static positions to strengthen and stabilize specific joint angles. Isometric strength training (IST) presents several advantages, including reduced fatigue, enhanced joint angle-specific strength, and improved performance in activities such as running, jumping, and isometric holds (Lum & Barbosa, 2019). IST can produce similar improvements in strength, power, and speed compared to traditional strength training (ST), with significant gains in dynamic strength and maximum velocity (Lum & Barbosa, 2019). Although power improvements were not statistically significant, IST can be an effective alternative to ST, particularly during congested fixture periods in soccer (Bailey et al., 2025). Functional training (FT), which focuses on sport-specific movements that mimic on-field demands, improves dynamic strength, balance, core stability, and overall athleticism (Xiao et al., 2025). High-intensity functional training (HIFT) effectively improves muscle strength, power, flexibility, and sport-specific performance, although it has no significant impact on endurance and agility (Wang et al., 2023). Targeted FT has been shown to improve anaerobic performance variables such as vertical jump and 10–30 m sprint (Erol et al., 2023).

Taken together, these findings show that there isn't just one way to improve physical performance in soccer, but rather a range of strength training methods that target different physiological and performance outcomes. Resistance and combined training are especially effective for building strength, power, and repeated sprint ability; plyometric and eccentric exercises focus on explosive qualities and injury prevention; HIIT provides game-specific conditioning; and isometric and functional training help improve stability and sport-specific skills.

This variety of methods highlights how adaptable strength training programs can be to the demands of soccer and the specific needs of athletes, especially in the female game.

Despite their proven effectiveness, strength training methods remain underexplored in women's soccer. Most research focuses on male athletes or lacks direct assessments of how specific training programs affect match performance. Addressing this gap is essential for optimizing training interventions tailored to the unique needs of female players, as recent studies have shown that in-season strength and sprint-based programs improved both testing and match performance metrics in professional and elite youth female soccer players.

1.5. EFFECTS OF STRENGTH TRAINING PROGRAMS ON FEMALE SOCCER PLAYERS

Strength training programs are essential for optimizing physical fitness, improving match performance, and mitigating injury risks in soccer players. In women's soccer, these interventions are particularly significant due to women athletes' specific physiological and biomechanical characteristics, such as lower absolute strength, higher susceptibility to ACL injuries, and unique hormonal influences (Hewett et al., 2006a; Hewett et al., 2006b). Strength training directly enhances aerobic capacity, anaerobic power, muscular strength, and biomechanical efficiency, attributes critical for meeting modern soccer's growing physical and tactical demands (Turner et al., 2013). However, research focusing on the effects of strength training on women's soccer players remains sparse, particularly regarding its impact on match-specific performance and running economy.

1.5.1. Effects on Physical Fitness Tests

Strength training interventions have shown significant improvements in key performance metrics assessed through physical fitness tests directly related to soccer-specific actions (Emmonds et al., 2019; Millar et al., 2020).

1.5.1.1. VO_2max (Aerobic Capacity)

VO_2max is a critical determinant of aerobic fitness, allowing players to sustain high-intensity efforts and recover more efficiently during matches. While traditionally enhanced through endurance-based training, strength training indirectly improves VO_2max by reducing the energy cost of running at submaximal speeds. Enhanced lower-body strength and neuromuscular coordination contribute to better oxygen utilization, enabling players to sustain higher workloads during competitive play (Haugen et al., 2014; Helgerud et al., 2001). However, few studies have specifically examined this interaction in women's soccer players, leaving an opportunity for further research.

1.5.1.2. Running Economy

Running economy, defined as the energy cost of running at a given velocity, is crucial for conserving energy during prolonged high-intensity actions, particularly in the latter stages of matches. Strength training—especially eccentric-focused exercises—improves the stiffness of the muscle-tendon unit, reducing ground contact time and enhancing biomechanical efficiency (Šuc et al., 2022). Improvements in running economy may benefit midfielders and defenders, who require prolonged aerobic output during matches. While documented in male athletes, limited research exists on the extent of these benefits in women's soccer players (Sánchez-Abselam et al., 2024; Winther et al., 2022).

1.5.1.3. Sprint, Maximal Sprint Speed and Acceleration

Sprinting and accelerating are fundamental actions in soccer, contributing to offensive plays, defensive recoveries, and transitions (Ozbar et al. 2014). A study by Ozbar et al. (2014) demonstrated that an 8-week plyometric training program resulted in an 8.1% improvement in 20-meter sprint performance among female soccer players. Another study showed that resistance training and plyometric exercises consistently improve COD speed and linear sprint in female soccer players. (Liu et al., 2024). A review study conducted by Pardos-Mainer et al. (2021) demonstrated that strength training (ST) enhanced 20-meter linear sprint speed, while plyometric training (PT) improved 15-meter, 20-meter, and 30-meter linear sprint speeds. Additionally, the study found that both PT and ST increased change of direction (COD) speed, with PT providing a greater benefit in this regard.

Contrary to expectations, Pedersen et al. (2022) did not find a relationship or effect of improvements in maximal strength on the transfer to sprint performance.

1.5.1.4. Countermovement Jump (CMJ)

CMJ height is a critical indicator of explosive power, reflecting an athlete's ability to perform aerial duels and rapid directional changes. Research on young female soccer players has demonstrated that both back squats and hip thrusts likely contribute to improvements in vertical jump height, ranging from 5% to 10%, without affecting horizontal jump performance (Millar et al., 2020). Lesinski et al. (2021) found that power training conducted throughout the season, at intensities of 50% to 95% of the 1-RM, enhanced countermovement jump (CMJ) performance in elite young female soccer players. Furthermore, a study by Fernandez Ortega et al. (2020) indicated that a 12-week regimen of strength and power training, consisting of three sessions per week, resulted in improvements in both CMJ and squat jump (SJ) performance. Additionally, Fischerova et al. (2021) reported that a six-week strength training program, with two sessions per week at 50% to 85% of the 1-RM, led to an 11% increase in CMJ among highly trained female soccer players. The review study demonstrated that both within- and between-mode analyses indicate that plyometric training (PT) offers greater benefits than strength training (ST) in improving vertical jump performance among female soccer players. The extent of improvement was considered trivial for ST (ES = 0.13) and moderate for PT (ES = 0.81) (Pardos-Mainer et al., 2021). These improvements are directly transferable to match scenarios.

1.5.1.5. Repeated-Sprint Ability (RSA)

RSA is crucial for sustaining high-intensity sprints during matches, especially in positions requiring frequent accelerations and decelerations (Datson et al., 2014; Gabbett et al., 2013). Strength training has been demonstrated to enhance anaerobic power and muscular endurance (Sporis et al., 2011), thereby facilitating quicker recovery between sprints and maintaining RSA under fatigue conditions (Rodríguez-Fernández et al., 2019). Pardos-Mainer et al. (2021) found that both plyometric training (PT) and strength training (ST) positively affect linear sprint performance in female soccer players. The study by Osses-Rivera et al. (2024)

indicates that complex/contrast training (CCT), performed at intensities between 75% and 90% of one repetition maximum (1 RM) and combined with jumps and sprints, results in improvements in the best time, mean time, and total time of the RSA test among elite female athletes during the competitive season. Additionally, research by Gonçalves et al. (2021) demonstrated that a coadjutant training program, primarily focused on abductor (ABD) and adductor (ADD) isometric strength exercises and the Yo-Yo Intermittent Recovery Test Level 1 (YYIR1), may enhance the RSA of female soccer players and improve performance during critical match phases. However, despite documented improvements in RSA, research often fails to establish a direct correlation between these enhancements and in-match sprint performance and recovery, particularly among female athletes.

1.5.2. Effects on Match Running Demands and Outcomes

Strength training programs significantly influence match running demands by enhancing key physical attributes such as power, strength, and endurance (Stone et al., 2022). These attributes directly translate to improved high-intensity actions, sprint performance, and overall match performance (Suchomel et al., 2016; Turner et al., 2013). These enhancements are critical for women's soccer players, who face increasing physical and tactical demands in the modern game (Beato et al., 2023).

Research has explored multiple training approaches in soccer (Raya-González & Sánchez Sánchez, 2018), consistently demonstrating improvements in players' physical fitness. In female athletes, Millar et al. (2020) showed that a six-week back squat program with high school players improved vertical jump performance, while Sporiš et al. (2011) observed higher VO_2max values after 12 weeks of strength training. Still, incorporating strength work into soccer periodization is challenging due to the sport's demanding and often unpredictable schedule (Wing, 2018; Gualtieri et al., 2020). Given these constraints, programs must balance performance gains with fatigue management. One proposed strategy is limiting sets to half of the maximum possible repetitions (González-Badillo et al., 2016), which has been linked to faster repetition velocity, less neuromuscular impairment, quicker recovery, and reduced hormonal and muscle stress compared

with training to failure. To date, however, this method has not been applied to female youth populations, leaving its effects on physical fitness outcomes untested.

From a practical perspective, strength and conditioning professionals highlight that enhancing physical attributes is closely tied to greater high-intensity running distances during competitive matches (Byrkjedal et al., 2023). Supporting this, Pedersen et al. (2022) established strong links between maximal strength, sprint capacity, jump height, and match-related performance in elite female soccer players. Improvements in match demands have been further associated with enhanced overall on-field performance (Arnason et al., 2004). Indeed, research has consistently shown that high-level teams cover more high-intensity distance during competition across both male (Pons et al., 2021) and female groups (Choice et al., 2022). In terms of training interventions, Pardos-Mainer et al. (2021) demonstrated that plyometric training (PT) outperformed traditional strength training (ST) in improving vertical jump, sprinting, and change of direction (COD) performance, likely due to PT's incorporation of sport-specific, dynamic movements. ST, by contrast, typically required at least eight weeks with two 30-minute sessions weekly before measurable improvements emerged. As a result, PT consistently surpassed ST in producing performance gains in female soccer athletes. Nonetheless, limited work has been done on whether adding a complementary strength program can further benefit soccer performance. Byrkjedal et al. (2023) found such programs beneficial for professional male players, particularly for sprinting and high-speed running, yet the same has not been examined in female players. This highlights a critical gap in the literature and a promising avenue for future investigation.

While theoretical benefits have been documented, there is a notable lack of studies assessing the impact of strength training programs on match load variables for female soccer players, highlighting the need for further research. Additional investigation is necessary to establish a direct correlation between improvements in running economy and match outcomes in female soccer. Future research should examine how specific strength training protocols affect metrics such as total distance covered, high-intensity running volume, and sprint frequency during

matches. Strength training is crucial for meeting the running demands of women's soccer matches, as it addresses contemporary soccer requirements by enhancing high-intensity running capabilities, sprint frequency, fatigue resistance, and running economy. Although progress has been made in integrating resistance and plyometric training, further research is needed to establish correlations between strength improvements and match-specific performance metrics in women's soccer. Enhanced collaboration among sports scientists, coaches, and analysts is essential for refining training interventions and optimizing competitive outcomes for female soccer players.

Research in women's soccer is lacking when it comes to directly linking strength and complementary training interventions with improvements in high-intensity running, sprint performance, and repeated sprint ability (RSA) during competitive matches. This points to a significant gap in understanding how training can be applied to enhance match performance. Few longitudinal studies have explored how fitness development in youth affects long-term career performance. In women's soccer, the shortage of gender-specific research further hinders progress, as much of the current evidence is based on studies of male athletes, despite female players' unique physiological and biomechanical traits. Therefore, there is an urgent need to create evidence-based strength training protocols specifically for women and examine these programs' long-term impacts over competitive seasons.

II – OBJECTIVES AND HYPOTHESES

II - OBJECTIVES AND HYPOTHESES

2.1. GENERAL OBJECTIVE

The main objective of this thesis is to investigate the effects of strength and sprint training interventions on the physical fitness and match performance of female soccer players across youth and professional levels. By examining short-term and long-term programs in youth and professional contexts, this research seeks to clarify how specific training methods transfer from controlled fitness tests to competitive match demands, and to provide evidence-based recommendations for optimizing training periodization in women's soccer.

2.2. SPECIFIC OBJECTIVES AND HYPOTHESES

The specific objectives and hypotheses outlined for each of the studies included in the present thesis are presented below:

2.2.1. Study 1: Young elite female players: In-season strength training (10 weeks)

Objective 1. To determine whether adding a 10-week in-season strength training program (two sessions per week) improves physical fitness (CMJ, VO2max) and match performance (TD, VHSR, Vmax) compared to soccer training alone in adolescent elite female players.

Hypothesis 1.

H1a. Players participating in strength training will show greater improvements in physical fitness (CMJ, VO2max) compared to the CG.

H1b. Players in the strength training group will achieve better improvements in match performance metrics (TD, VHSR, Vmax) compared to the CG.

H1c. Strength training will simultaneously enhance physical performance and match running performance within a single competitive season.

2.2.2. Study 2: Professional female players: Traditional vs. Modified Integrated Sprint Training (12 weeks)

Objective 2. To compare the effects of a 12-week TST program and MIST program on physical performance tests (5, 10, 30 m sprints, VO2max) and match sprint-related metrics (VHSR, number of sprints) in professional female soccer players.

Hypothesis 2.

H2a. The TST intervention will demonstrate greater improvements in linear sprint performance (5, 10, and 30 m) than MIST.

H2b. The MIST program will lead to greater improvements in match sprint performance (VHSR, number of sprints) than TST.

2.2.3. Study 3: Young elite female players: Long-term traditional strength training (two seasons)

Objective 3. To evaluate the long-term effects of a two-season ST program on physical fitness (CMJ, VO_2max) and match running performance (TD, VHSR, Vmax) in young elite female soccer players.

Hypothesis 3.

H3a. Throughout the two-season intervention, the ST group will show progressively greater improvements in CMJ and estimated VO_2max compared to the CG.

H3b. The ST group will produce sustained and cumulative improvements in match performance (TD, VHSR, Vmax) compared to the CG.

2.2.4. Integrated Thesis Perspective

Taken together, these three studies aim to provide a comprehensive evaluation of how targeted strength and sprint-based training methods influence the multidimensional performance profile of female soccer players. It is expected that method-specific adaptations will develop, with traditional sprint training being most effective for linear sprint performance, while integrated sprint training better supports match sprint demands. Similarly, short-term strength training in youth players is expected to produce meaningful improvements in both fitness and match outcomes, whereas long-term programs will lead to superior and more sustainable adaptations over multiple seasons. Collectively, this thesis seeks to advance understanding of evidence-based training strategies that can inform the design of periodized and context-specific interventions to optimize performance in female soccer.

III–STUDY 1

III - IMPACT OF A 10-WEEK STRENGTH TRAINING PROGRAM ON PHYSICAL PERFORMANCE AND MATCH EXTERNAL LOAD IN YOUNG ELITE FEMALE SOCCER PLAYERS

3.1. ABSTRACT

Background: Soccer is a physically demanding sport characterized by frequent high-intensity efforts, which are particularly relevant in women's competitions. Improving high-speed running and aerobic capacity has been linked to better on-field performance. Strength training has shown promise in enhancing these physical attributes, but its application in young female soccer players remains underexplored. This study aimed to investigate the effects of a 10-week in-season strength training program on physical performance and match running demands in young female soccer players. Methods: Thirty-two U18 Danish female professional soccer players from two comparable teams voluntarily participated in the study. Teams were allocated to either an experimental group, performing twice-weekly strength training (EG, n = 16) or a control group (CG, n = 16). Vertical jump performance and Yo-Yo IR2 performance as an estimation for maximal oxygen uptake (VO2max) were assessed both pre and post intervention. Additionally, players' match external demands (i.e., total distance, distance covered at speeds above 23 km·h−1, and maximum velocity achieved) were monitored using Global Positioning System devices during four matches before and after the intervention. Results: Significant within-group differences were observed across all variables for the EG ($p = 0.001$; ES = 1.08 to 1.45, large), without differences in the CG ($p > 0.01$). Between-group analysis indicated significant differences favoring the EG in all variables ($F = 27.40$ to 47.17; $p = 0.001$). Conclusions: The application of a 10-week strength training program led to improvements in physical and match running performance among young female soccer players, underscoring the importance of incorporating strength training programs into female soccer periodization to enhance performance.

Keywords: resistance training; women; football; team-sport; GPS.

3.2. INTRODUCTION

Soccer is a physically demanding intermittent team sport characterized by alternating periods of low- and high-intensity activity (Ade et al., 2016; Pons et al., 2021). Notably, these physical demands differ between men's and women's competitions (Milanović et al., 2017), making it essential to analyze them specifically by gender. In women's soccer, recent research has reported that players cover a total distance of 9 to 10 km per match (Bradley et al., 2014; Datson et al., 2017), with an average of approximately 30 sprints (Mara et al., 2017), along with 200 accelerations and 150 decelerations per game (Ramos et al., 2019). Additionally, female players run around 500 m at speeds exceeding 19.0 km·h−1 and 125 m at speeds above 22.5 km·h−1 (Scott et al., 2020). These findings underscore the importance of enhancing high-intensity capabilities for competitive success (Faude et al., 2012). Furthermore, improving maximal oxygen uptake (VO2max) is essential for delaying fatigue and supporting repeated high-intensity efforts with minimal recovery time during matches (Slimani et al., 2019). Therefore, identifying effective strategies to develop these capacities is critical for strength and conditioning coaches.

For this purpose, strength training has been widely recognized as a key factor (Nimphius et al., 2010; Silva et al., 2015). In this context, the effects of several methodologies have been examined (Raya González & Sánchez Sánchez, 2018), yielding significant improvements in physical performance among soccer players. Specifically, in female soccer, Millar et al. (2020) implemented, during the in-season period, a 6-week strength training program focused on back squats in female high school soccer players, achieving significant increases in vertical jump performance. Similarly, Sporiš et al. (2011) observed improvements in VO2max among female soccer players following a 12-week strength training program during the second off-season period (from November to March). However, soccer presents unique conditions that must be considered when integrating strength training programs into soccer periodization (Wing, 2018). For example, soccer schedules are often unpredictable and subject to frequent changes, characterizing the sport as highly competitive, with more than one match per week (Gualtieri et al., 2020). Additionally, differences between players, such as starters and non-starters,

influence the available time for training (Guimarães et al., 2024). These factors must be accounted for to identify the optimal approach regarding frequency, methods, exercises, and session timing. Given the limited time available for implementing specific strength training sessions, it is essential to adopt strategies that enhance performance without inducing excessive fatigue. In this regard, González-Badillo et al. (2016) proposed performing half of the maximum possible repetitions for each load during strength training programs. These authors found that this approach promotes faster mean repetition velocities, minimizes neuromuscular performance impairments, facilitates quicker recovery, and reduces hormonal responses and muscle damage compared to completing all possible repetitions. However, this methodology has not yet been applied to young female populations to evaluate its effects on physical performance variables, which is adequate for this population (i.e., young players with scarce experience with resistance training) instead of reaching muscle failure.

Strength and conditioning coaches have emphasized the importance of improving physical performance variables to achieve subsequent increases in distances covered at a high intensity during official matches in the soccer population (Byrkjedal et al., 2023). In this context, Pedersen et al. (2022) demonstrated a strong association between maximal strength, sprint performance, jump height, and match physical performance in high-level female soccer players. Consequently, increases in match load demands contribute to enhanced on-field performance (Arnason et al., 2004). This is supported by previous research showing that high-standard teams cover greater high-intensity distances during official matches in both male (Pons et al., 2021) and female soccer players (Choice et al., 2022). However, few studies have investigated whether a complementary strength training program can improve soccer players' performance. In this regard, Byrkjedal et al. (2023) confirmed that strength training, applied during the in-season period, is an effective method to enhance external match performance in professional male soccer players, particularly in high-speed running and sprinting variables. Nevertheless, no studies have yet evaluated whether a complementary strength training program for female soccer players could positively impact their match external load variables or used a strength training methodology in which

participants complete only half of their maximum possible repetitions, highlighting the need for future research in this area.

To cover this gap, a 10-week strength program was applied in young elite female soccer players during their regular in season. Specifically, the aim of this study was to analyze the effects of a 10-week strength training program on physical performance and match running demands in young female soccer players. Based on prior studies (Byrkjedal et al., 2023; Lambright et al., 2024; Sporiš et al., 2011), we hypothesized that a structured training intervention would lead to significant improvements in both physical performance and match running performance among female players in the experimental group compared to a control group.

3.3. Materials and Methods

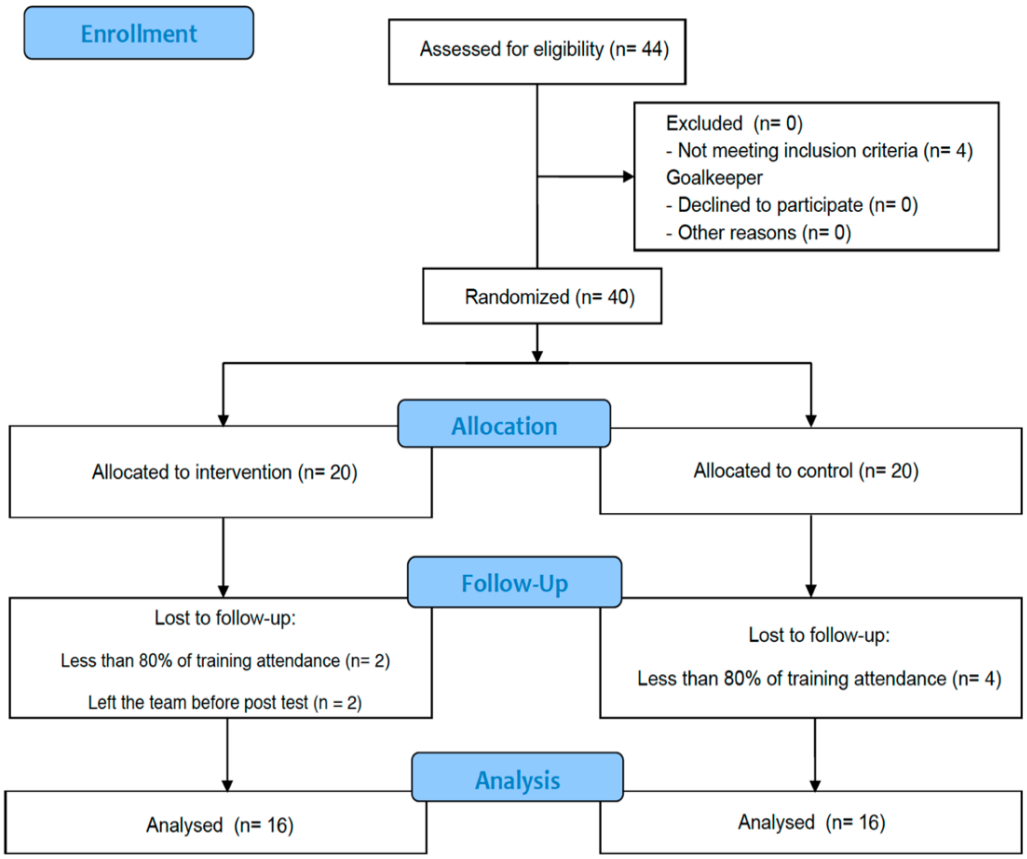
3.3.1. Study Design

A quasi-experimental design was employed to evaluate the impact of a 10-week strength training program (two sessions per week) on the physical performance and match running demands of young female soccer players. Physical performance was assessed at baseline and post training in a single session, which included a jump test (countermovement jump, CMJ) and an endurance test (Yo-Yo Intermittent Recovery Test). These assessments were conducted on the team's natural grass training field, with players wearing their own soccer boots. All testing sessions took place in the afternoon between 5:00 p.m. and 7:00 p.m. Additionally, players' match external demands (i.e., total distance, distance covered at above 23 km·h−1, and maximum velocity achieved) were tracked using Global Positioning System (GPS) devices during four matches before and after the intervention period. To standardize conditions, players were instructed to have their last meal 3 h before testing, avoid caffeinated beverages, and refrain from intense physical activity prior to assessments. A strength and conditioning specialist supervised all testing sessions, providing verbal encouragement throughout the protocols (Raya-González, Castillo, et al., 2021).

3.3.2. Participants

Thirty-two U18 Danish female elite soccer players (age = 16.4 ± 0.8 years) voluntarily participated in the study. A priori power analysis was conducted using G*Power (version 3.1.9.2, Universität Kiel, Kiel, Germany). The analysis indicated that a minimum sample size of 16 participants per group was required to achieve a statistical power (1–3) of 0.80, based on an assumed effect size (ES) of 0.90 (large effect) and a significance level (α) of 0.05. Participants belonged to two different teams competing at the highest level for their age. Both teams followed the same style and training schedule, trained 4 times per week [i.e., first session: recovery or compensation; second session: strength (small-sided games with a reduce number of players); third session: endurance (large-sided games with a high number of players); and fourth session: reaction (medium-sided games with a high number of players)], and played one official match during the weekend. Players were eligible for inclusion in the study if they had been part of the same soccer academy for the past two years, attended at least 80% of training sessions over the 10-week period, had a minimum of four years of experience in systematic soccer training, with low–medium experience in resistance training, and had not sustained any injuries in the two months prior to the study. Teams were randomly assigned to either the control group (CG; n = 16; age: 16.4 ± 0.7 years; height: 168.7 ± 5.2 cm; body mass: 62.5 ± 6.4 kg; body mass index: 21.9 ± 1.4 kg·m−2) or to the experimental group (EG; n = 16; age: 16.4 ± 0.8 years; height: 167.5 ± 5.6 cm body mass: 60.9 ± 6.5 kg; body mass index: 21.7 ± 1.7 kg·m−2), with all the players of the same team being parts of each group. Initially, 44 players were recruited for the study, but 4 goalkeepers were excluded due to the distinct nature of their training and role in the game, 2 players left the teams prior to post assessment, and 6 players were injured during the intervention period and did not complete 80% of the training sessions (Figure 1). Prior to participation, all players received detailed information about the study procedures, including potential risks and benefits. Written informed consent was obtained from their parents or legal guardians. The study adhered to the principles of the Declaration of Helsinki (2013) and was approved by the ethical committee of the Catholic University of Murcia under the internal registration number CE062112 (25 June 2021).

Figure 1. *CONSORT diagram of participant's recruitment, allocation, follow-up, and analysis.*



3.3.3. Procedures

During the 10-week intervention, players from both groups followed their regular in-season weekly soccer training routine, with the EG incorporating two strength training sessions per week while the CG had no strength training and followed their regular training periodization. The weekly training program (i.e., microcycle) was designed collaboratively by the coach and the strength and conditioning specialist, consisting of four soccer training sessions and one official match. Prior to the intervention, players in the EG completed a 2-week familiarization strength training program. All participants were already accustomed to the testing protocols from routine preseason assessments at the club and were familiar with the GPS devices, having worn them throughout competitive matches during the season. Physical performance assessments were conducted in

two testing sessions: Session 1 followed the sequence of the countermovement jump (CMJ) test and the Yo-Yo Intermittent Recovery Level 2 test to minimize fatigue accumulation, while Session 2 included the one-repetition maximum (1RM) assessment. Data from four matches before and four matches after the intervention period were also collected. Before each testing session, a standardized 15 min warm-up was performed. This warm-up included 7 min of slow jogging and walking locomotion, followed by 8 min of jump exercises, progressive acceleration, and sprint drills over 10 and 30 m distances.

3.3.4. Test

3.3.4.1. Countermovement Jump Height

Players completed two bilateral countermovement jumps (CMJs) with 1 min of rest between attempts. They were instructed to perform a downward motion followed by a rapid and complete extension of the lower limbs to maximize jump height, keeping their hands on their hips throughout the movement. The MyJump 2.0 mobile application was used to measure CMJ height, a tool shown to be highly valid ($r = 0.995$) and reliable (intraclass correlation coefficient = 0.997) for this purpose (Balsalobre-Fernández et al., 2015). All jumps were recorded at 240 Hz with an iPhone 8 Plus mobile device (Apple Inc., Cupertino, CA, USA) (Raya-González, Scanlan, et al., 2021). The best jump height (in cm) was selected for further analysis.

3.3.4.2. Yo-Yo Intermittent Recovery Level 2 Test

A single set of this test was completed, which involved performing 2 × 20 m shuttle runs at progressively increasing speeds, with 10 s of active recovery between runs. The recovery consisted of jogging 2 × 5 m. Players followed an auditory beep signal, and the test concluded when they failed to reach the finish line in sync with the beep on two consecutive attempts. The total distance covered (in m) was recorded as the test result (Krustrup et al., 2003). From this test, each player's estimated VO2max was calculated indirectly. The test area was marked with cones, forming a 20 m long and 2 m wide running lane. An additional cone, placed 5 m behind the finish line, indicated the jogging distance for the active recovery period.

3.3.5. Match Running Demands

The Polar Team Pro (Polar Electro, Kempele, Finland) device was used to monitor match external demands. It is an advanced athlete monitoring system designed for team sports, integrating a 10 Hz GPS, 200 Hz tri-axial accelerometer, gyroscope, magnetometer, and heart rate monitor. These devices were positioned on the chest of players, with each player using the same device during the entire experimental period. These devices have shown high accuracy and acceptable reliability compared to the gold standard (Akyildiz et al., 2020). Specifically, the following variables were monitored: total distance covered in meters (TD), very-high-speed running distance (VHSR, >23 km·h−1), and maximum velocity achieved during matches (Vmax).

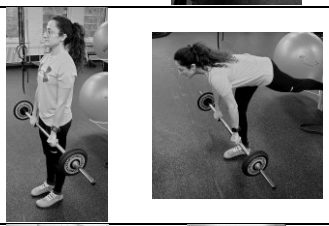
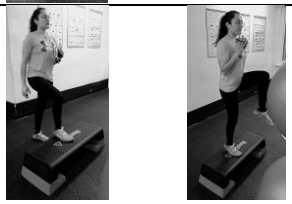
3.3.6. Strength Training Program

Players participated in a 10-week complementary strength training program (CSTT), conducted prior to regular soccer training and following a standardized warm-up. The CSTT incorporated strength, range of motion (ROM), and balance exercises, as detailed in Tables 1 and 2. Strength exercises targeting major muscle groups (e.g., chest, legs, back) were performed at half of the maximum number of repetitions per set, with 6 repetitions of the possible 12 [70% 1RM load (4 × 6 (12))]. This approach was based on evidence from a prior study, conducted with physically active sports science students, demonstrating that performing half the maximum number of repetitions per set promotes faster mean repetition velocities, minimizes neuromuscular performance impairments, facilitates faster recovery, and reduces hormonal responses and muscle damage following exercise (González-Badillo et al., 2016). An incremental load test was conducted to determine the 1RM value for each exercise (Sánchez-Medina & González-Badillo, 2011).

The initial load for all participants was set at 20 kg and was progressively increased by 10 kg per set until reaching 0.5 m/s in mean propulsive velocity. Subsequently, the load was increased by 5 to 2.5 kg until the participant could no longer move it. A rest period of at least 5 min was allowed between sets. A re-evaluation was implemented prior to the sessions of the 6th week. Balance exercises

were performed on Bosu, with players having to reach 3 movement directions with their hand, completing 3 sets per exercise. Players completed Session 1 (Table 2) during their first strength training session of the week and Session 2 (Table 3) during their second strength training session. Prior to the pre-test session, players underwent a 2-week anatomical adaptation phase (2 sessions per week). Throughout the 10-week in-season intervention period, both CG and EG players adhered to their regular in-season routines, comprising 4 weekly 60–90 min training sessions in addition to competitive matches.

Table 2. *Session 1 for the complementary strength training program.*

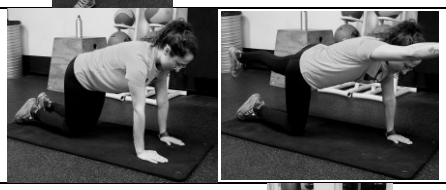
Exercises	Illustrations	Sets	Repetitions
Bulgarian split squat		4	6(12)
Quick steps with band		4	10 s
Dumble bent row		4	6(12)
One leg deadlift		4	6(12)
Quick step up		4	6 each leg

Lever chest press		4	6(12)
Cable abduction + adduction		2	12
Reverse hyperextension		3	12
Knee up crunch + leg raise		3	15 + 10
Plank series		3	30 s + 10 s + 30 s + 10 s

One leg on Bosu and reach 3 directions with each hand		3	One tour each leg

Notes: 6 (12) = to perform 6 reps of 12 possible reps; body weight exercises did not follow the half rep method.

Table 3. *Session 2 for the complementary strength training program.*

Exercises	Illustrations	Sets	Repetitions
Walking lunge		4	6
Bird dog		3	12 each side
4-sided change of direction CMJ and drop jump		3	3 tours

Prone hamstring curl		4	6
Leg raise and hip raise		3	6 + 6
Boxing		3	1 m
Abduction + adduction with band		2	12
V-sit trunk rotation with weight		3	6 each side

One leg side to side jump and hold			4	5
Plank series			3	30 s + 10 s + 30 s + 10 s

Notes: 6 (12) = to perform 6 reps of 12 possible reps; body weight exercises did not follow the half rep method.

3.3.7. Statistical Analysis

Descriptive statistics are presented as means ± standard deviations (SDs). The Shapiro– Wilk test was conducted to assess the normality of the data distribution, and Levene's test was utilized to confirm the homogeneity of variances. To detect between-group and within-groups differences, an analysis of covariance (ANCOVA), incorporating baseline values as covariates, was performed. When significant F values were found, Bonferroni post hoc analysis was performed. Effect sizes (ESs) were computed using Cohen's method to evaluate the magnitude of effects and were interpreted as follows: <0.2, trivial; 0.20–0.49, small; 0.50–0.80, moderate; and >0.80, large (Cohen, 1988). Statistical analyses were carried out using SPSS v29 (SPSS Inc., Chicago, IL, USA). Based on the Bonferroni correction, statistical significance was set at $p < 0.01$.

3.4. RESULTS

No significant between-groups differences were found when baseline values were compared.

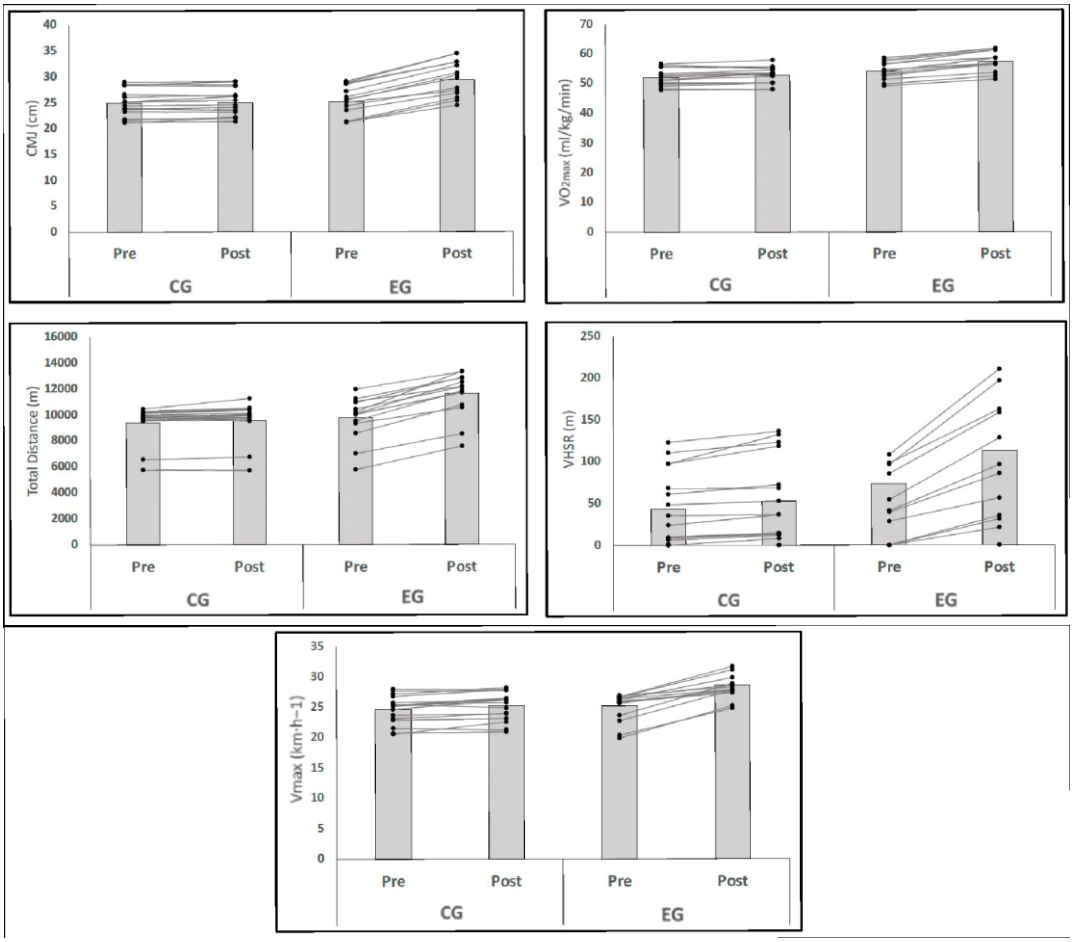
The changes in physical performance and match load variables before (baseline) and after (post training) the 10-week intervention period are presented in Table 4 and Figure 2.

Table 4. *Changes in physical performance and match load variables before (baseline) and after (post-training) the 10-week intervention period.*

	CG (n = 16)					EG (n = 16)					Between group differences	
Variables	**Baseline (mean ± SD)**	**Post training (mean ± SD)**	**Δ (%)**	**p**	**ES**	**Baseline (mean ± SD)**	**Post training (mean ± SD)**	**Δ (%)**	**p**	**ES**	**F**	**p**
CMJ (cm)	24.84 ± 2.72	25.07 ± 2.65	0.93	0.044	0.08	25.10 ± 2.84	29.20 ± 3.37	16.33	0.001	1.44	45.75	0.001
VO2max (ml/kg/min)	52.03 ± 2.87	52.51 ± 2.83	0.92	0.028	0.17	54.01 ± 2.78	57.14 ± 3.22	5.80	0.001	1.13	47.17	0.001
TD (m)	9377.00 ± 1300.00	9543.00 ± 1370.00	1.77	0.004	0.13	9773.00 ± 1566.00	11628.00 ± 160.70	19.39	0.001	1.18	31.59	0.001
VHSR (m)	42.88 ± 44.17	52.67 ± 49.93	22.83	0.024	0.22	47.00 ± 41.90	92.38 ± 71.90	96.55	0.001	1.08	27.40	0.001
Vmax (km·h-1)	24.63 ± 2.35	25.24 ± 2.39	2.48	0.002	0.26	25.17 ± 2.33	28.56 ± 2.20	13.47	0.001	1.45	38.26	0.001

** Abbreviations: CG = control group; EG = experimental group; SD = standard deviation; Δ (%): percentage of change between pre and post intervention; p: level of significance; ES: effect size; CMJ = countermovement jump; VO2max = maximal oxygen uptake; TD = total distance; VHSR = distance covered at above of 24 km·h-1; Vmax = maximum velocity achieved during matches. Significance level was set at $p < 0.05$.*

Figure 2. *Individual changes in physical performance and match load variables before (baseline) and after (post training) the 10-week intervention period. Abbreviations: CG = control group; EG = experimental group*



In the within-group analysis, the experimental group (EG) exhibited substantial improvements in all variables ($p = 0.001$), with large effect sizes (ESs). CMJ performance increased by 16.33% (ES = 1.44), VO2max improved by 5.80% (ES = 1.13), and TD showed a marked increase of 19.39% (ES = 1.18). Moreover, VHSR almost doubled, with an increase of 96.55% (ES = 1.08), and Vmax improved by 13.47% (ES = 1.45), highlighting the considerable magnitude of the training effects in the EG. Conversely, no within-group differences were observed in the CG for any variable.

Between-group comparisons revealed significant differences in favour of the EG across all variables ($p = 0.001$). The CMJ showed the largest group difference,

followed closely by VO2max and TD. VHSR and Vmax also demonstrated substantial between-group effects, confirming the superior improvements in physical performance and match load performance in the EG compared to the CG.

3.5. DISCUSSION

This study aimed to examine the effects of a 10-week strength training program on physical performance and match running performance in young female soccer players during their regular in-season period. The CG did not perform any strength training, as it was not included in their in-season periodization program. To the best of our knowledge, this is the first study to investigate the impact of strength training based on completing half of the maximum number of repetitions per set on match load performance in this population (i.e., female elite U-18 soccer players). The main obtained findings indicated that players in the EG achieved significantly greater improvements compared to those in the CG.

The CMJ is widely recognized by soccer strength and conditioning professionals as a reliable measure of lower extremity power (Nuzzo et al., 2008), which is strongly associated with success in soccer (Faude et al., 2012). Consequently, training programs should prioritize improving this parameter. In this study, increases in CMJ performance were observed in the EG following the intervention period, with significant between-group differences in favour of this group. These findings align with those of Millar et al. (2020), who reported a 4.9% improvement in vertical jump performance after implementing a 6-week in-season strength training program focused on back squats in female high school soccer players. Similarly, Lambright et al. (2024) conducted an 8-week strength training program (three sessions/week) during the preseason in young female soccer players (i.e., 16 years), observing improvements of 1.19 ± 2.71 cm in CMJ performance post intervention. The training group also seemed to improve the estimated VO2max, potentially derived from an improvement in the muscles' ability to use oxygen. Enhancements in VO2max contribute to delaying the onset of fatigue, thereby enabling repeated high-intensity efforts with minimal recovery time during matches (Slimani et al., 2019). In this study, an estimated improvement

in VO2max were observed in the EG (5.8%), although it cannot be ruled out that the improvement in Yo-Yo IR2 performance, was related to improvements in muscle strength and power. Similar findings have been reported in previous research. For example, Sporiš et al. (2011) documented increases in VO2max following a 12-week strength training program (three sessions/week) during the off-season period in elite female soccer players (under 20 years). These results highlight the importance of incorporating strength training programs into soccer periodization to enhance both high-intensity actions and aerobic power. Also, it is necessary to highlight that these strength training programs could be enhanced if their methodology is based on performing half of the reps in the main lifts, since although prior studies presented significant improvements, in the present study, these improvements were also achieved but in a more time-efficient manner (i.e., half the reps), while generating less labour that could interfere with soccer performance.

Certain external load metrics, such as TD, VHSR, and Vmax achieved during matches, are critical determinants of soccer performance, with top-tier teams often exhibiting the highest values in these variables (Pons et al., 2021). Consequently, it is essential to develop strategies that enhance performance in these metrics during matches to achieve greater soccer success. In this study, the between-group comparison revealed significantly greater improvements in the EG for TD, VHSR, and Vmax. These findings may be attributed to the strong relationship between strength levels and high-intensity actions, as well as external match performance (Pedersen et al., 2022; Wisløff et al., 2004). Also, we hypothesize that the applied strength training could improve sprint mechanics, support higher maximum velocities, potentiate repeated-sprint ability, enable more very-high-speed running bouts, and delay neuromuscular fatigue, facilitating greater total distance covered during match play. Despite this, no previous studies have specifically examined the impact of strength training programs on external match load performance in young female soccer players, although this has been explored in men's soccer. For example, Byrkjedal et al. (2023) implemented two distinct strength training programs (i.e., regulated vs. self-selected) over a 10-week period (one session per week) in professional male soccer players. Both groups demonstrated improvements in external match load variables, such as high-speed running and

sprint running. These findings reinforce the notion that strength training is a crucial component for enhancing external match performance during official competitions.

Despite the promising findings, this study has several limitations that practitioners should consider. The main limitation is that two teams were involved, and all the players of the same team were allocated into the same group. In this sense, although the training standards of both groups were similar, this could have impacted the results obtained due to the influence of the coaches. Another limitation is that the EG completed a higher total training volume, as the CG did not supplement their regular soccer training. Also, only two teams participated in the study, consistently maintaining the same roles. Therefore, future research involving a greater number of teams or employing a crossover design is needed to draw more robust conclusions. In addition, the assumed GPS variability must be considered, mainly when high-intensity distances are assessed. Finally, other important abilities, including flexibility, change in direction speed, and repeated-sprint ability (RSA) must be assessed in future studies. Finally, the study exclusively included female soccer players, which limits the generalizability of the findings to male players, highlighting the need for similar studies in male populations.

3.6. CONCLUSIONS

The main findings in this study showed improvements in young female soccer players' physical performance and match running performance after the application of a 10-week strength training program. Using a practical approach, it is suggested to incorporate the proposed strength training program, focused on the lower limb, into young female soccer players' periodization to improve not only physical performance but also match load parameters. Future studies considering the impact of the strength program on injury occurrence or long-term studies analyzing the retention of performance gains should be performed.

IV – STUDY 2

IV -THE DIFFERENTIAL EFFECTS OF TWO COMPLEMENTARY SPRINT-BASED TRAINING PROGRAMS ON SPRINT PERFORMANCE IN PROFESSIONAL FEMALE SOCCER PLAYERS

4.1. ABSTRACT

This research investigated the effects of two 12-week sprint training programs—Traditional Sprint Training (TST) and Modified Integrated Sprint Training (MIST)—on the sprint performance and match running demands of professional female soccer players. Forty-five players from two professional teams were assigned to either the TST group or the MIST group based on availability. Each group participated in two sprint sessions weekly, supplementing their regular in-season schedule. Physical performance was measured using 30-meter sprint tests, including 5 m, 10 m, and 30 m splits, and the Yo-Yo Intermittent Recovery Test Level 2. Match demands were assessed using GPS technology during four official matches, concentrating on very high-speed running distances (VHSR; >23 $km \cdot h^{-1}$) and the number of sprints. Both groups demonstrated significant improvements in most metrics ($p \leq 0.05$), except for VO_2max in the TST group ($p = 0.328$; effect size [ES] = 0.09). Comparative analysis revealed that the TST group achieved significantly greater improvements in sprint times ($p = 0.017$ to 0.000; effect size [ES] = 0.77 to 1.74), while the MIST group showed superior enhancements in match sprint metrics ($p = 0.016$ to 0.000; ES = 0.66 to 1.89). No significant differences in VO_2max were observed between groups. These findings indicate that both training methods are effective, with TST being more advantageous for linear sprint development, while MIST is more effective for improving on-field sprint performance. Coaches should consider the specific needs and performance objectives of each player when selecting training strategies.

Keywords: Sprint training; high-speed running; match metrics; female soccer.

4.2. INTRODUCTION

Modern soccer is a highly demanding team-sport characterized by the unpredictable alternation of low- to moderate-intensity actions with high-intensity efforts (Rodríguez Porras et al., 2024). In this context, previous research has highlighted the crucial role of high-intensity actions in achieving sporting success (García-Calvo et al., 2025). Among these, sprinting has been identified as one of the most decisive actions, given that sprints are the most frequent movements preceding goal-scoring opportunities (Faude et al., 2012). The increasing emphasis on sprint performance and the distance covered at high intensity has led to a significant rise in the physical demands imposed on players during official competitions (Rodríguez Porras et al., 2024). Consequently, these growing physical requirements have influenced the way training programs are structured and periodized, particularly in women's soccer. Despite the recent surge in scientific interest in this area within women's soccer, there remains a lack of consensus regarding the most effective training methodology to enhance the performance of high-intensity actions. While various training approaches have been proposed, including resistance training, sprint interval training, and high-intensity interval training, the optimal strategy for maximizing sprint performance in female footballers is still unknown. Further research is necessary to establish evidence-based guidelines that can be effectively implemented to improve high-intensity performance and overall physical preparedness in elite female soccer players.

Regarding this, sprint-based training programs have demonstrated significant improvements in the physical fitness of female soccer players (Stankovic et al., 2023). For example, Mathisen & Pettersen (2015) found that an 8-week sprint training program was highly effective in enhancing sprinting ability in young female soccer players. Similarly, Shalfawi et al. (2013) reported positive effects of an 8-week sprint training program, implemented in a repeated-sprint fashion, on sprint performance in young female soccer players. Furthermore, Johnson et al. (2013) applied a treadmill-based training regimen for female soccer players and observed a significant improvement in 40-yard sprint times following a 6-week intervention period. Despite these promising findings, it is important to note that

sprint actions in soccer are not always linear (Kobal et al., 2021). The presence of external factors such as ball movement, teammates, and opponents, introduce an element of unpredictability, influencing the execution and effectiveness of sprint actions (Preissler et al., 2023). This highlights the need for a paradigm shift in sprinting training programs for female footballers, incorporating multidirectional sprinting drills and decision-making components to better replicate real-game scenarios.

On the other hand, it is necessary to highlight that the main aim of a complementary training program when it is implemented in soccer players is not only to improve the athletes' physical fitness in an analytic way but improving the on-field soccer players in the involved players (Lambright et al., 2024). This is supported by strong association observed between the performance on high-intensity actions and match physical performance in high-level female soccer players (Pedersen et al., 2022). Despite this, few studies have investigated whether a complementary training program can improve soccer players' performance, although these have found promising results, showing that complementary training focused on high-intensity actions is an effective method to enhance external match performance in soccer players, mainly in high-speed running and sprinting variables (Byrkjedal et al., 2023). However, the effects of these programs on female soccer player are understudied, and to date, no studies have analyzed the influence of a complementary sprint-based training program on match load performance in professional female soccer players, so further studies are required on this topic.

Therefore, the aim of this study was to analyze the differentiate impact of two 12-week sprint-based training programs (i.e., traditional vs. modified) on the physical fitness and match running demands of professional female soccer players. Based on prior studies (Byrkjedal et al., 2023; Pedersen et al., 2022), we hypothesized that traditional program would has a great impact on sprint tests, meanwhile the modified program, due to its specificity, could further improve match load performance in professional female soccer players.

4.3. METHOD

4.3.1. Study Design

A quasi-experimental design was adopted to compare the effects of two distinct 12-week sprint-based training programs (i.e., traditional vs. modified) on the physical fitness and match running demands of professional female soccer players. Physical fitness was evaluated at baseline and post-intervention during a single testing session, which included a 30m linear sprint test (with splits at 5m, 10m, and 30m) and an endurance test (Yo-Yo Intermittent Recovery Test). Additionally, players' match external demands (i.e., total distance covered at speeds exceeding 23 $km \cdot h^{-1}$ and the number of sprints completed) were monitored using Global Positioning System (GPS) devices during four competitive matches both before and after the intervention period. All fitness tests were conducted on the team's natural grass training field, with players wearing their own soccer boots. Testing sessions took place in the late afternoon (5:00 PM to 7:00 PM), and players were instructed to have their last meal at least three hours prior to testing, to avoid caffeinated beverages, and to refrain from intense physical activity on the day of assessment.

4.3.2. Participants

A total of 45 professional female soccer players from Denmark were initially recruited for this investigation. A power analysis was performed in advance using G*Power software (version 3.1.9.2, Universität Kiel, Germany), indicating that at least 20 participants would be required to detect a statistically significant effect with 84% power ($1-\beta = 0.84$), assuming a large effect size (ES = 0.90) and a significance threshold of $\alpha = 0.05$. The athletes belonged to two elite-level teams within their age category, both of which adhered to an identical training schedule consisting of four weekly practice sessions and one official match each weekend. To be included in the study, players had to meet several criteria: regular participation in at least 80% of training sessions throughout the 12-week intervention period, a minimum of four years of structured soccer training experience, and absence of injury in the two months prior to the study. Goalkeepers

were excluded due to the specific characteristics of their role and training requirements. Based on availability, players were distributed into one of two groups: the Modified Integrated Sprint Training group (MIST; n = 23; age: 23.7 ± 3.2 years; height: 170.1 ± 6.9 cm; body mass: 60.9 ± 5.9 kg) or the Traditional Sprint Training group (TST; n = 17; age: 23.9 ± 3.3 years; height: 171.7 ± 6.1 cm; body mass: 61.7 ± 4.7 kg). Before enrollment, all participants received comprehensive information about the nature and aims of the study, including any associated risks and anticipated benefits. Informed consent was obtained in writing from their parents or legal representatives. The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki (2013) and received approval from the Ethics Committee of the Catholic University of Murcia under the internal registration number CE062112 (25 June 2021).

.

4.3.3. Procedures

Over a 12-week intervention period, professional female players adhered to their regular in-season training schedule, with two weekly sprint training sessions, differentiated by each group (i.e., MIST and TST). The weekly microcycle, collaboratively designed by the head coach and strength conditioning coach, comprised five technical-tactical training sessions and one official match. Before and after the intervention period, physical performance evaluations were conducted across two sequential testing sessions: 1) Yo-Yo Intermittent Recovery Test, and 2) 30-m linear sprint test. Each evaluation session was preceded by a standardized 15-minute warm-up protocol divided into two phases: 7 minutes of low-intensity locomotion (jogging and walking) followed by 8 minutes of plyometric exercises and progressive sprint/acceleration drills over 10- and 30-meter distances. Additionally, performance data from four matches pre- and post-intervention were analyzed. All players were already proficient with the testing protocols, having undergone similar preseason assessments at the club, and were accustomed to wearing GPS devices during competitive matches throughout the season.

4.3.4. Test

Linear sprint test. Players performed two linear sprints over a 30 m distance. The starting position was set 0.5 m behind the first timing gate (Microgate Polifemo, Microgate, Bolzano, Italy), which was positioned 0.4 m above the ground. Time recording was automatically triggered as players passed the first gate at the 0 m mark, after which they were instructed to sprint at maximum effort to the finish line at 30 m. The straight-line sprint test was conducted on an outdoor soccer pitch.

Yo yo intermittent recovery test level 2. This test required participants to execute repeated 20-meter shuttle sprints at incrementally escalating velocities, interspersed with 10-second active recovery intervals involving back-and-forth 5-meter jogging segments (Krustrup et al., 2003). Athletes synchronized their movements with pre-recorded audio cues, and the protocol terminated when an individual twice consecutively failed to meet the pace requirements. The cumulative distance achieved (in meters) served as the primary performance metric, from which maximal oxygen uptake (VO_2max) values were indirectly extrapolated. The testing zone comprised a 20-meter × 2-meter rectangular corridor demarcated by cones, with an additional marker positioned 5 meters beyond the endpoint to delineate the recovery jogging path. During active recovery phases, participants decelerated and traversed the 5-meter buffer zone at reduced intensity before recommencing high-intensity efforts. Test administrators recorded the final distance attained once athletes could no longer maintain the dictated tempo across two successive sprint cycles.

4.3.4.1. Sprint match running demands

The Polar Team Pro (Polar Electro, Kempele, Finland) system was used to monitor external match demands. This advanced athlete-tracking technology, designed for team sports, integrates a 10 Hz GPS, a 200 Hz tri-axial accelerometer, a gyroscope, a magnetometer, and a heart rate monitor. The devices were positioned on the players' upper backs, with each player using the same unit throughout the experimental period. Previous research has demonstrated their high accuracy and acceptable reliability when compared to gold-standard measurement methods (Akyildiz et al., 2022). Specifically, very high-speed running

distance (VHSR, > 23 km·h−1), and the number of the sprints completed during matches (Sprints) were registered.

4.3.4.2. Sprint training program

Elite female athletes participated in one of two specialized sprint training protocols (MIST/TST) across a 12-week intervention period, maintaining a biweekly training frequency. The MIST adopted a holistic approach emphasizing game-specific movements, where each training sequence involved two interconnected elements: 1) combined sprint-shooting drills followed by 2) situational 2v2 gameplay scenarios. Detailed periodization parameters including work-rest ratios and intensity progression for MIST are outlined in Table 5. In contrast, TST protocol employed a reductionist methodology, requiring athletes to perform high-volume linear sprints in isolation from tactical or environmental cues. As detailed in Table 6, TST's programming prioritized unidirectional acceleration mechanics without contextual interference. Both regimens systematically manipulated training density through predetermined loading schemes and recovery intervals while maintaining equivalent session frequencies.

Table 5. *Modified Integrated Sprint Training (MIST)*

	Weeks			
Variables	***1-2-3***	***4-5-6***	***7-8-9***	***10-11-12***
*Sprint reps (n)**	*2x3*	*2x3*	*2x4*	*2x5*
Sprint distance (m)	*30-30*	*50-50*	*60-60*	*60-60*
Shooting distance (m)	*18/20*	*18/20*	*18/20*	*18/20*
2v2 Situational Play (m)	*70*	*60*	*105*	*105*
Between sprints recovery (s)	*75*	*75*	*75*	*75*
Between sets recovery (s)	*240*	*240*	*180*	*180*

*Abbreviations: *: 2x5 denotes 2 sets of 5 repetitions.*

Table 6. *Traditional Sprint Training (TST)*

	Weeks			
Variables	***1-2-3***	***4-5-6***	***7-8-9***	***10-11-12***
*Sprint reps (n)**	*2x3*	*2x3*	*2x4*	*2x5*
Sprint distance (m)	*30-30*	*50-50*	*60-60*	*60-60*
Between sprints recovery (s)	*75*	*75*	*75*	*75*
Between sets recovery (s)	*240*	*240*	*180*	*180*

*Abbreviations: *: 2x5 denotes 2 sets of 5 repetitions.*

4.3.5. Statistical Analysis

Descriptive statistics are presented as mean ± standard deviation (SD). To assess the normality of the data distribution, and the homogeneity of variances, the Shapiro-Wilk test and Levene's test were conducted, respectively. A paired-samples t-test was applied to examine the within-group differences, and an analysis of covariance (ANCOVA), incorporating baseline values as covariates, were performed to assess the between-group differences. Effect sizes (ES) were computed using Cohen's method to evaluate the magnitude of effects and were interpreted as follows: < 0.2, trivial; 0.20–0.49, small; 0.50–0.80, moderate; and > 0.80, large (Cohen, 1988). Statistical analyses were carried out using SPSS v29 (SPSS Inc., Chicago, IL), with the level of significance set at $p < 0.05$.

4.4. RESULTS

In Table 7 are presented the changes in physical fitness and match load variables before (baseline) and after (post-training) the application of the sprint-based training programs. Female players allocated in the MIST group showed significant improvement in all analyzed variables (p = 0.005 to 0.000; ES = 0.66 to 1.89, moderate to large), while players in the TST group significantly improved their values in all variables (p = 0.006 to 0.000; ES = 0.77 to 1.74, moderate to large) except for the VO2max (p = 0.328; ES = 0.09, trivial). Between-groups analysis revealed differences in favor of the TST in SP5, SP10 and SP30 (F = 6.26 to 17.71; p

= 0.017 to 0.000) and in favor to the MIST in VHSR and Sprints variables (F = 6.36 to 19.61; p = 0.016 to 0.000), without differences in VO2max.

Table 7. *Changes in physical fitness and match load variables before (baseline) and after (post-training) the application of the sprint-based training programs.*

	MIST (n = 23)					*TST (n = 17)*					*Between group differences*	
Variables	*Baseline (mean ± SD)*	*Post training (mean ± SD)*	*Δ (%)*	*p*	*ES*	*Baseline (mean ± SD)*	*Post training (mean ± SD)*	*Δ (%)*	*p*	*ES*	*F*	*p*
SP5 (s)	1.16 ± 0.06	1.11 ± 0.05	4.31	0.000	1.44	1.23 ± 0.08	1.20 ± 0.08	2.44	0.006	0.77	6.26	0.017
SP10 (s)	1.98 ± 0.08	1.90 ± 0.08	4.04	0.000	1.76	2.06 ± 0.11	2.03 ± 0.11	1.46	0.006	0.77	14.22	0.000
SP30 (S)	4.75 ± 0.18	4.64 ± 0.18	2.32	0.000	1.89	4.84 ± 0.18	4.80 ± 0.18	0.83	0.003	0.85	17.71	0.000
VO_{2max} (ml/kg/min)	47.35 ± 4.11	48.46 ± 4.63	2.34	0.005	0.66	45.61 ± 4.89	46.09 ± 5.27	1.05	0.282	0.09	0.98	0.328
VHSR (m)	129.39 ± 61.68	247.48 ± 119.27	91.27	0.000	0.94	106.77 ± 60.89	119.88 ± 61.23	12.28	0.000	1.35	19.61	0.000
Sprints (n)	8.52 ± 3.75	13.48 ± 6.05	58.22	0.000	1.28	7.18 ± 3.83	8.82 ± 4.35	22.84	0.000	1.74	6.36	0.016

Abbreviations: CG = control group; EG = experimental group; SD = standard deviation; Δ (%): percentage of change between pre and post intervention; p: level of significance; ES: effect size; SP5 = linear sprint over 5 m distance; SP10 = linear sprint over 10 m distance; SP30 = linear sprint over 30 m distance; VO2max = maximal oxygen uptake; VHSR = distance covered at above of 23 km·h-1; Sprints = number of sprints covered during matches. Significance level was set at $p < 0.05$.

4.5. DISCUSSION

This study aimed to analyze the differential impact of two 12-week sprint-based training programs (i.e., traditional vs. modified) on the physical fitness and match running demands of professional female soccer players. This is the first study that analyzes the effects of these sprint training programs on match running demands, since most of the prior literature only considered fitness tests. The main findings showed that players in MIST obtained greater improvements in match variables (i.e., VHSR and Sprints), while their counterparts in the TST improved more in all the split times in the linear sprint test, without differences in VO2max.

Another concern is how well training results transfer from controlled test settings to actual match performance. While the TST group showed better outcomes in linear sprint tests, these improvements may have limited importance during competitions, where sprints are rarely performed without external

influences (Preissler et al., 2023). The current findings support the idea that improvements in acceleration and speed, although beneficial, need to be combined with drills that reflect the real-match conditions by including perceptual and decision-making challenges (Gualtieri et al., 2023; Preissler et al., 2023). This integrated approach can help players not only boost raw speed but also enhance their ability to use that speed effectively in the unpredictable situations of soccer matches.

When looking to improve the performance of high-intensity actions, the training program must be focused on these actions, based on the specificity training principle (Haff & Nimphius, 2012). However, for this purpose, other variables, such as VO_2max, should be improved, since it contributes to delaying the onset of fatigue, thereby enabling repeated high-intensity efforts with minimal recovery time during matches (Slimani et al., 2019). Regarding this, players belonging to both groups, i.e., MIST and TST, improved their linear sprint performance. These results confirm those obtained by prior studies (Johnson et al., 2013; Mathisen & Pettersen, 2015; Shalfawi et al., 2013), which reported significant improvements in the sprint performance of female soccer players through several sprint training programs (i.e., from 6 to 8 weeks).

Despite this, players in TST improved significantly more than the players in the MIST group, which could be due to the specificity of the task included in their sprint-based training program (i.e., controlled sprints in terms of distance, recovery time and uncertainty). In relation to VO2max, MIST improved their capacity, possibly due to the chain of actions proposed in the training program for this group. However, no significant between-group differences were observed, suggesting the necessity of combining different tasks to improve both sprint performance and VO2max level, being the latter a basis for improving high-intensity actions. It is also worth noting that the MIST program not only improved on-field metrics but also generated a positive change in VO_2max, although no significant differences between groups were detected. This finding suggests that integrating sprint actions with game-like activities may impose higher cardiorespiratory loads compared to isolated sprint drills, which could be particularly beneficial in delaying fatigue and sustaining repeated high-intensity

actions (Slimani et al., 2019). This aligns with the notion that endurance and sprint capacities are interdependent qualities for soccer performance, especially in female players who often cover substantial high-speed running distances across matches (Rodríguez Porras et al., 2024).

Despite the promising results obtained in the fitness tests, it seems necessary for a complementary training program to also impact the female soccer players' on-field performance, mainly in sprint variables, which are widely related to soccer performance (Faude et al., 2012). According to Gualtieri et al. (2023), the integration of game-based running exercises with soccer circuit-based drills is advisable to ensure adequate exposure to high-speed and sprint running in professional adult soccer. The results showed that female players in both groups improved their on-field sprint performance (i.e., VHSR and Sprints) after the intervention period. However, the between-group analysis revealed significantly greater improvements in the GPS variables in favor of the players in the MIST group compared to their counterparts in the TST group. These differences may be attributed to the principle of specificity (Haff & Nimphius, 2012; Gualtieri et al., 2023), as players in the MIST group completed their training program through activities that engaged perceptual and decision-making mechanisms. These mechanisms directly influenced sprint execution, mirroring the demands of real-game scenarios in which teammates, rivals, and the ball influence the players' behaviors. In contrast, players in the TST group performed sprint exercises in an isolated, analytical manner. While both groups demonstrated improvements, the TST group exhibited lower gains compared to the MIST group, likely due to the absence of contextual and cognitive challenges that simulate competitive environments. Despite the promising findings, no previous studies have specifically examined the impact of a complementary sprint-based training program on professional female soccer players' on-field performances, so future studies on this topic are required to confirm the obtained findings.

From a practical standpoint, the observed differences highlight the importance of carefully selecting the type of sprint training according to the competitive context and the players' individual needs. For instance, TST might be more appropriate during off-season or rehabilitation phases, where rebuilding

linear sprint mechanics and maximal velocity is critical (Raya-González et al., 2022). In contrast, MIST seems more effective during in-season periods when optimizing players' game performance and improving high-intensity external load variables is a priority (Byrkjedal et al., 2023; Pedersen et al., 2022). Coaches may therefore benefit from periodizing both training modalities within a season to achieve complementary benefits.

This study is not exempt from limitations, which practitioners must acknowledge. Mainly, two different teams were involved in each group. Although both teams followed the same weekly structure and similar methodology, this could have influenced the results. However, the fact that the players were professionals made other types of design (i.e., crossover for each team) difficult. Additionally, only female senior soccer players participated in the study, so it is challenging to generalize the findings to male players or younger female players. Several important external load metrics, including accelerations and decelerations, were not considered and should be included in future research on this topic.

Considering sprinting's significant impact on match outcomes, such as scoring a goal (Faude et al., 2012), optimizing both controlled sprint ability and match-specific sprint expression is essential. The present study offers new insights, and future research should examine additional external load variables, including accelerations, decelerations, and changes of direction, which are common and influential in elite female soccer (Stankovic et al., 2023). Incorporating these measures will help gain a more comprehensive understanding of how sprint-based programs influence competitive performance.

4.6. CONCLUSION

The findings of this study revealed that both complementary sprint-based training programs (i.e., MIST and TST) are effective for improve the sprint performance in professional female soccer players. However, the obtained results showed that players in the TST groups improve better in the linear sprint test, in all distances, compared to their counterparts in the MIST, which get greater improvement in their sprint performance during official matches. These results

suggest the importance of choosing the type of complementary sprint-based training program attending to the individual needs of each female soccer player.

V – STUDY 3

V - IMPLEMENTING A TWO-SEASON TRADITIONAL STRENGTH TRAINING INTERVENTION: CHRONIC ADAPTATIONS IN PHYSICAL FITNESS AND EXTERNAL MATCH DEMANDS OF ELITE YOUNG FEMALE SOCCER PLAYERS.

5.1. ABSTRACT

This study aimed to analyze the impact of a long-term traditional strength training intervention across two full competitive seasons to evaluate physical fitness performance and external match demands in elite female youth soccer players. Twenty-eight Danish female young elite soccer players (age: 16.5 ± 0.8 years), belonging to two different soccer teams competing in the highest level for their age, participated in the study. Teams were allocated to either an experimental group, performing twice-weekly strength training for two years (EG, n = 14) or a control group (CG, n = 16). Physical fitness level, including vertical jump performance and Yo-Yo IR2 performance for maximal oxygen uptake (VO2max), was assessed at four different time points: at the beginning of season 1; at the end of season 1; at the beginning of season 2; and the end of season 2. Additionally, players' match external demands (i.e., total distance, distance covered at speeds above 23 $km \cdot h^{-1}$, and maximum velocity achieved) were monitored using Global Positioning System devices during four matches before and after the intervention, in the same 4 time-points. Experimental group players obtained greater improvements in both physical fitness and external match load performance, compared to the players in the control group, showing enhancements in all comparisons along the time-points. These results suggest the necessity of including strength training programs as an essential part of female soccer players' periodization, not only to improve their performance, but also to facilitate their transition to professional soccer.

Keywords: Resistance training; longitudinal; youth; performance; women; football.

5.2. INTRODUCTION

The physical demands of female soccer require players to develop superior lower-body power, aerobic capacity, and match-running performance to meet competitive standards (Rodríguez Porras et al., 2024). While traditional strength training (ST) is widely implemented in adult soccer programs (Byrkjedal et al., 2023; Sporiš et al., 2011), its longitudinal effects on female youth athletes remain understudied, particularly concerning the simultaneous development of lower-limb power (CMJ), aerobic fitness (VO_2max), and external load metrics during competition (Cherappurath et al., 2024). Existing literature has predominantly focused on male cohorts or short-term interventions (6–12 weeks) (Otero-Esquina et al., 2017; Raya-González et al., 2021), limiting the understanding of how sustained strength training across multiple seasons influences physiological adaptations during critical periods of adolescent development (Pierce et al., 2021). Female athletes face unique challenges, including hormonal fluctuations and differing neuromuscular maturation patterns, which may modulate training responsiveness compared to males (Kissow et al., 2022). Consequently, there is a pressing need to investigate the efficacy of structured, long-term ST in optimizing performance metrics specific to elite female youth soccer players.

Current evidence suggests that ST (e.g., squats, deadlifts, plyometrics) enhances CMJ height in adolescent athletes by improving the rate of force development and motor unit recruitment (Balsalobre-Fernández et al., 2015; Keiner et al., 2022). However, the transfer of these gains to soccer-specific endurance and in-match performance (e.g., total distance covered, high-speed running) is less clear, particularly over extended periods. Aerobic capacity (VO_2max) is a known determinant of recovery between high-intensity efforts during matches, yet the interaction between strength training and VO_2max in youth females remains debated (Sporiš et al., 2011). Some studies report interference effects when combining heavy resistance training with aerobic development, while others demonstrate synergistic benefits (Seipp et al., 2023). This discrepancy highlights the

importance of longitudinal data to clarify whether ST complements or hinders soccer-specific endurance adaptations in growing athletes.

The external demands of soccer (e.g., accelerations, decelerations, sprint distances) are increasingly quantified via Global Position System (GPS) metrics, providing objective measures of match performance (Al Haddad et al., 2018). While ST has been shown to improve sprint performance and change-of-direction ability (Keiner et al., 2014) its longitudinal impact on in-game movement profiles, especially in female youth players, is poorly understood. Prior interventions have typically examined these outcomes in isolation over short durations, neglecting the cumulative effects of multi-year training programs (Deprez et al., 2015). Given that elite youth soccer involves progressive increases in competitive load across seasons, understanding how ST influences both physiological capacities and their translation to match performance is critical for long-term athlete development.

The aim of this study was to implement a long-term ST intervention across two full competitive seasons to evaluate its effects on CMJ, VO2max, and external match demands in elite female youth soccer players. Based on prior studies, we hypothesized that players who complete the long-term intervention would obtain greater improvements in both physical fitness and external match load performance compared to their counterparts in the control group.

5.3. METHOD

5.3.1. Study Design

An experimental longitudinal design was applied to assess the long-term effects of a ST (i.e., two sessions per week during two consecutive seasons) on the physical fitness and external match demands in young female soccer players. Physical fitness variables were evaluated at four different moments: at the beginning of season 1 [i.e., after the first 4 official matches, (Pre S1)]; at the end of the season 1 [i.e., prior to the first last official matches, (Post S1)]; at the beginning of season 2 [i.e., after the first 4 official matches, (Pre S2)]; at the end of the season 2 [i.e., prior to the first last official matches, (Post S2)]. Each evaluation was

performed in a single session (in the afternoon between 5:00 PM and 7:00 PM), and a jump test (i.e., countermovement jump, CMJ) and an endurance test (i.e., Yo-Yo Intermittent Recovery Level 2 Test) were included. Both tests were conducted on the team's training field (i.e., natural grass), with players wearing their soccer boots. In addition, the external match demands (i.e., total distance, distance covered at above 23 km·h-1, and the maximum velocity achieved) of the four matches before and after the evaluation sessions were registered through Global Positioning System (GPS) devices. All the assessment sessions were supervised by a strength and conditioning specialist, who provided verbal encouragement during evaluations.

5.3.2. Participants

Twenty-eight U18 Danish female elite soccer players, belonging to two different soccer teams competing in the highest level for their age, participated in the study. An a priori power analysis was performed in G*Power software (v3.1.9.2; Universität Kiel, Germany). This calculation determined that 20 participants would be sufficient to achieve 0.84 statistical power (1-β), given a large effect size (ES = 0.90) and $\alpha = 0.05$. The two participating teams adhered to identical periodization models and training schedules, completing four pitch sessions weekly alongside competitive weekend matches. For eligibility, players must accomplish the following characteristics: 1) continuous enrollment in the academy for ≥2 4 months; 2) > 80% training attendance during the intervention period; 3) ≥ 4 years of structured soccer development; and 4) injury-free status for 60 days pre-intervention. Given participants' neuromuscular immaturity and limited resistance training experience, repetitions were prescribed at half of the maximum number capacity to avoid failure training. Goalkeepers were excluded due to position-specific physiological demands. Teams underwent block randomization to either control (CG; n = 14; age: 16.4 ± 0.8 years; height: 167.9 ± 4.9 cm; body mass: 61.1 ± 5.9 kg; body mass index: 20.7 ± 1.7 kg·m−2) or experimental (EG; n = 14; age: 16.6 ± 0.8 years; height: 166.5 ± 5.5 cm body mass: 60.1 ± 6.1 kg; body mass index: 22.4 ± 1.2 kg·m−2) conditions, preserving team-unit integrity. After a comprehensive briefing regarding protocols, risks, and benefits, written informed consent was secured from parents/guardians. The investigation complied with Declaration of

Helsinki guidelines (2013) and received ethical approval from the Catholic University of Murcia Institutional Review Board (Ref: CE062112; Date: 25 June 2021).

5.3.3. Procedures

Throughout the 2-season intervention, both groups maintained their standard competitive period training regimen. The EG supplemented their program with two weekly neuromuscular training sessions, while the CG continued their regular periodization without including strength training. Microcycle design was developed collaboratively by coaching and strength staff and comprised four pitch sessions and one competitive match weekly. All players were familiarized with assessment protocols through routine club monitoring and GPS technology exposure during seasonal competition. Physical performance was evaluated across two sessions: 1) countermovement jump (CMJ) followed by Yo-Yo Intermittent Recovery Level 2 (minimizing fatigue interdependence), and 2) 1RM assessment in bilateral lower-body resistance exercises. Match external load variables were recorded from four fixtures pre- and post-intervention for each season. Standardized 15-minute neuromuscular priming preceded all testing, comprising 7 minutes of progressive locomotion (jog-walk transitions) and 8 minutes of plyometric progressions coupled with acceleration-sprint drills over 10m/30m distances.

5.3.4. Test

Countermovement Jump Height. Participants executed two maximal-effort bilateral countermovement jumps (CMJ) separated by 60-second passive recovery intervals. Standardized instructions emphasized achieving maximal triple extension impulse through rapid descent, followed by explosive concentric action while maintaining hands akimbo position to minimize upper-body contribution. Jump height was quantified using the MyJump 2.0 iOS application (v3.1.4), which demonstrates near-perfect criterion validity ($r = 0.995$) and test-retest reliability (ICC = 0.997) for flight-time derived vertical displacement metrics (Balsalobre-Fernández et al., 2015). All trials were captured at 240 Hz sampling frequency using an iPhone 8 Plus (Apple Inc., Cupertino, CA) with a stabilized tripod at sagittal

plane alignment (Raya-González, Scanlan, et al., 2021). The trial exhibiting the highest vertical displacement (cm) was selected for subsequent analysis.

Yo-Yo Intermittent Recovery Level 2 Test. Participants performed one trial of the Yo-Yo Intermittent Recovery Test Level 1, executing repeated 20-m shuttle runs at incrementally escalating velocities interspersed with 10-second active recovery intervals. These brief recovery periods required athletes to jog 5 m outward and return (total 10 m) within the allotted time. Running pace was regulated by audio cues from a standardized protocol, with test termination occurring when participants twice consecutively failed to reach the designated line synchronously with the auditory signal. Total accumulated distance (meters) served as the primary performance metric (Krustrup et al., 2003). This outcome allowed indirect prediction of maximal oxygen uptake (VO_2max) using validated algorithms. The testing corridor comprised parallel cones demarcating a 20 × 2 m lane, with an additional marker positioned 5 m beyond the endpoint to designate the recovery jog turnaround.

Match Running Demands. External match loads were quantified using Polar Team Pro systems (Polar Electro Oy, Kempele, Finland). This athlete monitoring technology integrates 10-Hz GPS with 200-Hz inertial movement units (triaxial accelerometers, gyroscopes, digital compasses) and integrated heart rate telemetry. Devices were secured in manufacturer-supplied thoracic harnesses, with individual unit assignment maintained throughout the study to control inter-device variability. The system demonstrates excellent criterion validity (typical error < 3%) and inter-unit reliability (CV < 5%) against gold-standard motion capture (Akyildiz et al., 2020). Specifically, the following variables were monitored: total distance covered in meters (TD), very high-speed running distance (VHSR, > 23 km·h−1), and the maximum velocity achieved during matches (Vmax).

5.3.5. Intervention Program

Players participated in a 2-season ST program, conducted prior to regular soccer training and following a standardized warm-up. The ST integrated strength

exercises, mobility development, and postural control exercises as detailed in Tables 1 and 2. Major muscle group exercises (pectoral, lower limbs, dorsal) employed submaximal loading (70% 1RM), executing 6 repetitions per set at 50% of maximum repetition capacity [denoted 4×6(12)]. This prescription is derived from empirical evidence demonstrating that halving maximal repetition volume optimizes mean concentric velocity, attenuates neuromuscular fatigue, accelerates recovery kinetics, and reduces cortisol response and exercise-induced muscle damage in the athletic population (González-Badillo et al., 2016). An incremental load test was conducted to determine the 1RM value for each exercise (Sánchez-Medina & González-Badillo, 2011), which was repeated across the 2 sessions in order to get an adapted load. The initial load for all participants was set at 20 kg and was incremented until mean propulsive velocity fell below 0.5 $m \cdot s^{-1}$, followed by 2.5-5kg increases until failure. Inter-set recovery exceeded 5 minutes. Session-1 (Table 8) corresponded to weekly initiation; Session-2 (Table 9) to secondary sessions. Preceding formal testing, a 2-week anatomical adaptation phase (2 sessions/week) ensured tissue readiness.

Table 8. *Session-1 for the Traditional Strength Training Program.*

Exercises	Sets	Repetitions
Bulgarian split squat	4	6(12)
Quick steps with band	4	10´´
Dumble bent row	4	6(12)
One leg deadlift	4	6(12)
Quick step up	4	6 each leg
Lever chest press	4	6(12)
Cable abduction + adduction	2	12
Reverse hyperextension	3	12
Knee up crunch + leg raise	3	15 + 10
Plank series	3	30' '+ 10" + 30" + 10"
One leg on Bosu and reach 3 directions with each hand	3	One tour each leg

Table 9. *Session-2 for the Complementary Strength Training Program.*

Exercises	Sets	Repetitions
Walking lunge	4	6
Bird dog	3	12 each side
4 side cod CMJ & drop jump	3	3 tours
Prone hamstring curl	4	6
Leg raise & hip raise	3	6 + 6

Boxing	3	1´
Abduction + adduction with band	2	12
V-sit trunk rotation with weight	3	6 each side
One leg side to side jump and hold	4	5
Plank series	3	30' '+ 10" + 30" + 10"

5.3.6. Statistical Analysis

Descriptive data are presented as mean ± standard deviation (SD). The Shapiro-Wilk and Levene's test were conducted to confirm the normality of the data distribution and the homogeneity of variances, respectively. To assess the within-group differences among the different periods, a paired-samples t-test was applied. To evaluate the between-group differences for each period comparison, an analysis of covariance (ANCOVA) incorporating baseline values as covariates was conducted. The magnitude of effects was calculated through the effect sizes, which were evaluated using Cohen's method. These data were interpreted as follows: < 0.2, trivial; 0.20–0.49, small; 0.50–0.80, moderate; and > 0.80, large (Cohen, 1988). Statistical analyses were carried out using SPSS v29 (SPSS Inc., Chicago, IL), establishing the level of significance at $p < 0.05$. To control for Type I error due to multiple analyses, a Bonferroni correction was applied, and consequently, statistical significance was set at $p < 0.01$.

5.4. RESULTS

In Table 10 are presented the descriptive data for each variable, period and group.

Table 10a. *Descriptive data related to physical fitness and match load variables across the 2-years follow-up*

	CG (n = 14)			
Variables	*Pre S1 (mean ± SD)*	*Post S1 (mean ± SD)*	*Pre S2 (mean ± SD)*	*Post S2 (mean ± SD)*
CMJ (cm)	24.90 ± 2.91	25.39 ± 2.75	25.10 ± 2.86	25.56 ± 2.89
VO_{2max} (ml/kg/min)	52.54 ± 2.74	52.99 ± 2.64	52.53 ± 2.55	52.88 ± 2.41
TD (m)	9839.27 ± 291.23	10085.45 ± 457.22	9876.99 ± 371.54	10200.61 ± 423.79
VHSR (m)	48.64 ± 43.76	62.43 ± 48.31	50.93 ± 44.03	65.36 ± 48.04

Vmax (km·h^{-1})	25.13 ± 2.05	25.97 ± 1.81	25.42 ± 1.95	26.27 ± 1.67

Table 11b. *Descriptive data related to physical fitness and match load variables across the 2-years follow-up*

	EG (n = 14)			
Variables	*Pre S1 (mean ± SD)*	*Post S1 (mean ± SD)*	*Pre S2 (mean ± SD)*	*Post S2 (mean ± SD)*
CMJ (cm)	25.14 ± 3.05	29.51 ± 3.62	29.01 ± 3.48	31.52 ± 2.78
VO_{2max} (ml/kg/min)	54.55 ± 2.49	57.82 ± 2.80	56.46 ± 2.29	58.64 ± 2.33
TD (m)	10261.73 ± 847.55	12182.32 ± 830.76	11346.97 ± 713.52	12217.81 ± 752.22
VHSR (m)	53.71 ± 40.47	113.93 ± 65.46	102.43 ± 62.30	125.57 ± 66.29
Vmax (km·h^{-1})	25.90 ± 1.29	29.22 ± 1.76	28.72 ± 1.56	30.59 ± 1.35

Abbreviations: S1 = season 1; S2 = season 2; CG = control group; EG = experimental group; SD = standard deviation; CMJ = countermovement jump; VO2max = maximal oxygen uptake; TD = total distance; VHSR = distance covered at above of 23 km·h-1; Vmax = maximum velocity achieved during matches.

Within-group changes for the CG are shown in Figure 3. Significant differences were found in CMJ between Pre S1 and Post S1 (p = 0.001; ES = 0.17, trivial) and PostS2 (p = 0.001; ES = 0.23, small) and between Pre S2 and Post S2 (p = 0.001; ES = 0.16, trivial). In relation to VO2max, no significant differences were observed (p = 0.041; ES = 0.17, trivial). Regarding match load variables, significant differences in TD were shown between Pre S1 and Post S1 (p = 0.001; ES = 0.85, large) and PostS2 (p = 0.001; ES = 1.24, large) and between Pre S2 and Post S2 (p = 0.001; ES = 0.87, large). Also, significant differences were found in VHSR between Pre S1 and Post S1 (p = 0.001; ES = 0.32, small) and PostS2 (p = 0.001; ES = 0.38, small) and between Pre S2 and Post S2 (p = 0.001; ES = 0.33, small). Finally, significant differences regarding Vmax were found between Pre S1 and Post S1 (p = 0.001; ES = 0.41, small) and PostS2 (p = 0.001; ES = 0.56, moderate) and between Pre S2 and Post S2 (p = 0.001; ES = 0.44, small).

Figure 3. *Within-group changes in CMJ and VO_2max*

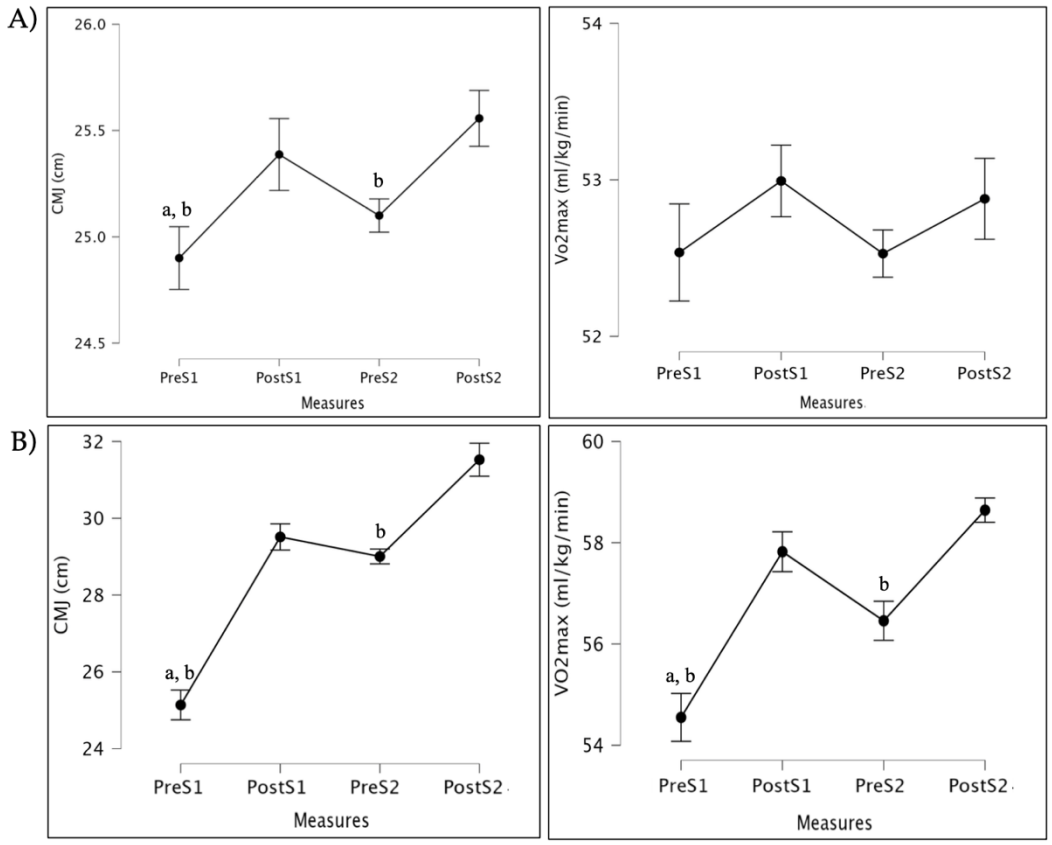
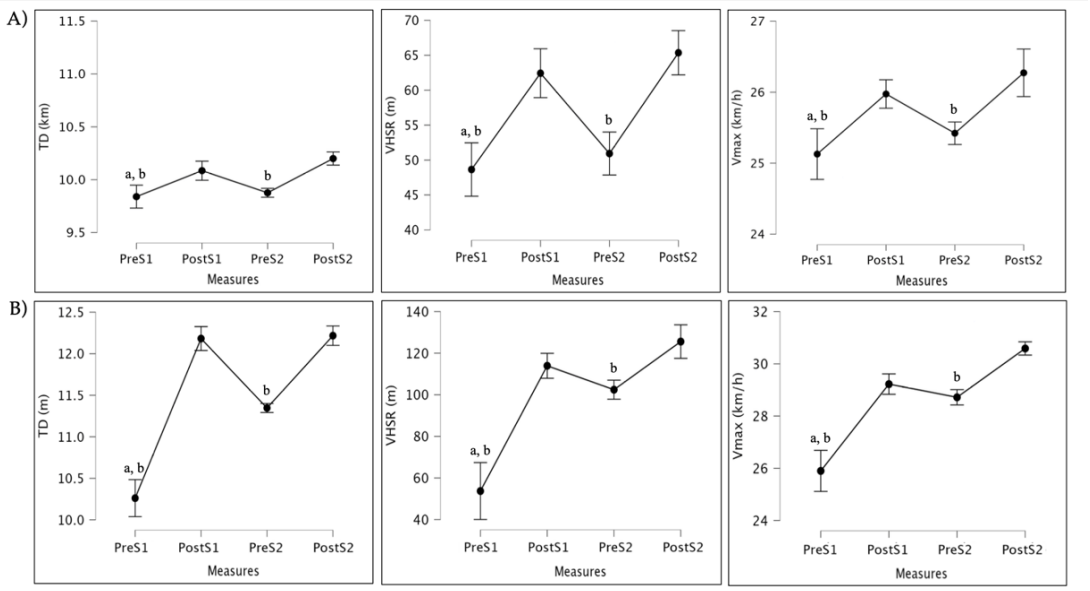


Figure 4 presents the within-group changes for the EG. For the CMJ, significant differences were obtained between Pre S1 and Post S1 (p = 0.001; ES = 1.27, large) and PostS2 (p = 0.001; ES = 2.09, large) and between Pre S2 and Post S2 (p = 0.001; ES = 0.72, moderate). Regarding to VO2max, significant differences were observed between Pre S1 and Post S1 (p = 0.001; ES = 1.31, large) and PostS2 (p = 0.001; ES = 1.64, large) and between Pre S2 and Post S2 (p = 0.001; ES = 0.95, large). In relation to match load variables, significant differences in TD were shown between Pre S1 and Post S1 (p = 0.001; ES = 2.27, large) and PostS2 (p = 0.001; ES = 2.31, large) and between Pre S2 and Post S2 (p = 0.001; ES = 1.22, large). In VHSR, significant differences were observed between Pre S1 and Post S1 (p = 0.001; ES = 1.49, large) and PostS2 (p = 0.001; ES = 1.78, large) and between Pre S2 and Post S2 (p = 0.001; ES = 0.37, small). Lastly, significant differences regarding Vmax were

found between Pre S1 and Post S1 (p = 0.001; ES = 2.57, large) and Post S2 (p = 0.001; ES = 3.64, large) and between Pre S2 and Post S2 (p = 0.001; ES = 1.18, large).

Figure 4. *Within-group changes in TD, VHSR and Vmax*



Between-groups differences are presented in Table 11. When comparing Pre S1 with Post S1, significant differences in favor of EG in all variables were observed (F = 28.14 to 176.71; p = 0.001), similarly to the comparison with Post S2 (F = 54.56 to 469.16; p = 0.001). Finally, in the between-groups comparison considering Pre S2 and Post S2 periods, significant differences in favor of EG were found in all variables except for VHSR (F = 1.54 to 113.31; p = 0.001).

Table 12. *Between-groups differences in physical fitness and match load variables across the 2-years follow-up*

	Between group differences					
	Pre S1 vs Post S1		*Pre S2 vs Post S2*		*Pre S1 vs Post S2*	
Variables	*F*	*p*	*F*	*p*	*F*	*p*
CMJ (cm)	176.71	0.001	113.31	0.001	469.16	0.001
VO_{2max} (ml/kg/min)	50.74	0.001	40.77	0.001	190.22	0.001
TD (m)	104.08	0.001	35.50	0.001	81.68	0.001
VHSR (m)	45.65	0.001	17.67	0.226	127.62	0.001
Vmax ($km \cdot h^{-1}$)	28.14	0.001	1.54	0.001	54.56	0.001

Abbreviations: S1 = season 1; S2 = season 2; CMJ = countermovement jump; VO2max = maximal oxygen uptake; TD = total distance; VHSR = distance covered at above of 23 km·h-1; Vmax = maximum velocity achieved during matches. Significance level was set at $p < 0.01$.

5.5. DISCUSSION

This study implemented a long-term ST intervention across two consecutive competitive seasons to examine its effects on CMJ performance, maximal oxygen uptake (VO_2max), and external match loads in elite female youth soccer players. To our knowledge, this represents the first longitudinal investigation analysing the effects of a 2-year strength program in female soccer players while incorporating official competition demands. Key findings demonstrated significantly greater improvements in the EG across all performance variables throughout the 2-year intervention period.

To monitor long-term physical development in female youth soccer players, the CMJ test represents a relevant assessment tool (Nuzzo et al., 2008). It is a reliable and sensitive metric for evaluating lower-body strength (Springham et al., 2024), a quality extensively linked to soccer performance (Faude et al., 2012). In this regard, the CG exhibited moderate CMJ improvements after both competitive seasons compared to baseline assessments from Seasons 1 and 2 (i.e., Pre S1 and Pre S2). These gains likely reflect players' maturational development during peak growth phases, where habitual soccer stimuli may potentiate lower-body strength adaptations (Perroni et al., 2024). Similarly, the EG demonstrated significant CMJ enhancements across all intervention time-points. Crucially, EG improvements substantially exceeded CG gains ($p < 0.01$), corroborating previous evidence on

strength training's positive effects on CMJ performance. These benefits appear amplified when interventions are sustained long-term. Collectively, these findings underscore the necessity of integrating strength training into youth soccer periodization to optimize long-term strength development and athletic performance.

Comprehensive monitoring of physical development in female youth soccer players necessitates the inclusion of valid endurance assessments (Nowak et al., 2024). The Yo-Yo Intermittent Recovery Level 2 test provides a reliable prediction of maximal oxygen uptake (VO_2max) in this population (Lockie et al., 2017). Specifically, players in CG showed no significant improvements in VO_2max across seasons, whereas the EG players demonstrated meaningful enhancements at all time-points ($p < 0.001$). These findings align with those obtained by (Sporiš et al., 2011) who observed significant VO_2max improvements following a 12-week off-season strength program in elite female players. Importantly, we obtained an estimated VO_2max through the Yo-Yo IR2 test, as the team had already been utilizing it as part of their routine physical performance assessments.

In addition to these endurance-related gains, strength training has also been shown to improve aerobic capacity indirectly, by enhancing force production capacity, neuromuscular coordination, and efficiency of oxygen utilization (Haugen et al., 2014; Helgerud et al., 2001). These adaptations contribute to improved running economy, defined as the energy cost of running at a given velocity, which is particularly important in sustaining prolonged high-intensity actions during matches (Šuc et al., 2022; Winther et al., 2022).

However, few studies have specifically examined this interaction in women's soccer players, leaving an opportunity for further research. For this reason, VO_2max assessments were incorporated in the present interventions, as we aimed to determine whether well-designed strength training could also enhance endurance capacity in female soccer players. This approach was complemented by GPS-derived match metrics, including total distance, very-high-speed running distance, number of sprints, and maximum velocity, providing a more

comprehensive evaluation of how strength training adaptations translate into match performance.

The observed endurance gains likely stem from strength training-induced adaptations, including increased muscle mass, enhanced force production capacity, and improved oxygen utilization efficiency (Kraemer et al., 1988). This reinforces the imperative for integrating strength training programs, specifically, training at half-maximal repetition capacity, to holistically optimize athletic preparedness in developing soccer players.

While enhancing physical capacity in female youth soccer players is critical (M Taylor et al., 2012), both for performance outcomes and holistic adolescent development, the primary aim of any training program remains competitive success (Wang et al., 2025). Previous research confirms that external match load variables, such as TD, VHSR and Vmax constitute key performance determinants, and improving these metrics may therefore facilitate competitive achievement (Faude et al., 2012). Despite established performance relationships, few studies have examined how strength training interventions affect competition demands in soccer. For instance, Byrkjedal et al. (2023) implemented two 10-week strength protocols (regulated vs. self-selected; 1 session/week) in professional male players, observing improved high-speed running and sprint metrics in both groups. However, no prior investigations have addressed this in female youth populations. In our study, both groups exhibited improved external load metrics during follow-up, though EG gains were significantly greater ($p < 0.001$). These enhancements likely derive from strength training-induced adaptations including: 1) optimized sprint mechanics supporting higher maximum velocities, 2) potentiated repeated-sprint ability enabling more very high-speed running bouts, and 3) delayed neuromuscular fatigue facilitating greater distance coverage across velocity thresholds during official matches. These results reinforce the idea that strength training is a key factor in soccer periodization across all ages, with particular relevance for young soccer players, impacting their performance and facilitating their transition to professional soccer.

Several methodological considerations warrant acknowledgment. First, training volume disparity existed between groups, as the EG supplemented regular training with strength sessions while players in the CG maintained standard programming. Second, cluster allocation by team (rather than individual randomization) may introduce confounding despite both groups following comparable periodization models. Third, inherent GPS measurement variability, particularly concerning high-intensity running metrics, should be considered when interpreting locomotor data. Finally, the exclusive inclusion of female athletes necessitates caution when extrapolating findings to male populations, underscoring the need for gender-specific replication studies.

5.6. CONCLUSIONS

Participants in the EG group experienced higher improvements in both physical fitness and external match load performance, compared to their counterparts in the CG, showing enhancements in all comparisons along the intervention period. These results suggest the imperative necessity to include strength training programs as a relevant part of female soccer players' periodization, not only to improve their performance, but also to facilitate their transition to professional soccer.

VI – CONCLUSIONS AND PRACTICAL APPLICATIONS

VI -CONCLUSIONS AND PRACTICAL APPLICATIONS

6.1. CONCLUSIONS

6.1.1. General Conclusion

This thesis demonstrates that strength and sprint training interventions are effective strategies for improving the physical fitness and match performance of female soccer players. Short-term strength training enhanced neuromuscular performance and match running demands in youth players, while sprint training produced method-specific adaptations in professionals: TST improved linear sprint ability, and MIST enhanced match-related sprinting. Long-term strength training across two seasons resulted in progressive and sustainable improvements, underscoring its role in player development. Collectively, these findings confirm that context-specific and periodized training approaches are essential to maximize both immediate and long-term performance in women's soccer.

6.1.2. Specific Conclusions

Study 1

- A 10-week in-season ST program in youth female soccer players significantly improved CMJ and estimated VO_2max compared to the CG.
- The ST group also achieved superior improvements in TD, VHSR, and Vmax compared to the CG.
- These results demonstrate that in-season ST enhances both physical fitness and match performance within a single competitive season.

Study 2

- Both TST and MIST improved performance in professional female players, but with distinct outcomes.

- TST was more effective for linear sprint performance in 5 m, 10 m, and 30 m sprint tests.
- MIST was more effective for match-related metrics, including VHSR and the number of sprints.
- These results confirm that sprint training adaptations are method-specific and should be aligned with players' performance objectives.

Study 3

- A ST program implemented over two consecutive competitive seasons resulted in consistent and lasting improvements in CMJ, VO_2max.
- The ST also resulted in sustained and cumulative improvements in TD, VHSR, and Vmax compared to the CG.
- These results fully support the hypothesis that long-term strength training produces superior and sustainable adaptations.

6.2. PRACTICAL APPLICATIONS

The findings of this thesis have important implications for training and developing female soccer players. First, Study 1 shows that in-season strength training can effectively enhance both physical fitness and match performance in adolescent elite female players. The ability to improve countermovement jump, aerobic capacity, and match metrics (like total distance, very-high-speed running, and maximum velocity) suggests that well-planned strength training can complement soccer practice without overloading athletes. In practical terms, two weekly strength training sessions are a manageable and effective approach within busy competition schedules. Second, Study 2 highlights the importance of matching training methods with specific performance goals. Traditional sprint training is more effective for improving isolated linear sprint performance, while modified integrated sprint training offers greater benefits for match sprint demands, such as very-high-speed running distance and sprint frequency. This indicates that practitioners should choose sprint methods based on whether the goal is to improve test performance or match-related skills. Third, Study 3

highlighted the long-term benefits of systematically implementing traditional strength training across multiple seasons. Consistent gains in fitness and match running performance demonstrate that strength training should not be viewed as optional but as a core part of long-term player development programs. Coaches and practitioners are encouraged to incorporate strength training within a periodized framework to achieve both immediate and lasting performance improvements. Overall, these findings support integrating strength and sprint-based methods into comprehensive, periodized training programs for female soccer players. By thoughtfully choosing and structuring training modalities, practitioners can address both short-term performance needs and long-term development goals.

VII – LIMITATIONS AND FUTURE WORK

VII - LIMITATIONS AND FUTURE WORK

7.1. LIMITATIONS

While the present thesis provides important insights into the effects of strength and sprint training interventions on physical fitness and match performance in female soccer players, several limitations must be recognized.

The first limitation concerns sample size. All three studies involved elite and professional female players, where recruitment naturally limits the number of participants. Although significant within-group and between-group differences were identified, the relatively small sample sizes restrict the ability to generalize these findings to broader populations or other competitive levels.

Second, the outcome measures mainly focused on standardized fitness assessments (e.g., sprint times, countermovement jump, Yo-Yo IR2) and external match performance variables (e.g., total distance, very-high-speed running, sprint count, maximum velocity). While these metrics are highly relevant to soccer, they do not encompass the entire spectrum of adaptations. In particular, performance indicators such as running economy (RE) and repeated-sprint ability (RSA) could not be measured in the present studies due to logistical and time constraints. Their omission reduces the breadth of performance insights provided and should be regarded as an area for future investigation. Physiological markers (such as hormonal, neuromuscular, or metabolic changes), as well as technical-tactical performance indicators, were not systematically analysed, limiting the comprehensive scope of interpretation.

Third, the design and length of the interventions present important considerations. Study 1 (10-week in-season strength training) and Study 2 (12-week sprint training) demonstrated short-term adaptations but did not explore long-

term retention. Conversely, Study 3 spanned two competitive seasons but focused solely on traditional strength training, thereby excluding other potentially valuable modalities like plyometric or eccentric training in a longitudinal context.

Finally, contextual factors may have influenced the interventions and results. Variability in training load from regular soccer practice, menstrual cycle phases, and recovery status was not fully controlled. Although these factors reflect real-world soccer conditions, they introduce variability that can interact with training adaptations and help explain differences in responses.

7.2. FUTURE WORK

Several promising avenues for future research arise from this thesis. First, future studies should aim to increase sample sizes by collaborating across multiple clubs or countries. Larger samples would enhance statistical power and enable subgroup analyses (e.g., by age, playing position, or competitive level), leading to more detailed recommendations for practitioners. Second, subsequent research should expand the range of outcome measures. Including physiological markers (e.g., hormonal, neuromuscular, and metabolic responses), biomechanical assessments (e.g., sprint mechanics), and technical-tactical indicators would provide a more complete understanding of how training interventions impact soccer performance. Third, long-term studies are necessary to compare the effectiveness of various strength training methods. While Study 3 showed the benefits of traditional strength training over two seasons, further research should investigate the long-term effects of plyometric, eccentric, and combined approaches. This will help determine if these methods offer superior or complementary benefits compared to traditional training. Fourth, more focus should be placed on how contextual and individual factors influence adaptation. Variables such as menstrual cycle phases, biological maturation in youth players, and match congestion likely interact with training responses. Future research should systematically examine these factors and incorporate them into personalized programming strategies. Finally, studies should investigate optimal

periodization models for integrating strength and sprint training into the broader demands of female soccer. Understanding how to schedule these interventions throughout the competitive season and how to balance immediate performance gains with long-term development will be essential for refining evidence-based training strategies.

VIII – BIBLIOGRAPHICAL REFERENCES

VIII - BIBLIOGRAPHICAL REFERENCES

Ade, J., Fitzpatrick, J., & Bradley, P. S. (2016). High-intensity efforts in elite soccer matches and associated movement patterns, technical skills and tactical actions. Information for position-specific training drills. *Journal of Sports Sciences*, *34*(24), 2205–2214. https://doi.org/10.1080/02640414.2016.1217343

Akyildiz, Z., yıldız, M., & Clemente, F. (2020). The reliability and accuracy of Polar Team Pro GPS units. *Proceedings of the Institution of Mechanical Engineers Part P Journal of Sports Engineering and Technology*, *236*. https://doi.org/10.1177/1754337120976660

Al Haddad, H., Méndez-Villanueva, A., Torreño, N., Munguía-Izquierdo, D., & Suárez-Arrones, L. (2018). Variability of GPS-derived running performance during official matches in elite professional soccer players. *The Journal of Sports Medicine and Physical Fitness*, *58*(10), 1439–1445. https://doi.org/10.23736/S0022-4707.17.07500-4

Andersson, H. A., Randers, M. B., Heiner-Møller, A., Krustrup, P., & Mohr, M. (2010). Elite female soccer players perform more high-intensity running when playing in international games compared with domestic league games. *Journal of Strength and Conditioning Research*, *24*(4), 912–919. https://doi.org/10.1519/JSC.0b013e3181d09f21

Arazi, H., Keihaniyan, A., EatemadyBoroujeni, A., Oftade, A., Takhsha, S., Asadi, A., & Ramirez-Campillo, R. (2017). Effects of heart rate vs. speed-based high intensity interval training on aerobic and anaerobic capacity of female

soccer players. *Sports (Basel, Switzerland)*, *5*(3), 57. https://doi.org/10.3390/sports5030057

Armada-Cortés, E., Benítez-Muñoz, J. A., San Juan, A. F., & Sánchez-Sánchez, J. (2022). Evaluation of neuromuscular fatigue in a repeat sprint ability, countermovement jump and hamstring test in elite female soccer players. *International Journal of Environmental Research and Public Health*, *19*(22), 15069. https://doi.org/10.3390/ijerph192215069

Arnason, A., Sigurdsson, S. B., Gudmundsson, A., Holme, I., Engebretsen, L., & Bahr, R. (2004). Physical fitness, injuries, and team performance in soccer. *Medicine and Science in Sports and Exercise*, *36*(2), 278–285. https://doi.org/10.1249/01.MSS.0000113478.92945.CA

Arslan, E., Orer, G. E., & Clemente, F. M. (2020). Running-based high-intensity interval training vs. small-sided game training programs: Effects on the physical performance, psychophysiological responses and technical skills in young soccer players. *Biology of Sport*, *37*(2), 165–173. https://doi.org/10.5114/biolsport.2020.94237

Bailey, L. S., Phillips ,Joe, Farrell ,George, McQuilliam ,Stephen J., & and Erskine, R. M. (n.d.). Effect of six weeks' isometric strength training compared to traditional strength training on gains in strength, power, and speed in male academy soccer players. *Research Quarterly for Exercise and Sport*, *0*(0), 1–8. https://doi.org/10.1080/02701367.2025.2488843

Balsalobre-Fernández, C., Glaister, M., & Lockey, R. A. (2015). The validity and reliability of an iPhone app for measuring vertical jump performance.

Journal of Sports Sciences, *33*(15), 1574–1579. https://doi.org/10.1080/02640414.2014.996184

Bangsbo, J., Mohr, M., & Krustrup, P. (2006). Physical and metabolic demands of training and match-play in the elite football player. *Journal of Sports Sciences*, *24*(7), 665–674. https://doi.org/10.1080/02640410500482529

Bangsbo, J., Iaia, F., & Krustrup, P. (2008). The Yo-Yo Intermittent Recovery Test: A useful tool for evaluation of physical performance in intermittent sports. *Sports Medicine*, *38*, 37–51.

Baumgart, C., Freiwald, J., & Hoppe, M. W. (2018). Sprint mechanical properties of female and different aged male top-level German soccer players. *Sports (Basel, Switzerland)*, *6*(4), 161. https://doi.org/10.3390/sports6040161

Beato, M., Datson, N., Anderson, L., Brownlee, T., Coates, A., & Hulton, A. (2023). Rationale and practical recommendations for testing protocols in female soccer: A narrative review. *Journal of Strength and Conditioning Research*, *37*(9), 1912–1922. https://doi.org/10.1519/JSC.0000000000004509

Bradley, P. S., Bendiksen, M., Dellal, A., Mohr, M., Wilkie, A., Datson, N., Orntoft, C., Zebis, M., Gomez-Diaz, A., Bangsbo, J., & Krustrup, P. (2014). The application of the Yo-Yo intermittent endurance level 2 test to elite female soccer populations. *Scandinavian Journal of Medicine & Science in Sports*, *24*(1), 43–54. https://doi.org/10.1111/j.1600-0838.2012.01483.x

Brito, J., Vasconcellos, F., Oliveira, J., Krustrup, P., & Rebelo, A. (2014). Short-term performance effects of three different low-volume strength-training

programmes in college male soccer players. *Journal of Human Kinetics*, *40*, 121–128. https://doi.org/10.2478/hukin-2014-0014

Buchheit, M., Mendez-Villanueva, A., Delhomel, G., Brughelli, M., & Ahmaidi, S. (2010). Improving repeated sprint ability in young elite soccer players: Repeated shuttle sprints vs. explosive strength training. *Journal of Strength and Conditioning Research*, *24*(10), 2715–2722. https://doi.org/10.1519/JSC.0b013e3181bf0223

Buonsenso, A., Centorbi, M., Iuliano, E., Di Martino, G., Della Valle, C., Fiorilli, G., Calcagno, G., & di Cagno, A. (2023). A Systematic review of flywheel training effectiveness and application on sport specific performances. *Sports (Basel, Switzerland)*, *11*(4), 76. https://doi.org/10.3390/sports11040076

Bush, M., Barnes, C., Archer, D. T., Hogg, B., & Bradley, P. S. (2015). Evolution of match performance parameters for various playing positions in the English Premier League. *Human Movement Science*, *39*, 1–11. https://doi.org/10.1016/j.humov.2014.10.003

Byrkjedal, P. T., Thunshelle, A., Spencer, M., Luteberget, L. S., Ivarsson, A., Vårvik, F. T., Lindberg, K., & Bjørnsen, T. (2023). In-season autoregulation of one weekly strength training session maintains physical and external load match performance in professional male football players. *Journal of Sports Sciences*, *41*(6), 536–546. https://doi.org/10.1080/02640414.2023.2227536

Chalabaev, A., Sarrazin, P., Fontayne, P., Boiché, J., & Clément-Guillotin, C. (2013). The influence of sex stereotypes and gender roles on participation and performance in sport and exercise: Review and future directions. *Psychology*

of Sport and Exercise, *14*(2), 136–144. https://doi.org/10.1016/j.psychsport.2012.10.005

Cherappurath, N., Shamshadali, P., Elayaraja, M., & Ki, D. A. K. (2024). Mapping the field: A bibliometric analysis of women's football research trends and future directions. *Apunts Sports Medicine*, *59*(223). https://doi.org/10.1016/j.apunsm.2024.100448

Choice, E., Tufano, J., Jagger, K., Hooker, K., & Cochrane-Snyman, K. C. (2022). Differences across Playing levels for match-play physical demands in women's professional and collegiate soccer: A narrative review. *Sports (Basel, Switzerland)*, *10*(10), 141. https://doi.org/10.3390/sports10100141

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed). L. Erlbaum Associates.

Çetin, O., & Koçak, M. (2022). Repeated Sprint ability of youth football players in the same age category according to playing position and competition level. *Montenegrin Journal of Sports Science and Medicine*, *11*(1), 59–63. https://doi.org/10.26773/mjssm.220307

Darragi, M., Zouhal, H., Bousselmi, M., Karamti, H. M., Clark, C. C. T., Laher, I., Hackney, A. C., Granacher, U., & Zouita, A. B. M. (2024). Effects of in-season strength training on physical fitness and injury prevention in North African elite young female soccer players. *Sports Medicine - Open*, *10*(1), 94. https://doi.org/10.1186/s40798-024-00762-0

Datson, N., Drust, B., Weston, M., Jarman, I. H., Lisboa, P. J., & Gregson, W. (2017). Match physical performance of elite female soccer players during

international competition. *Journal of Strength and Conditioning Research*, *31*(9), 2379–2387. https://doi.org/10.1519/JSC.0000000000001575

Datson, N., Hulton, A., Andersson, H., Lewis, T., Weston, M., Drust, B., & Gregson, W. (2014). Applied physiology of female soccer: An update. *Sports Medicine*, *44*(9), 1225–1240. https://doi.org/10.1007/s40279-014-0199-1

Dellal, A., Lago-Peñas, C., Rey, E., Chamari, K., & Orhant, E. (2013). The effects of a congested fixture period on physical performance, technical activity and injury rate during matches in a professional soccer team. *British Journal of Sports Medicine, 47(*12), 810–815. https://doi.org/10.1136/bjsports-2012-091290

Deprez, D., Valente-Dos-Santos, J., Coelho-E-Silva, M. J., Lenoir, M., Philippaerts, R., & Vaeyens, R. (2015). Longitudinal development of explosive leg power from childhood to adulthood in soccer players. *International Journal of Sports Medicine*, *36*(8), 672–679. https://doi.org/10.1055/s-0034-1398577

Douglas, J., Pearson, S., Ross, A., & McGuigan, M. (2017). Chronic adaptations to eccentric training: A systematic review. *Sports Medicine, 47*(5), 917–941. https://doi.org/10.1007/s40279-016-0628-4

Emmonds, S., Nicholson, G., Begg, C., Jones, B., & Bissas, A. (2019). Importance of physical qualities for speed and change of direction ability in elite female soccer players. *Journal of Strength and Conditioning Research, 33*(6), 1669–1677. https://doi.org/10.1519/JSC.0000000000002114

Eniseler, N., Şahan, Ç., Özcan, I., & Dinler, K. (2017). High-intensity small-sided games versus repeated sprint training in junior soccer players. *Journal of Human Kinetics, 60,* 101–111. https://doi.org/10.1515/hukin-2017-0104

Erol, S., Yapici, A., & Gumusdag, H. (2023). The effect of functional training applied to soccer players on anaerobic performance. *Journal of ROL Sport Sciences, 4(*1), Article 1. https://doi.org/10.5281/zenodo.7740746

Faude, O., Koch, T., & Meyer, T. (2012). Straight sprinting is the most frequent action in goal situations in professional football. *Journal of Sports Sciences*, *30*(7), 625–631. https://doi.org/10.1080/02640414.2012.665940

Fédération Internationale de Football Association. (2007). Big Count 2006: Statistical summary report. Retrieved April 28, 2025, from https://rtmag.co.il/images/FIFA_BIG_COUNT.pdf

Fédération Internationale de Football Association. (2023a). Global Engagement & Audience Report (Executive summary), FIFA Women's World Cup Australia & New Zealand 2023™. Inside FIFA. Retrieved April 28, 2025, from https://inside.fifa.com/tournament-organisation/audience-reports/australia-new-zealand-2023

Fédération Internationale de Football Association. (2023b). Women's Football: Member Associations Survey Report 2023. Zurich, Switzerland: FIFA. Retrieved April 29, 2025, from https://digitalhub.fifa.com/m/28ed34bd888832a8/original/FIFA-Women-s-Football-MA-Survey-Report-2023.pdf

Fédération Internationale de Football Association. (2024). Women's Football Strategy: 2024–2027. Zurich, Switzerland: FIFA. Retrieved April 29, 2025, from https://digitalhub.fifa.com/m/16fe7c8e9a285f15/original/FIFA-Women-s-Football-Strategy-2024-2027_EN.pdf

Fernandez Ortega, J. A., los Reyes, Y. G. D., & Garavito Peña, F. R. (2020). Effects of strength training based on velocity versus traditional training on muscle mass, neuromuscular activation, and indicators of maximal power and strength in girls soccer players. *Apunts Sports Medicine, 55*(206), 53–61. https://doi.org/10.1016/j.apunsm.2020.03.002

Ferraz, A., Duarte-Mendes, P., Sarmento, H., Valente-Dos-Santos, J., & Travassos, B. (2023). Tracking devices and physical performance analysis in team sports: A comprehensive framework for research—trends and future directions. *Frontiers in Sports and Active Living, 5*, 1284086. https://doi.org/10.3389/fspor.2023.1284086

Fink, J.S. (2015) 'Female athletes, women's sport, and the sport media commercial complex: have we really "come a long way, baby"?', *Sport Management Review, vol. 18,* no. 3, pp. 331–42. https://doi.org/10.1016/j.smr.2014.05.001

Fischerova, P., Nitychoruk, M., Smolka, W., Zak, M., Golas, A., & Maszczyk, A. (2021). The impact of strength training on the improvement of jumping ability and selected power parameters of the lower limbs in soccer players. *Baltic Journal of Health and Physical Activity, 13*(1). https://doi.org/10.29359/BJHPA.13.1.09

Gabbett, T. J., Wiig, H., & Spencer, M. (2013). Repeated high-intensity running and sprinting in elite women's soccer competition. *International Journal of Sports Physiology and Performance, 8*(2), 130–138. https://doi.org/10.1123/ijspp.8.2.130

García-Calvo, T., Lobo-Triviño, D., Raya-González, J., López Del Campo, R., Resta, R., Pons, E., & Ponce-Bordón, J. C. (2025). The evolution of match running performance in the top two Spanish soccer leagues: A comparative four-season study. *Journal of Functional Morphology and Kinesiology, 10*(1), 27. https://doi.org/10.3390/jfmk10010027

Gonçalves, L., Clemente, F. M., Barrera, J. I., Sarmento, H., González-Fernández, F. T., Palucci Vieira, L. H., Figueiredo, A. J., Clark, C. C. T., & Carral, J. M. C. (2021). Relationships between fitness status and match running performance in adult women soccer players: A cohort study. *Medicina, 57*(6), 617. https://doi.org/10.3390/medicina57060617

González-Badillo, J. J., Rodríguez-Rosell, D., Sánchez-Medina, L., Ribas, J., López-López, C., Mora-Custodio, R., Yañez-García, J. M., & Pareja-Blanco, F. (2016). Short-term recovery following resistance exercise leading or not to failure. *International Journal of Sports Medicine*, *37*(4), 295–304. https://doi.org/10.1055/s-0035-1564254

Gualtieri, A., Rampinini, E., Sassi, R., & Beato, M. (2020). Workload monitoring in top-level soccer players during congested fixture periods. *International Journal of Sports Medicine*, *41*(10), 677–681. https://doi.org/10.1055/a-1171-1865

Guimarães, R., García Calvo, T., Lobo-Triviño, D., Ponce Bordón, J., & Raya-González, J. (2024). Holistic workload quantification within a professional soccer microcycle considering players' match participation. *Applied Sciences*, *14*, 5139. https://doi.org/10.3390/app14125139

Haff, G. G., & Nimphius, S. (2012). Training principles for power. *Strength and Conditioning Journal*, *34*(6), 2–12. https://doi.org/10.1519/SSC.0b013e31826db467

Haller, N., Hübler, E., Stöggl, T., & Simon, P. (2022). Evidence‐based recovery in soccer – low‐effort approaches for practitioners. *Journal of Human Kinetics, 82*, 75–99. https://doi.org/10.2478/hukin-2022-0082

Harkness-Armstrong, A., Till, K., Datson, N., Myhill, N., & Emmonds, S. (2022). A systematic review of match-play characteristics in women's soccer. *PloS One*, *17*(6), e0268334. https://doi.org/10.1371/journal.pone.0268334

Haugen, T. A., Tønnessen, E., Hem, E., Leirstein, S., & Seiler, S. (2014). VO2max characteristics of elite female soccer players, 1989-2007. *International Journal of Sports Physiology and Performance*, *9*(3), 515–521. https://doi.org/10.1123/ijspp.2012-0150

Helgerud, J., Engen, L. C., Wisloff, U., & Hoff, J. (2001). Aerobic endurance training improves soccer performance. *Medicine and Science in Sports and Exercise*, *33*(11), 1925–1931.

Herzberg, S. D., Motu'apuaka, M. L., Lambert, W., Fu, R., Brady, J., & Guise, J.-M. (2017). The effect of menstrual cycle and contraceptives on ACL injuries and

laxity: A systematic review and meta-analysis. *The American Journal of Sports Medicine, 45*(10), 2475–2484. https://doi.org/10.1177/0363546516675250

Hewett, T. E., Ford, K. R., & Myer, G. D. (2006a). Anterior cruciate ligament injuries in female athletes: Part 2, a meta-analysis of neuromuscular interventions aimed at injury prevention. *The American Journal of Sports Medicine, 34*(3), 490–498. https://doi.org/10.1177/0363546505282619

Hewett, T. E., Myer, G. D., & Ford, K. R. (2006b). Anterior cruciate ligament injuries in female athletes: Part 1, mechanisms and risk factors. *The American Journal of Sports Medicine, 34(*2), 299–311. https://doi.org/10.1177/0363546505284183

Hu, C., Du, Z., Tao, M., & Song, Y. (2023). Effects of different hamstring eccentric exercise programs on preventing lower extremity injuries: A systematic review and meta-analysis. *International Journal of Environmental Research and Public Health, 20*(3), 2057. https://doi.org/10.3390/ijerph20032057

Hung, C.-H., Su, C.-H., & Wang, D. (2025). The role of high-intensity interval training (HIIT) in neuromuscular adaptations: Implications for strength and power development—A review. *Life, 15*(4), Article 4. https://doi.org/10.3390/life15040657

Ishøi, L., Hölmich, P., Aagaard, P., Thorborg, K., Bandholm, T., & Serner, A. (2018). Effects of the Nordic Hamstring exercise on sprint capacity in male football players: a randomized controlled trial. *Journal of Sports Sciences, 36*(14), 1663–1672. https://doi.org/10.1080/02640414.2017.1409609

Johnson, A. W., Eastman, C. S., Feland, J. B., Mitchell, U. H., Mortensen, B. B., & Eggett, D. (2013). Effect of high-speed treadmill training with a body weight

support system in a sport acceleration program with female soccer players. *Journal of Strength and Conditioning Research, 27*(6), 1496–1502. https://doi.org/10.1519/JSC.0B013E31826CAC04

Keiner, M., Kadlubowski, B., Sander, A., Hartmann, H., & Wirth, K. (2022). Effects of 10 Months of speed, functional, and traditional strength training on strength, linear sprint, change of direction, and jump performance in trained adolescent soccer players. *Journal of Strength and Conditioning Research*, *36*(8), 2236–2246. https://doi.org/10.1519/JSC.0000000000003807

Keiner, M., Sander, A., Wirth, K., & Schmidtbleicher, D. (2014). Long-term strength training effects on change-of-direction sprint performance. *Journal of Strength and Conditioning Research*, *28*(1), 223–231. https://doi.org/10.1519/JSC.0b013e318295644b

Kirkendall, D. T., & Krustrup, P. (2022). Studying professional and recreational female footballers: A bibliometric exercise. *Scandinavian Journal of Medicine & Science in Sports, 32*(Suppl. 1), 12–26. https://doi.org/10.1111/sms.14019

Kissow, J., Jacobsen, K. J., Gunnarsson, T. P., Jessen, S., & Hostrup, M. (2022). Effects of follicular and luteal phase-based menstrual cycle resistance training on muscle strength and mass. *Sports Medicine*, *52*(12), 2813–2819. https://doi.org/10.1007/s40279-022-01679-y

Kobal, R., Freitas, T. T., Fílter, A., Requena, B., Barroso, R., Rossetti, M., Jorge, R. M., Carvalho, L., Pereira, L. A., & Loturco, I. (2021). Curve sprint in elite female soccer players: Relationship with Linear sprint and jump

performance. *International Journal of Environmental Research and Public Health, 18*(5), 2306. https://doi.org/10.3390/IJERPH18052306

Kraemer, W. J., Deschenes, M. R., & Fleck, S. J. (1988). Physiological adaptations to resistance exercise. Implications for athletic conditioning. *Sports Medicine*, *6*(4), 246–256. https://doi.org/10.2165/00007256-198806040-00006

Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J., Steensberg, A., Pedersen, P. K., & Bangsbo, J. (2003). The Yo-Yo intermittent recovery test: Physiological response, reliability, and validity. *Medicine and Science in Sports and Exercise*, *35*(4), 697–705. https://doi.org/10.1249/01.MSS.0000058441.94520.32

Krustrup, P., Mohr, M., Ellingsgaard, H., & Bangsbo, J. (2005). Physical demands during an elite female soccer game: Importance of training status. *Medicine & Science in Sports & Exercise*, *37*(7), 1242–1248. https://doi.org/10.1249/01.mss.0000170062.73981.94

Krustrup, P., Mohr, M., Nybo, L., Draganidis, D., Randers, M. B., Ermidis, G., Ørntoft, C., Røddik, L., Batsilas, D., Poulios, A., Ørtenblad, N., Loules, G., Deli, C. K., Batrakoulis, A., Nielsen, J. L., Jamurtas, A. Z., & Fatouros, I. G. (2022). Muscle metabolism and impaired sprint performance in an elite women's football game. *Scandinavian Journal of Medicine & Science in Sports, 32* Suppl 1, 27–38. https://doi.org/10.1111/sms.13970

Krustrup, P., Zebis, M., Jensen, J. M., & Mohr, M. (2010). Game-induced fatigue patterns in elite female soccer. *Journal of Strength and Conditioning Research, 24*(2), 437–441. https://doi.org/10.1519/JSC.0b013e3181c09b79

Lambright, K. R., Bunn, J. A., Figueroa, Y., & Muñoz, M. (2024). *Resistance training versus interval training in female youth soccer players*. https://doi.org/10.1123/wspaj.2024-0076

Lesinski, M., Prieske, O., Chaabene, H., & Granacher, U. (2021). Seasonal effects of strength endurance vs. power training in young female soccer athletes. *Journal of Strength and Conditioning Research, 35*(Suppl), S90–S96. https://doi.org/10.1519/JSC.0000000000003564

Liu, H., Li, R., Zheng, W., Ramirez-Campillo, R., Sáez de Villarreal, E., & Zhang, M. (2024). The effect of combined strength, plyometric, and sprint training on repeated sprint ability in team-sport athletes: A systematic review and meta-analysis. *Journal of Sports Science and Medicine, 23*(4), 718–743. https://doi.org/10.52082/jssm.2024.718

Lockie, R. G., Jalilvand, F., Moreno, M. R., Orjalo, A. J., Risso, F. G., & Nimphius, S. (2017). Yo-Yo Intermittent Recovery Test Level 2 and its relationship with other typical soccer field tests in female collegiate soccer players. *Journal of Strength and Conditioning Research*, *31*(10), 2667–2677. https://doi.org/10.1519/JSC.0000000000001734

Lum, D., & Barbosa, T. M. (2019). Brief review: Effects of isometric strength training on strength and dynamic performance. *International Journal of Sports Medicine, 40*(6), 363–375. https://doi.org/10.1055/a-0863-4539

M Taylor, J., D Portas, M., D Wright, M., Hurst, C., & Weston, M. (2012). Within-Season variation of fitness in elite youth female soccer players. *Journal of Athletic Enhancement*, *01*(02). https://doi.org/10.4172/2324-9080.1000102

Maneiro, R., Galatti, L., Diniz, C., Silva, D., Wang, S., Shen, M., Li, P., & Liu, H. (2025). Factors related to the success in women's football–a systematic review. *Frontiers in Sports and Active Living*, *7*, 1602457. https://doi.org/10.3389/FSPOR.2025.1602457

Mara, J. K., Thompson, K. G., Pumpa, K. L., & Morgan, S. (2017). Quantifying the high-speed running and sprinting profiles of elite female soccer players during competitive matches using an optical player tracking system. *Journal of Strength and Conditioning Research*, *31*(6), 1500–1508. https://doi.org/10.1519/JSC.0000000000001629

Mathisen, G., & Pettersen, S. (2015). The effect of speed training on sprint and agility performance in 15-year-old female soccer players. *LASE Journal of Sport Science, 6*(2), 61–70. https://doi.org/10.1515/ljss-2016-0006

McQuilliam, S. J., Clark, D. R., Erskine, R. M., & Brownlee, T. E. (2022). Mind the gap! A survey comparing current strength training methods used in men's versus women's first team and academy soccer. *Science and Medicine in Football, 6*(5), 597–604. https://doi.org/10.1080/24733938.2022.2070267

Mendiguchia J, Conceição F, Edouard P, Fonseca M, Pereira R, Lopes H, et al. (2020) Sprint versus isolated eccentric training: Comparative effects on hamstring architecture and performance in soccer players. *PLoS ONE 15*(2): e0228283. https://doi.org/10.1371/journal.pone.0228283

Milanović, Z., Sporiš, G., James, N., Trajković, N., Ignjatović, A., Sarmento, H., Trecroci, A., & Mendes, B. M. B. (2017). Physiological demands, morphological characteristics, physical abilities and injuries of female

soccer players. *Journal of Human Kinetics*, *60*, 77–83. https://doi.org/10.1515/hukin-2017-0091

Millar, N. A., Colenso-Semple, L. M., Lockie, R. G., Marttinen, R. H. J., & Galpin, A. J. (2020). In-season hip thrust vs. back squat training in female High School soccer players. *International Journal of Exercise Science*, *13*(4), 49–61.

Mjølsnes, R., Arnason, A., Østhagen, T., Raastad, T., & Bahr, R. (2004). A 10-week randomized trial comparing eccentric vs. concentric hamstring strength training in well-trained soccer players. *Scandinavian Journal of Medicine & Science in Sports, 14*(5), 311–317. https://doi.org/10.1046/j.1600-0838.2003.367.x

Mohr, M., Krustrup, P., Andersson, H., Kirkendall, D., & Bangsbo, J. (2008). Match activities of elite women soccer players at different performance levels. *Journal of Strength and Conditioning Research, 22*(2), 341–349. https://doi.org/10.1519/JSC.0b013e318165fef6

Mohr, M., Krustrup, P., & Bangsbo, J. (2003). Match performance of high-standard soccer players with special reference to development of fatigue. *Journal of Sports Sciences*, *21*(7), 519–528. https://doi.org/10.1080/0264041031000071182

Mujika, I., Santisteban, J., Impellizzeri, F. M., & Castagna, C. (2009). Fitness determinants of success in men's and women's football. *Journal of Sports Sciences, 27*(2), 107–114. https://doi.org/10.1080/02640410802428071

Nassis, G. P., Brito, J., Tomás, R., Heiner-Møller, K., Harder, P., Kryger, K. O., & Krustrup, P. (2021). Elite women's football: Evolution and challenges for the

years ahead. *Scandinavian Journal of Medicine & Science in Sports, 32* Suppl 1, 7–11. https://doi.org/10.1111/sms.14094

Nevado-Garrosa, F., Torreblanca-MartÍnez, V., Paredes-HernÁndez, V., Del Campo-Vecino, J., & Balsalobre-Fernández, C. (2021). Effects of an eccentric overload and small-side games training in match accelerations and decelerations performance in female under-23 soccer players. *The Journal of Sports Medicine and Physical Fitness, 61*(3), 365–371. https://doi.org/10.23736/S0022-4707.20.11232-5

Nimphius, S., McGuigan, M. R., & Newton, R. U. (2010). Relationship between strength, power, speed, and change of direction performance of female softball players. *Journal of Strength and Conditioning Research*, *24*(4), 885–895. https://doi.org/10.1519/JSC.0b013e3181d4d41d

Nonnato, A., Hulton, A. T., Brownlee, T. E., & Beato, M. (2022). The effect of a single session of plyometric training per week on fitness parameters in professional female soccer players: A randomized controlled trial. *Journal of Strength and Conditioning Research, 36*(4), 1046–1052. https://doi.org/10.1519/JSC.0000000000003591

Nowak, M., Szymanek-Pilarczyk, M., Stolarczyk, A., Oleksy, Ł., Muracki, J., & Wąsik, J. (2024). Normative and limit values of speed, endurance and power tests results of young football players. *Frontiers in Physiology*, *15*, 1502694. https://doi.org/10.3389/fphys.2024.1502694

Nuzzo, J. L., McBride, J. M., Cormie, P., & McCaulley, G. O. (2008). Relationship between countermovement jump performance and multijoint isometric and

dynamic tests of strength. *Journal of Strength and Conditioning Research*, *22*(3), 699–707. https://doi.org/10.1519/JSC.0b013e31816d5eda

Osses-Rivera, A., Yáñez-Sepúlveda, R., Jannas-Vela, S., Vigh-Larsen, J. F., & Monsalves-Álvarez, M. (2024). Effects of strength training on repeated sprint ability in team sports players: A systematic review. *PeerJ, 12*, e17756. https://doi.org/10.7717/peerj.17756

Otero-Esquina, C., de Hoyo Lora, M., Gonzalo-Skok, Ó., Domínguez-Cobo, S., & Sánchez, H. (2017). Is strength-training frequency a key factor to develop performance adaptations in young elite soccer players? *European Journal of Sport Science*, *17*(10), 1241–1251. https://doi.org/10.1080/17461391.2017.1378372

Ozbar, N., Ates, S., & Agopyan, A. (2014). The effect of 8-week plyometric training on leg power, jump and sprint performance in female soccer players. *Journal of Strength and Conditioning Research, 28*(10), 2888–2894. https://doi.org/10.1519/jsc.0000000000000541

Papla, M., Krzysztofik, M., Wojdala, G., Roczniok, R., Oslizlo, M., & Golas, A. (2020). Relationships between linear sprint, lower-body power output and change of direction performance in elite soccer players. *International Journal of Environmental Research and Public Health, 17*(17), 6119. https://doi.org/10.3390/ijerph17176119

Pardos-Mainer, E., Lozano, D., Torrontegui-Duarte, M., Cartón-Llorente, A., & Roso-Moliner, A. (2021). Effects of strength vs. plyometric training programs on vertical jumping, linear sprint and change of direction speed

performance in female soccer players: A systematic review and meta-analysis. *International Journal of Environmental Research and Public Health, 18*(9), 4604. https://doi.org/10.3390/ijerph18020401

Pecci, J., Muñoz-López, A., Jones, P. A., & Sañudo, B. (2023). Effects of 6 weeks in-season flywheel squat resistance training on strength, vertical jump, change of direction and sprint performance in professional female soccer players. *Biology of Sport, 40*(2), 521–529. https://doi.org/10.5114/biolsport.2023.118022

Pedersen, S., Welde, B., Sagelv, E. H., Heitmann, K. A., B Randers, M., Johansen, D., & Pettersen, S. A. (2022). Associations between maximal strength, sprint, and jump height and match physical performance in high-level female football players. *Scandinavian Journal of Medicine & Science in Sports*, *32 Suppl 1*, 54–61. https://doi.org/10.1111/sms.14009

Perroni, F., Amatori, S., Corsi, L., Bensi, R., Guidetti, L., Baldari, C., Rocchi, M. B. L., Castagna, C., Gobbi, E., Sisti, D., & Buzzachera, C. F. (2024). Assessment of Performance in youth soccer players: Should we consider the maturation status? *Journal of Human Kinetics*, *93*, 119–131. https://doi.org/10.5114/jhk/184276

Petersen, J., Thorborg, K., Nielsen, M. B., Budtz-Jørgensen, E., & Hölmich, P. (2011). Preventive effect of eccentric training on acute hamstring injuries in men's soccer: a cluster-randomized controlled trial. *The American Journal of Sports Medicine, 39*(11), 2296–2303. https://doi.org/10.1177/0363546511419277

Pérez Armendáriz, M. L., Spyrou, K., & Alcaraz, P. E. (2024). Match demands of female team sports: A scoping review. *Biology of Sport, 41*(1), 175–199. https://doi.org/10.5114/biolsport.2024.129476

Pierce, K. C., Hornsby, W. G., & Stone, M. H. (2021). Weightlifting for Children and adolescents: A narrative review. *Sports Health*, *14*(1), 45–56. https://doi.org/10.1177/19417381211056094

Pons, E., Ponce-Bordón, J. C., Díaz-García, J., López Del Campo, R., Resta, R., Peirau, X., & García-Calvo, T. (2021). A Longitudinal exploration of match running performance during a football match in the Spanish La Liga: A Four-Season Study. *International Journal of Environmental Research and Public Health*, *18*(3), 1133. https://doi.org/10.3390/ijerph18031133

Preissler, A. A. B., Schons, P., Clemente, F. M., de Vargas, G. D., Klein, L. M., Silva, A. F., Nobari, H., & Kruel, L. F. M. (2023). Correlations between linear sprint with the ball, linear sprint without the ball, and change-of-direction without the ball in professional female soccer players. *Scientific Reports, 13*(1), 39. https://doi.org/10.1038/S41598-022-27255-Y

Ramírez-Campillo, R., García-Pinillos, F., Chaabene, H., Moran, J., Behm, D. G., & Granacher, U. (2021). Effects of plyometric jump training on electromyographic activity and its relationship to strength and jump performance in healthy trained and untrained populations: A systematic review of randomized controlled trials. *Journal of Strength and Conditioning Research, 35*(7), 2053–2065. https://doi.org/10.1519/JSC.0000000000004056

Ramos, G. P., Nakamura, F. Y., Penna, E. M., Wilke, C. F., Pereira, L. A., Loturco, I., Capelli, L., Mahseredjian, F., Silami-Garcia, E., & Coimbra, C. C. (2019). Activity profiles in U17, U20, and senior women's Brazilian national soccer teams during international competitions: Are there meaningful differences? *Journal of Strength and Conditioning Research*, *33*(12), 3414–3422. https://doi.org/10.1519/JSC.0000000000002170

Rampinini, E., Bishop, D., Marcora, S. M., Ferrari Bravo, D., Sassi, R., & Impellizzeri, F. M. (2007). Validity of simple field tests as indicators of match-related physical performance in top-level professional soccer players. *International Journal of Sports Medicine*, *28*(3), 228–235. https://doi.org/10.1055/s-2006-924340

Randell, R. K., Clifford, T., Drust, B., Moss, S. L., Unnithan, V. B., De Ste Croix, M. B. A., Datson, N., Martin, D., Mayho, H., Carter, J. M., & Rollo, I. (2021). Physiological characteristics of female soccer players and health and performance considerations: A narrative review. *Sports Medicine (Auckland, N.z.)*, *51*(7), 1377–1399. https://doi.org/10.1007/s40279-021-01458-1

Raya-González, J., Castillo, D., de Keijzer, K. L., & Beato, M. (2021). The effect of a weekly flywheel resistance training session on elite U-16 soccer players' physical performance during the competitive season. A randomized controlled trial. *Research in Sports Medicine (Print)*, *29*(6), 571–585. https://doi.org/10.1080/15438627.2020.1870978

Raya-González, J., Pulido, J. J., Beato, M., Ponce-Bordón, J. C., López del Campo, R., Resta, R., & García-Calvo, T. (2022). Analysis of the effect of injuries on

match performance variables in professional soccer Players: A retrospective, experimental longitudinal design. *Sports Medicine - Open*, *8*(1), 31. https://doi.org/10.1186/s40798-022-00427-w

Raya González, J., & Sánchez Sánchez, J. (2018). Métodos de entrenamiento de la fuerza para la mejora de las acciones en el fútbol [Strength Training Methods for Improving Actions in Football]. *Apunts Educación Física y Deportes*, *136*, 72–93. https://doi.org/10.5672/apunts.2014-0983.es.(2018/2).132.06

Raya-González, J., Scanlan, A. T., Soto-Célix, M., Rodríguez-Fernández, A., & Castillo, D. (2021). Caffeine Ingestion improves performance during fitness tests but does not alter activity during simulated games in professional basketball players. *International Journal of Sports Physiology and Performance*, *16*(3), 387–394. https://doi.org/10.1123/ijspp.2020-0144

Rey, E., Carrera, S., Padrón-Cabo, A., & Costa, P. B. (2024). Effectiveness of short vs. long-distance sprint training on sprinting and agility performance in young soccer players. *Biology of Sport*, *41*(1), 87–93. https://doi.org/10.5114/biolsport.2024.127384

Rodríguez-Fernández, A., Sanchez-Sanchez, J., Ramirez-Campillo, R., Nakamura, F. Y., Rodríguez-Marroyo, J. A., & Villa-Vicente, J. G. (2019). Relationship between repeated sprint ability, aerobic capacity, intermittent endurance, and heart rate recovery in youth soccer players. *The Journal of Strength & Conditioning Research*, *33*(12), 3406. https://doi.org/10.1519/JSC.0000000000002193

Rodríguez Porras, L. D., Solano-Mora, L., Rivas-Borbón, M., Moreno-Villanueva, A., Soler-López, A., Pino-Ortega, J., & Ugalde-Ramírez, J. A. (2024). Profile of Physical demands in female soccer players during competitions: A systematic review. *Strength & Conditioning Journal*, *46*(5), 567. https://doi.org/10.1519/SSC.0000000000000829

Sánchez-Abselam, O., González-Fernández, F. T., Figueiredo, A., Castillo-Rodríguez, A., & Onetti-Onetti, W. (2024). Effect of the role, playing position and the body characteristics on physical performance in female soccer players. *Heliyon*, *10*(7). https://doi.org/10.1016/j.heliyon.2024.e29240

Sánchez-Medina, L., & González-Badillo, J. J. (2011). Velocity loss as an indicator of neuromuscular fatigue during resistance training. *Medicine and Science in Sports and Exercise*, *43*(9), 1725–1734. https://doi.org/10.1249/MSS.0b013e318213f880

Sánchez-Sánchez, J., Rodríguez-Fernández, A., Granacher, U., Afonso, J., & Ramírez-Campillo, R. (2024). Plyometric jump training effects on maximal strength in soccer players: A systematic review with meta-analysis of randomized-controlled studies. *Sports Medicine - Open*, *10*(1), 52. https://doi.org/10.1186/s40798-024-00720-w

Scott, D., Norris, D., & Lovell, R. (2020). Dose-response relationship between external load and wellness in elite women's soccer matches: Do customized velocity thresholds add value? *International Journal of Sports Physiology and Performance*, *15*. https://doi.org/10.1123/ijspp.2019-0660

Seipp, D., Quittmann, O. J., Fasold, F., & Klatt, S. (2023). Concurrent training in team sports: A systematic review. *International Journal of Sports Science & Coaching*, *18*(4), 1342–1364. https://doi.org/10.1177/17479541221099846

Shalfawi, S., Young, M., Tonessen, E., Haugen, T., & Enoksen, E. (2013). The effect of repeated agility training vs. repeated sprint training on elite female soccer players' physical performance. *Article in Kinesiology*, *19*(3), 29–42. https://www.researchgate.net/publication/265847371

Silva, J. R., Nassis, G. P., & Rebelo, A. (2015). Strength training in soccer with a specific focus on highly trained players. *Sports Medicine - Open*, *1*(1), 17. https://doi.org/10.1186/s40798-015-0006-z

Slimani, M., Znazen, H., Miarka, B., & Bragazzi, N. L. (2019). Maximum oxygen uptake of male soccer players according to their competitive level, playing position and age group: Implication from a Network Meta-Analysis. *Journal of Human Kinetics*, *66*, 233–245. https://doi.org/10.2478/hukin-2018-0060

Sporiš, G., Jovanović, M., Krakan, I., & Fiorentini, F. (2011). Effects of strength training on aerobic and anaerobic power in female soccer players. *Sport Science : International Scientific Journal of Kinesiology*, *4*(2), 32–37.

Springham, M., Singh, N., Stewart, P., Matthews, J., Jones, I., Norton-Sherwood, C., May, D., Salter, J., Strudwick, A. J., & Shaw, J. W. (2024). Countermovement jump and isometric strength test-retest reliability in english premier league academy football players. *International Journal of Sports Physiology and Performance*, *19*(12), 1444–1454. https://doi.org/10.1123/ijspp.2023-0473

Stankovic, M., Đorđević, D., Katanic, B., Petrovic, A., Jelaska, I., Bjelica, D., & Mekic, A. (2023). Speed and agility training in female soccer players—A systematic review. *Sport Mont Journal*, *21*, 117–122. https://doi.org/10.26773/smj.231018

Stone, M. H., Hornsby, W. G., Suarez, D. G., Duca, M., & Pierce, K. C. (2022). Training specificity for athletes: Emphasis on strength-power training: A narrative review. *Journal of Functional Morphology and Kinesiology*, *7*(4), 102. https://doi.org/10.3390/jfmk7040102

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer: An update. *Sports Medicine*, *35*(6), 501–536. https://doi.org/10.2165/00007256-200535060-00004

Suchomel, T. J., Nimphius, S., & Stone, M. H. (2016). The importance of muscular strength in athletic performance. *Sports Medicine*, *46*(10), 1419–1449. https://doi.org/10.1007/s40279-016-0486-0

Sung, E.-S., & Kim, J.-H. (2019). The resistance training effects of different weight level during menstrual cycle in female. *Journal of Exercise Rehabilitation*, *15*(2), 249–253. https://doi.org/10.12965/jer.193808.024

Šuc, A., Šarko, P., Pleša, J., & Kozinc, Ž. (2022). Resistance exercise for improving running economy and running biomechanics and decreasing running-related injury risk: A narrative review. *Sports*, *10*(7), Article 7. https://doi.org/10.3390/sports10070098

Torreblanca-Martínez, V., Nevado-Garrosa, F., Otero-Saborido, F. M., & Gonzalez-Jurado, J. A. (2020). Effects of fatigue induced by repeated-sprint on kicking

accuracy and velocity in female soccer players. *PLoS ONE, 15*(1), e0227214. https://doi.org/10.1371/journal.pone.0227214

Turner, E., Munro, A. G., & Comfort, P. (2013). Female soccer: Part 1—A needs analysis. *Strength and Conditioning Journal, 35*(1), 51–57. https://doi.org/10.1519/SSC.0b013e318281f689

Versey, N. G., Halson, S. L., & Dawson, B. T. (2013). Water immersion recovery for athletes: Effect on exercise performance and practical recommendations. *Sports Medicine, 43*(11), 1101–1130. https://doi.org/10.1007/s40279-013-0063-8

Wang, S., Shen, M., Li, P., & Liu, H. (2025). Factors related to the success in women's football-a systematic review. *Frontiers in Sports and Active Living*, *7*, 1602457. https://doi.org/10.3389/fspor.2025.1602457

Wang, X., Soh, K. G., Samsudin, S., Deng, N., Liu, X., Zhao, Y., & Akbar, S. (2023). Effects of high-intensity functional training on physical fitness and sport-specific performance among the athletes: A systematic review with meta-analysis. *PLoS ONE, 18*(12), e0295531. https://doi.org/10.1371/journal.pone.0295531

Wen, X., Song, F., Yang, L., & Xu, Q. (2024). Small-sided soccer games promote greater adaptations on vertical jump and change-of-direction deficit and similar adaptations in aerobic capacity than high-intensity interval training in females. *Journal of Sports Science & Medicine, 23*(2), 445–454. https://doi.org/10.52082/jssm.2024.445

Wing, C. (2018). In-season strength and power training considerations for professional soccer teams competing within national level competitions. *Strength and Conditioning Journal*, *40*, 1. https://doi.org/10.1519/SSC.0000000000000377

Wing, C. E., Turner, A. N., & Bishop, C. J. (2021). Importance of strength and power on key performance indicators in elite youth soccer. *Journal of Strength and Conditioning Research,* *35*(6), 1684–1690. https://doi.org/10.1519/JSC.0000000000002446

Winther, A. K., Baptista, I., Pedersen, S., Randers, M. B., Johansen, D., Krustrup, P., & Pettersen, S. A. (2022). Position specific physical performance and running intensity fluctuations in elite women's football. *Scandinavian Journal of Medicine & Science in Sports*, *32*(S1), 105–114. https://doi.org/10.1111/sms.14105

Wisløff, U., Castagna, C., Helgerud, J., Jones, R., & Hoff, J. (2004). Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *British Journal of Sports Medicine*, *38*(3), 285–288. https://doi.org/10.1136/bjsm.2002.002071

Xiao, W., Bu, T., Zhang, J., Cai, H., Zhu, W., Bai, X., Zhang, L., & Geok, S. K. (2025). Effects of functional training on physical and technical performance among the athletic population: A systematic review and narrative synthesis. *BMC Sports Science, Medicine and Rehabilitation, 17*, 2. https://doi.org/10.1186/s13102-024-01040-y

Xing, Y., Chamera, T., Chen, L., & Zhang, S. (2023). Aerobic power across positions—An investigation into women's soccer performance. *Annals of Agricultural and Environmental Medicine: AAEM*, *30*(4), 749–754. https://doi.org/10.26444/aaem/169854

Zhang, Y., Zhuang, Y., Zhang, L., & Sun, M. (2024). The impact of eccentric training on athlete movement speed: A systematic review. *Frontiers in Physiology, 15*. https://doi.org/10.3389/fphys.2024.1492023

Zouita, A., Darragi, M., Bousselmi, M., Sghaeir, Z., Clark, C. C. T., Hackney, A. C., Granacher, U., & Zouhal, H. (2023). The Effects of resistance training on muscular fitness, muscle morphology, and body composition in elite female athletes: A systematic review. *Sports Medicine, 53*(9), 1709–1735. https://doi.org/10.1007/s40279-023-01859-4

IX – APPENDICES

IX - APPENDICES

APPENDIX 1. STUDY 1: IMPACT OF A 10-WEEK STRENGTH TRAINING PROGRAM ON PERFORMANCE AND MATCH EXTERNAL LOAD IN YOUNG ELITE FEMALE SOCCER PLAYERS

Reference:

Bal, S. P., Martínez-Aranda, L. M., Krustrup, P., & Raya-González, J. (2025). Impact of a 10-Week Strength Training Program on Physical Performance and Match External Load in Young Elite Female Soccer Players. Journal of Functional Morphology and Kinesiology, 10(3), 289. https://doi.org/10.3390/jfmk10030289

Journal of *Functional Morphology and Kinesiology*

MDPI

Article

Impact of a 10-Week Strength Training Program on Physical Performance and Match External Load in Young Elite Female Soccer Players

Sefika Pelin Bal [1,2,†], Luis Manuel Martínez-Aranda [3,4,*,†], Peter Krustrup [2,5] and Javier Raya-González [6]

[1] Facultad de Deporte, UCAM Universidad Católica de Murcia, 30107 Murcia, Spain; spbal@alu.ucam.edu
[2] Department of Sports Science and Clinical Biomechanics, SDU Sport and Health Sciences Cluster (SHSC), University of Southern Denmark, 5230 Odense-M, Denmark; pkrustrup@health.sdu.dk
[3] Department of Sports and Computer Sciences, Faculty of Sports Sciences, Universidad Pablo de Olavide, 41013 Seville, Spain
[4] Science-Based Training Research Group (SEJ-680), Physical Performance and Sports Research Center, Universidad Pablo de Olavide, 41013 Seville, Spain
[5] Danish Institute for Advanced Study (DIAS), Faculty of Health Sciences, University of Southern Denmark, 5230 Odense-M, Denmark
[6] Grupo de Investigación en Deporte y Educación Física para el Desarrollo Personal y Social (GIDEPSO), Department of Specific Didactics, Faculty of Education Sciences and Psychology, University of Córdoba, 14004 Córdoba, Spain; rayagonzalezjavier@gmail.com
* Correspondence: lmmarara@upo.es
† These authors equally contributed to this work.

Abstract

Background: Soccer is a physically demanding sport characterized by frequent high-intensity efforts, which are particularly relevant in women's competitions. Improving high-speed running and aerobic capacity has been linked to better on-field performance. Strength training has shown promise in enhancing these physical attributes, but its application in young female soccer players remains underexplored. This study aimed to investigate the effects of a 10-week in-season strength training program on physical performance and match running demands in young female soccer players. Methods: Thirty-two U18 Danish female professional soccer players from two comparable teams voluntarily participated in the study. Teams were allocated to either an experimental group, performing twice-weekly strength training (EG, n = 16) or a control group (CG, n = 16). Vertical jump performance and Yo-Yo IR2 performance as an estimation for maximal oxygen uptake (VO_2max) were assessed both pre and post intervention. Additionally, players' match external demands (i.e., total distance, distance covered at speeds above 23 km·h^{-1}, and maximum velocity achieved) were monitored using Global Positioning System devices during four matches before and after the intervention. Results: Significant within-group differences were observed across all variables for the EG (p = 0.001; ES = 1.08 to 1.45, large), without differences in the CG (p > 0.01). Between-group analysis indicated significant differences favoring the EG in all variables (F = 27.40 to 47.17; p = 0.001). Conclusions: The application of a 10-week strength training program led to improvements in physical and match running performance among young female soccer players, underscoring the importance of incorporating strength training programs into female soccer periodization to enhance performance.

Keywords: resistance training; women; football; team-sport; GPS

check for updates

Academic Editor: Athanasios Tsoukos

Received: 1 July 2025
Revised: 20 July 2025
Accepted: 24 July 2025
Published: 28 July 2025

Citation: Bal, S.P.; Martínez-Aranda, L.M.; Krustrup, P.; Raya-González, J. Impact of a 10-Week Strength Training Program on Physical Performance and Match External Load in Young Elite Female Soccer Players. *J. Funct. Morphol. Kinesiol.* **2025**, *10*, 289. https://doi.org/10.3390/jfmk10030289

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Soccer is a physically demanding intermittent team sport characterized by alternating periods of low- and high-intensity activity [1,2]. Notably, these physical demands differ between men's and women's competitions [3], making it essential to analyze them specifically by gender. In women's soccer, recent research has reported that players cover a total distance of 9 to 10 km per match [4,5], with an average of approximately 30 sprints [6], along with 200 accelerations and 150 decelerations per game [7]. Additionally, female players run around 500 m at speeds exceeding 19.0 $km \cdot h^{-1}$ and 125 m at speeds above 22.5 $km \cdot h^{-1}$ [8]. These findings underscore the importance of enhancing high-intensity capabilities for competitive success [9]. Furthermore, improving maximal oxygen uptake (VO_2max) is essential for delaying fatigue and supporting repeated high-intensity efforts with minimal recovery time during matches [10]. Therefore, identifying effective strategies to develop these capacities is critical for strength and conditioning coaches.

For this purpose, strength training has been widely recognized as a key factor [11,12]. In this context, the effects of several methodologies have been examined [13], yielding significant improvements in physical performance among soccer players. Specifically, in female soccer, Millar et al. [14] implemented, during the in-season period, a 6-week strength training program focused on back squats in female high school soccer players, achieving significant increases in vertical jump performance. Similarly, Sporiš et al. [15] observed improvements in VO_2max among female soccer players following a 12-week strength training program during the second off-season period (from November to March). However, soccer presents unique conditions that must be considered when integrating strength training programs into soccer periodization [16]. For example, soccer schedules are often unpredictable and subject to frequent changes, characterizing the sport as highly competitive, with more than one match per week [17]. Additionally, differences between players, such as starters and non-starters, influence the available time for training [18]. These factors must be accounted for to identify the optimal approach regarding frequency, methods, exercises, and session timing. Given the limited time available for implementing specific strength training sessions, it is essential to adopt strategies that enhance performance without inducing excessive fatigue. In this regard, González-Badillo et al. [19] proposed performing half of the maximum possible repetitions for each load during strength training programs. These authors found that this approach promotes faster mean repetition velocities, minimizes neuromuscular performance impairments, facilitates quicker recovery, and reduces hormonal responses and muscle damage compared to completing all possible repetitions. However, this methodology has not yet been applied to young female populations to evaluate its effects on physical performance variables, which is adequate for this population (i.e., young players with scarce experience with resistance training) instead of reaching muscle failure.

Strength and conditioning coaches have emphasized the importance of improving physical performance variables to achieve subsequent increases in distances covered at a high intensity during official matches in the soccer population [20]. In this context, Pedersen et al. [21] demonstrated a strong association between maximal strength, sprint performance, jump height, and match physical performance in high-level female soccer players. Consequently, increases in match load demands contribute to enhanced on-field performance [22]. This is supported by previous research showing that high-standard teams cover greater high-intensity distances during official matches in both male [2] and female soccer players [23]. However, few studies have investigated whether a complementary strength training program can improve soccer players' performance. In this regard, Byrkjedal et al. [20] confirmed that strength training, applied during the in-season period, is an effective method to enhance external match performance in professional male soccer players, particularly in high-speed running and sprinting variables. Nevertheless, no

studies have yet evaluated whether a complementary strength training program for female soccer players could positively impact their match external load variables or used a strength training methodology in which participants complete only half of their maximum possible repetitions, highlighting the need for future research in this area.

To cover this gap, a 10-week strength program was applied in young elite female soccer players during their regular in season. Specifically, the aim of this study was to analyze the effects of a 10-week strength training program on physical performance and match running demands in young female soccer players. Based on prior studies [15,20,24], we hypothesized that a structured training intervention would lead to significant improvements in both physical performance and match running performance among female players in the experimental group compared to a control group.

2. Materials and Methods

2.1. Study Design

A quasi-experimental design was employed to evaluate the impact of a 10-week strength training program (two sessions per week) on the physical performance and match running demands of young female soccer players. Physical performance was assessed at baseline and post training in a single session, which included a jump test (countermovement jump, CMJ) and an endurance test (Yo-Yo Intermittent Recovery Test). These assessments were conducted on the team's natural grass training field, with players wearing their own soccer boots. All testing sessions took place in the afternoon between 5:00 p.m. and 7:00 p.m. Additionally, players' match external demands (i.e., total distance, distance covered at above 23 $km \cdot h^{-1}$, and maximum velocity achieved) were tracked using Global Positioning System (GPS) devices during four matches before and after the intervention period. To standardize conditions, players were instructed to have their last meal 3 h before testing, avoid caffeinated beverages, and refrain from intense physical activity prior to assessments. A strength and conditioning specialist supervised all testing sessions, providing verbal encouragement throughout the protocols [25].

2.2. Participants

Thirty-two U18 Danish female elite soccer players (age = 16.4 ± 0.8 years) voluntarily participated in the study. A priori power analysis was conducted using G*Power (version 3.1.9.2, Universität Kiel, Kiel, Germany). The analysis indicated that a minimum sample size of 16 participants per group was required to achieve a statistical power (1–3) of 0.80, based on an assumed effect size (ES) of 0.90 (large effect) and a significance level (α) of 0.05. Participants belonged to two different teams competing at the highest level for their age. Both teams followed the same style and training schedule, trained 4 times per week [i.e., first session: recovery or compensation; second session: strength (small-sided games with a reduce number of players); third session: endurance (large-sided games with a high number of players); and fourth session: reaction (medium-sided games with a high number of players)], and played one official match during the weekend. Players were eligible for inclusion in the study if they had been part of the same soccer academy for the past two years, attended at least 80% of training sessions over the 10-week period, had a minimum of four years of experience in systematic soccer training, with low–medium experience in resistance training, and had not sustained any injuries in the two months prior to the study. Teams were randomly assigned to either the control group (CG; n = 16; age: 16.4 ± 0.7 years; height: 168.7 ± 5.2 cm; body mass: 62.5 ± 6.4 kg; body mass index: 21.9 ± 1.4 $kg \cdot m^{-2}$) or to the experimental group (EG; n = 16; age: 16.4 ± 0.8 years; height: 167.5 ± 5.6 cm body mass: 60.9 ± 6.5 kg; body mass index: 21.7 ± 1.7 $kg \cdot m^{-2}$), with all the players of the same team being parts of each group. Initially, 44 players were recruited for the study, but 4 goalkeepers were excluded due to the distinct nature of their training and role in the game, 2 players left the teams prior to post assessment,

and 6 players were injured during the intervention period and did not complete 80% of the training sessions (Figure 1). Prior to participation, all players received detailed information about the study procedures, including potential risks and benefits. Written informed consent was obtained from their parents or legal guardians. The study adhered to the principles of the Declaration of Helsinki (2013) and was approved by the ethical committee of the Catholic University of Murcia under the internal registration number CE062112 (25 June 2021).

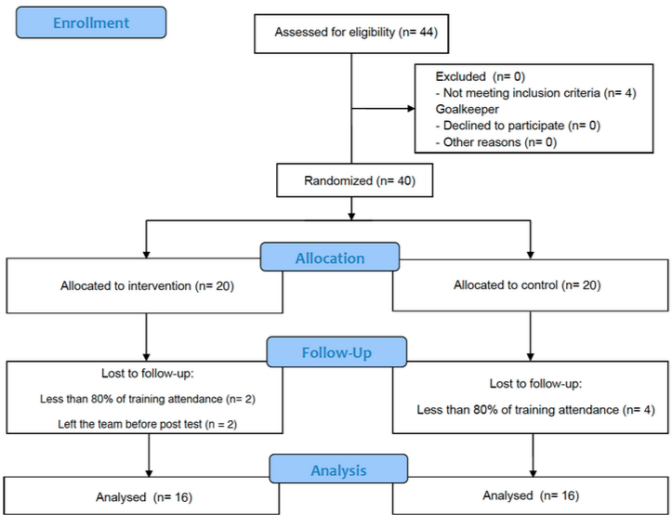


Figure 1. CONSORT diagram of participant's recruitment, allocation, follow-up, and analysis.

2.3. *Procedures*

During the 10-week intervention, players from both groups followed their regular in-season weekly soccer training routine, with the EG incorporating two strength training sessions per week while the CG had no strength training and followed their regular training periodization. The weekly training program (i.e., microcycle) was designed collaboratively by the coach and the strength and conditioning specialist, consisting of four soccer training sessions and one official match. Prior to the intervention, players in the EG completed a 2-week familiarization strength training program. All participants were already accustomed to the testing protocols from routine preseason assessments at the club and were familiar with the GPS devices, having worn them throughout competitive matches during the season. Physical performance assessments were conducted in two testing sessions: Session 1 followed the sequence of the countermovement jump (CMJ) test and the Yo-Yo Intermittent Recovery Level 2 test to minimize fatigue accumulation, while Session 2 included the one-repetition maximum (1RM) assessment. Data from four matches before and four matches after the intervention period were also collected. Before each testing session, a standardized 15 min warm-up was performed. This warm-up included 7 min of slow jogging and walking locomotion, followed by 8 min of jump exercises, progressive acceleration, and sprint drills over 10 and 30 m distances.

2.4. *Test*

2.4.1. Countermovement Jump Height

Players completed two bilateral countermovement jumps (CMJs) with 1 min of rest between attempts. They were instructed to perform a downward motion followed by

a rapid and complete extension of the lower limbs to maximize jump height, keeping their hands on their hips throughout the movement. The MyJump 2.0 mobile application was used to measure CMJ height, a tool shown to be highly valid (r = 0.995) and reliable (intraclass correlation coefficient = 0.997) for this purpose [26]. All jumps were recorded at 240 Hz with an iPhone 8 Plus mobile device (Apple Inc., Cupertino, CA, USA) [27]. The best jump height (in cm) was selected for further analysis.

2.4.2. Yo-Yo Intermittent Recovery Level 2 Test

A single set of this test was completed, which involved performing 2 × 20 m shuttle runs at progressively increasing speeds, with 10 s of active recovery between runs. The recovery consisted of jogging 2 × 5 m. Players followed an auditory beep signal, and the test concluded when they failed to reach the finish line in sync with the beep on two consecutive attempts. The total distance covered (in m) was recorded as the test result [28]. From this test, each player's estimated VO_2max was calculated indirectly. The test area was marked with cones, forming a 20 m long and 2 m wide running lane. An additional cone, placed 5 m behind the finish line, indicated the jogging distance for the active recovery period.

2.5. Match Running Demands

The Polar Team Pro (Polar Electro, Kempele, Finland) device was used to monitor match external demands. It is an advanced athlete monitoring system designed for team sports, integrating a 10 Hz GPS, 200 Hz tri-axial accelerometer, gyroscope, magnetometer, and heart rate monitor. These devices were positioned on the chest of players, with each player using the same device during the entire experimental period. These devices have shown high accuracy and acceptable reliability compared to the gold standard [29]. Specifically, the following variables were monitored: total distance covered in meters (TD), very-high-speed running distance (VHSR, >23 km·h^{-1}), and maximum velocity achieved during matches (Vmax).

2.6. Strength Training Program

Players participated in a 10-week complementary strength training program (CSTT), conducted prior to regular soccer training and following a standardized warm-up. The CSTT incorporated strength, range of motion (ROM), and balance exercises, as detailed in Tables 1 and 2. Strength exercises targeting major muscle groups (e.g., chest, legs, back) were performed at half of the maximum number of repetitions per set, with 6 repetitions of the possible 12 [70% 1RM load (4 × 6 (12))]. This approach was based on evidence from a prior study, conducted with physically active sports science students, demonstrating that performing half the maximum number of repetitions per set promotes faster mean repetition velocities, minimizes neuromuscular performance impairments, facilitates faster recovery, and reduces hormonal responses and muscle damage following exercise [19]. An incremental load test was conducted to determine the 1RM value for each exercise [30]. The initial load for all participants was set at 20 kg and was progressively increased by 10 kg per set until reaching 0.5 m/s in mean propulsive velocity. Subsequently, the load was increased by 5 to 2.5 kg until the participant could no longer move it. A rest period of at least 5 min was allowed between sets. A re-evaluation was implemented prior to the sessions of the 6th week. Balance exercises were performed on Bosu, with players having to reach 3 movement directions with their hand, completing 3 sets per exercise. Players completed Session 1 (Table 1) during their first strength training session of the week and Session 2 (Table 2) during their second strength training session. Prior to the pre-test session, players underwent a 2-week anatomical adaptation phase (2 sessions per week). Throughout the 10-week in-season intervention period, both CG and EG players adhered

to their regular in-season routines, comprising 4 weekly 60–90 min training sessions in addition to competitive matches.

Table 1. Session 1 for the complementary strength training program.

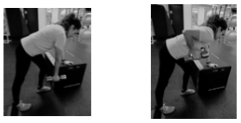
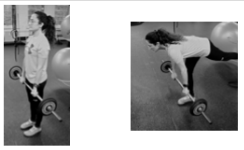
Exercises	Illustrations	Sets	Repetitions
Bulgarian split squat		4	6 (12)
Quick steps with band		4	10 s
Dumble bent row		4	6 (12)
One leg deadlift		4	6 (12)
Quick step up		4	6 each leg
Lever chest press		4	6 (12)

Table 1. *Cont.*

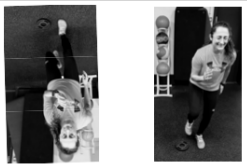
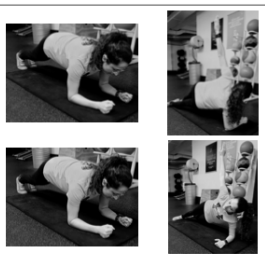
Exercises	Illustrations	Sets	Repetitions
Cable abduction + adduction		2	6 (12)
Reverse hyperextension		3	12
Knee up crunch + leg raise		3	15 + 10
Plank series		3	30 s + 10 s + 30 s + 10 s
One leg on Bosu, reaching 3 directions with each hand		3	One set each leg

Notes: 6 (12) = to perform 6 reps of 12 possible reps; body weight exercises did not follow the half rep method.

Table 2. Session 2 for the complementary strength training program.

Exercises	Illustrations	Sets	Repetitions
Walking lunge		4	6 (12)
Bird dog		3	12 each side
4-sided change of direction CMJ and drop jump		3	3 rounds
Prone hamstring curl		4	6
Leg raise and hip raise		3	6 + 6
Boxing		3	1 min

Table 2. *Cont.*

Exercises	Illustrations	Sets	Repetitions
Abduction + adduction with band		2	12
V-sit trunk rotation with weight		3	6 each side
One-leg side-to-side jump and hold		4	5
Plank series		3	30 s + 10 s + 30 s + 10 s

Notes: 6 (12) = to perform 6 reps of 12 possible reps; body weight exercises did not follow the half rep method.

2.7. Statistical Analysis

Descriptive statistics are presented as means ± standard deviations (SDs). The Shapiro–Wilk test was conducted to assess the normality of the data distribution, and Levene's test was utilized to confirm the homogeneity of variances. To detect between-group and within-groups differences, an analysis of covariance (ANCOVA), incorporating baseline values as covariates, was performed. When significant F values were found, Bonferroni post hoc analysis was performed. Effect sizes (ESs) were computed using Cohen's method to evaluate the magnitude of effects and were interpreted as follows: <0.2, trivial; 0.20–0.49, small; 0.50–0.80, moderate; and >0.80, large [31]. Statistical analyses were carried out using SPSS v29 (SPSS Inc., Chicago, IL, USA). Based on the Bonferroni correction, statistical significance was set at $p < 0.01$.

3. Results

No significant between-groups differences were found when baseline values were compared.

The changes in physical performance and match load variables before (baseline) and after (post training) the 10-week intervention period are presented in Table 3 and Figure 2.

Table 3. Changes in physical performance and match load variables before (baseline) and after (post training) the 10-week intervention period.

	CG (n = 16)					EG (n = 16)					Between Group Differences		
Variables	**Baseline (Mean ± SD)**	**Post Training (Mean ± SD)**	**Δ (%)**	**p**	**ES**	**Baseline (Mean ± SD)**	**Post Training (Mean ± SD)**	**Δ (%)**	**p**	**ES**	**F**	**p**	**η^2**
CMJ (cm)	24.84 ± 2.72	25.07 ± 2.65	0.93	1.000	0.08	25.10 ± 2.84	29.20 ± 3.37	16.33	0.001	1.44	45.75	0.001	0.302
VO_2max (ml/kg/min)	52.03 ± 2.87	52.51 ± 2.83	0.92	0.342	0.17	54.01 ± 2.78	57.14 ± 3.22	5.80	0.001	1.13	47.17	0.001	0.150
TD (m)	9377 ± 1300	9543 ± 1370	1.77	0.675	0.13	9773 ± 1566	11628 ± 160.70	19.39	0.001	1.18	31.59	0.001	0.250
VHSR (m)	42.88 ± 44.17	52.67 ± 49.93	22.83	0.694	0.22	47.00 ± 41.90	92.38 ± 71.90	96.55	0.001	1.08	27.40	0.001	0.074
Vmax (km·h^{-1})	24.63 ± 2.35	25.24 ± 2.39	2.48	0.498	0.26	25.17 ± 2.33	28.56 ± 2.20	13.47	0.001	1.45	38.26	0.001	0.294

Abbreviations: CG = control group; EG = experimental group; SD = standard deviation; Δ (%) = percentage of change between pre- and post-intervention values; p = level of significance; ES = effect size; CMJ = counter-movement jump; VO_2max = maximal oxygen uptake; TD = total distance; VHSR = distance covered at above of 23 km·h^{-1}; Vmax = maximum velocity achieved during matches. Significance level was set at $p < 0.05$.

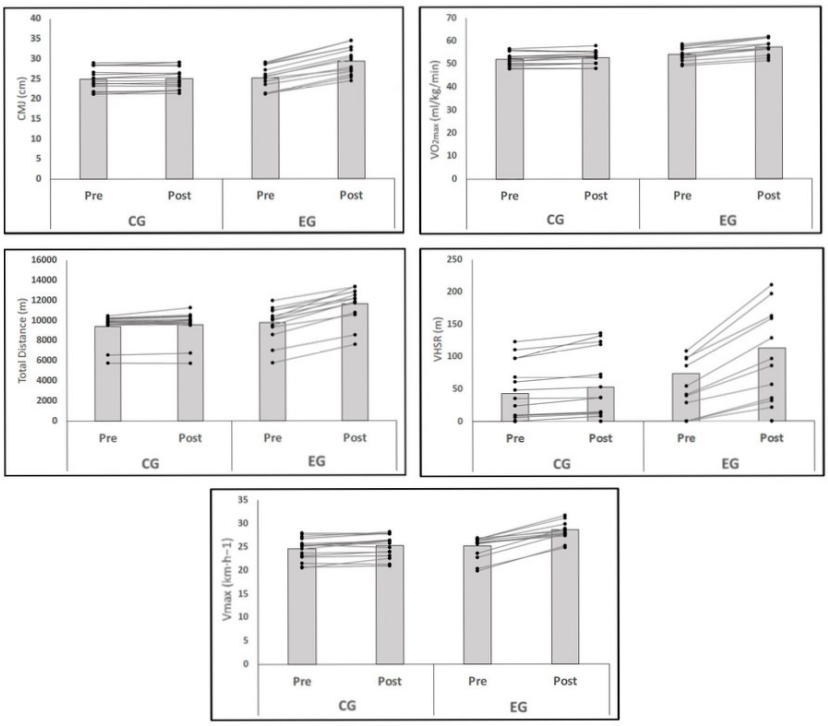


Figure 2. Individual changes in physical performance and match load variables before (baseline) and after (post training) the 10-week intervention period. Abbreviations: CG = control group; EG = experimental group.

In the within-group analysis, the experimental group (EG) exhibited substantial improvements in all variables (p = 0.001), with large effect sizes (ESs). CMJ performance increased by 16.33% (ES = 1.44), VO_2max improved by 5.80% (ES = 1.13), and TD showed a marked increase of 19.39% (ES = 1.18). Moreover, VHSR almost doubled, with an increase of 96.55% (ES = 1.08), and Vmax improved by 13.47% (ES = 1.45), highlighting the considerable magnitude of the training effects in the EG. Conversely, no within-group differences were observed in the CG for any variable.

Between-group comparisons revealed significant differences in favor of the EG across all variables (p = 0.001). The CMJ showed the largest group difference, followed closely by VO_2max and TD. VHSR and Vmax also demonstrated substantial between-group effects, confirming the superior improvements in physical performance and match load performance in the EG compared to the CG.

4. Discussion

This study aimed to examine the effects of a 10-week strength training program on physical performance and match running performance in young female soccer players during their regular in-season period. The CG did not perform any strength training, as it was not included in their in-season periodization program. To the best of our knowledge, this is the first study to investigate the impact of strength training based on completing half of the maximum number of repetitions per set on match load performance in this population (i.e., female elite U-18 soccer players). The main obtained findings indicated that players in the EG achieved significantly greater improvements compared to those in the CG.

The CMJ is widely recognized by soccer strength and conditioning professionals as a reliable measure of lower extremity power [32], which is strongly associated with success in soccer [9]. Consequently, training programs should prioritize improving this parameter. In this study, increases in CMJ performance were observed in the EG following the intervention period, with significant between-group differences in favor of this group. These findings align with those of Millar et al. [14], who reported a 4.9% improvement in vertical jump performance after implementing a 6-week in-season strength training program focused on back squats in female high school soccer players. Similarly, Lambright et al. [24] conducted an 8-week strength training program (three sessions/week) during the preseason in young female soccer players (i.e., 16 years), observing improvements of 1.19 $\pm$ 2.71 cm in CMJ performance post intervention. The training group also seemed to improve the estimated VO_2max, potentially derived from an improvement in the muscles' ability to use oxygen. Enhancements in VO_2max contribute to delaying the onset of fatigue, thereby enabling repeated high-intensity efforts with minimal recovery time during matches [10]. In this study, an estimated improvement in VO2max were observed in the EG (5.8%), although it cannot be ruled out that the improvement in Yo-Yo IR2 performance, was related to improvements in muscle strength and power. Similar findings have been reported in previous research. For example, Sporiš et al. [15] documented increases in VO_2max following a 12-week strength training program (three sessions/week) during the off-season period in elite female soccer players (under 20 years). These results highlight the importance of incorporating strength training programs into soccer periodization to enhance both high-intensity actions and aerobic power. Also, it is necessary to highlight that these strength training programs could be enhanced if their methodology is based on performing half of the reps in the main lifts, since although prior studies presented significant improvements, in the present study, these improvements were also achieved but in a more time-efficient manner (i.e., half the reps), while generating less labor that could interfere with soccer performance.

Certain external load metrics, such as TD, VHSR, and Vmax achieved during matches, are critical determinants of soccer performance, with top-tier teams often exhibiting the highest values in these variables [2]. Consequently, it is essential to develop strategies that enhance performance in these metrics during matches to achieve greater soccer success. In this study, the between-group comparison revealed significantly greater improvements in the EG for TD, VHSR, and Vmax. These findings may be attributed to the strong relationship between strength levels and high-intensity actions, as well as external match performance [21,33]. Also, we hypothesize that the applied strength training could improve sprint mechanics, support higher maximum velocities, potentiate repeated-sprint ability, enable more very-high-speed running bouts, and delay neuromuscular fatigue, facilitating greater total distance covered during match play. Despite this, no previous studies have specifically examined the impact of strength training programs on external match load performance in young female soccer players, although this has been explored in men's soccer. For example, Byrkjedal et al. [20] implemented two distinct strength training programs (i.e., regulated vs. self-selected) over a 10-week period (one session per week) in professional male soccer players. Both groups demonstrated improvements in external match load variables, such as high-speed running and sprint running. These findings reinforce the notion that strength training is a crucial component for enhancing external match performance during official competitions.

Despite the promising findings, this study has several limitations that practitioners should consider. The main limitation is that two teams were involved, and all the players of the same team were allocated into the same group. In this sense, although the training standards of both groups were similar, this could have impacted the results obtained due to the influence of the coaches. Another limitation is that the EG completed a higher total training volume, as the CG did not supplement their regular soccer training. Also, only two teams participated in the study, consistently maintaining the same roles. Therefore, future research involving a greater number of teams or employing a crossover design is needed to draw more robust conclusions. In addition, the assumed GPS variability must be considered, mainly when high-intensity distances are assessed. Finally, other important abilities, including flexibility, change in direction speed, and repeated-sprint ability (RSA) must be assessed in future studies. Finally, the study exclusively included female soccer players, which limits the generalizability of the findings to male players, highlighting the need for similar studies in male populations.

5. Conclusions

The main findings in this study showed improvements in young female soccer players' physical performance and match running performance after the application of a 10-week strength training program. Using a practical approach, it is suggested to incorporate the proposed strength training program, focused on the lower limb, into young female soccer players' periodization to improve not only physical performance but also match load parameters. Future studies considering the impact of the strength program on injury occurrence or long-term studies analyzing the retention of performance gains should be performed.

Author Contributions: Conceptualization, S.P.B. and L.M.M.-A.; methodology, S.P.B., L.M.M.-A. and J.R.-G.; software, S.P.B.; formal analysis, L.M.M.-A. and J.R.-G.; investigation, S.P.B., L.M.M.-A. and J.R.-G.; resources, S.P.B. and P.K.; data curation, L.M.M.-A. and J.R.-G.; writing—original draft preparation, S.P.B., L.M.M.-A. and J.R.-G.; writing—review and editing, L.M.M.-A. and J.R.-G.; visualization, S.P.B., L.M.M.-A., P.K. and J.R.-G.; supervision, L.M.M.-A. and J.R.-G.; project administration, L.M.M.-A. and J.R.-G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Ethics Committee of the Catholic University of Murcia (Code: CE062112; 25 June 2021).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data are available upon request to the corresponding author.

Acknowledgments: The authors express their gratitude to all the players involved in this study.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Ade, J.; Fitzpatrick, J.; Bradley, P.S. High-Intensity Efforts in Elite Soccer Matches and Associated Movement Patterns, Technical Skills and Tactical Actions. Information for Position-Specific Training Drills. *J. Sports Sci.* **2016**, *34*, 2205–2214. [CrossRef] [PubMed]
2. Pons, E.; Ponce-Bordón, J.C.; Díaz-García, J.; López Del Campo, R.; Resta, R.; Peirau, X.; García-Calvo, T. A Longitudinal Exploration of Match Running Performance during a Football Match in the Spanish La Liga: A Four-Season Study. *Int. J. Environ. Res. Public Health* **2021**, *18*, 1133. [CrossRef] [PubMed]
3. Milanović, Z.; Sporiš, G.; James, N.; Trajković, N.; Ignjatović, A.; Sarmento, H.; Trecroci, A.; Mendes, B.M.B. Physiological Demands, Morphological Characteristics, Physical Abilities and Injuries of Female Soccer Players. *J. Hum. Kinet.* **2017**, *60*, 77–83. [CrossRef] [PubMed]
4. Bradley, P.S.; Dellal, A.; Mohr, M.; Castellano, J.; Wilkie, A. Gender Differences in Match Performance Characteristics of Soccer Players Competing in the UEFA Champions League. *Hum. Mov. Sci.* **2014**, *33*, 159–171. [CrossRef]
5. Datson, N.; Drust, B.; Weston, M.; Jarman, I.H.; Lisboa, P.J.; Gregson, W. Match Physical Performance of Elite Female Soccer Players During International Competition. *J. Strength Cond. Res.* **2017**, *31*, 2379–2387. [CrossRef]
6. Mara, J.K.; Thompson, K.G.; Pumpa, K.L.; Morgan, S. Quantifying the High-Speed Running and Sprinting Profiles of Elite Female Soccer Players During Competitive Matches Using an Optical Player Tracking System. *J. Strength Cond. Res.* **2017**, *31*, 1500–1508. [CrossRef]
7. Ramos, G.P.; Nakamura, F.Y.; Penna, E.M.; Wilke, C.F.; Pereira, L.A.; Loturco, I.; Capelli, L.; Mahseredjian, F.; Silami-Garcia, E.; Coimbra, C.C. Activity Profiles in U17, U20, and Senior Women's Brazilian National Soccer Teams During International Competitions: Are There Meaningful Differences? *J. Strength Cond. Res.* **2019**, *33*, 3414–3422. [CrossRef]
8. Scott, D.; Norris, D.; Lovell, R. Dose-Response Relationship Between External Load and Wellness in Elite Women's Soccer Matches: Do Customized Velocity Thresholds Add Value? *Int. J. Sports Physiol. Perform.* **2020**, *15*, 1245–1251. [CrossRef]
9. Faude, O.; Koch, T.; Meyer, T. Straight Sprinting Is the Most Frequent Action in Goal Situations in Professional Football. *J. Sports Sci.* **2012**, *30*, 625–631. [CrossRef]
10. Slimani, M.; Znazen, H.; Miarka, B.; Bragazzi, N.L. Maximum Oxygen Uptake of Male Soccer Players According to Their Competitive Level, Playing Position and Age Group: Implication from a Network Meta-Analysis. *J. Hum. Kinet.* **2019**, *66*, 233–245. [CrossRef]
11. Nimphius, S.; McGuigan, M.R.; Newton, R.U. Relationship between Strength, Power, Speed, and Change of Direction Performance of Female Softball Players. *J. Strength Cond. Res.* **2010**, *24*, 885–895. [CrossRef]
12. Silva, J.R.; Nassis, G.P.; Rebelo, A. Strength Training in Soccer with a Specific Focus on Highly Trained Players. *Sports Med. Open* **2015**, *1*, 17. [CrossRef] [PubMed]
13. Raya González, J.; Sánchez Sánchez, J. Strength Training Methods for Improving Actions in Football. *Apunts Educ. Física Deport.* **2018**, *34*, 72–93. [CrossRef]
14. Millar, N.A.; Colenso-Semple, L.M.; Lockie, R.G.; Marttinen, R.H.J.; Galpin, A.J. In-Season Hip Thrust vs. Back Squat Training in Female High School Soccer Players. *Int. J. Exerc. Sci.* **2020**, *13*, 49–61. [CrossRef] [PubMed]
15. Sporiš, G.; Jovanović, M.; Krakan, I.; Fiorentini, F. Effects of Strength Training on Aerobic and Anaerobic Power in Female Soccer Players. *Sport Sci. Int. Sci. J. Kinesiol.* **2011**, *4*, 32–37.
16. Wing, C. In-Season Strength and Power Training Considerations for Professional Soccer Teams Competing Within National Level Competitions. *Strength Cond. J.* **2018**, *40*, 12–22. [CrossRef]
17. Gualtieri, A.; Rampinini, E.; Sassi, R.; Beato, M. Workload Monitoring in Top-Level Soccer Players During Congested Fixture Periods. *Int. J. Sports Med.* **2020**, *41*, 677–681. [CrossRef]
18. Guimarães, R.; García Calvo, T.; Lobo-Triviño, D.; Ponce Bordón, J.; Raya-González, J. Holistic Workload Quantification within a Professional Soccer Microcycle Considering Players' Match Participation. *Appl. Sci.* **2024**, *14*, 5139. [CrossRef]

19. González-Badillo, J.J.; Rodríguez-Rosell, D.; Sánchez-Medina, L.; Ribas, J.; López-López, C.; Mora-Custodio, R.; Yañez-García, J.M.; Pareja-Blanco, F. Short-Term Recovery Following Resistance Exercise Leading or Not to Failure. *Int. J. Sports Med.* **2016**, *37*, 295–304. [CrossRef]
20. Byrkjedal, P.T.; Thunshelle, A.; Spencer, M.; Luteberget, L.S.; Ivarsson, A.; Vårvik, F.T.; Lindberg, K.; Bjørnsen, T. In-Season Autoregulation of One Weekly Strength Training Session Maintains Physical and External Load Match Performance in Professional Male Football Players. *J. Sports Sci.* **2023**, *41*, 536–546. [CrossRef]
21. Pedersen, S.; Welde, B.; Sagelv, E.H.; Heitmann, K.A.; Randers, M.B.; Johansen, D.; Pettersen, S.A. Associations between Maximal Strength, Sprint, and Jump Height and Match Physical Performance in High-Level Female Football Players. *Scand. J. Med. Sci. Sports* **2022**, *32* (Suppl. S1), 54–61. [CrossRef]
22. Arnason, A.; Sigurdsson, S.B.; Gudmundsson, A.; Holme, I.; Engebretsen, L.; Bahr, R. Physical Fitness, Injuries, and Team Performance in Soccer. *Med. Sci. Sports Exerc.* **2004**, *36*, 278–285. [CrossRef] [PubMed]
23. Choice, E.; Tufano, J.; Jagger, K.; Hooker, K.; Cochrane-Snyman, K.C. Differences across Playing Levels for Match-Play Physical Demands in Women's Professional and Collegiate Soccer: A Narrative Review. *Sports* **2022**, *10*, 141. [CrossRef] [PubMed]
24. Lambright, K.R.; Bunn, J.A.; Figueroa, Y.; Muñoz, M. Resistance Training Versus Interval Training in Female Youth Soccer Players. *Women Sport Phys. Act. J.* **2024**, *32*. [CrossRef]
25. Raya-González, J.; Castillo, D.; de Keijzer, K.L.; Beato, M. The Effect of a Weekly Flywheel Resistance Training Session on Elite U-16 Soccer Players' Physical Performance during the Competitive Season. A Randomized Controlled Trial. *Res. Sports Med. Print* **2021**, *29*, 571–585. [CrossRef]
26. Balsalobre-Fernández, C.; Glaister, M.; Lockey, R.A. The Validity and Reliability of an iPhone App for Measuring Vertical Jump Performance. *J. Sports Sci.* **2015**, *33*, 1574–1579. [CrossRef]
27. Raya-González, J.; Scanlan, A.T.; Soto-Célix, M.; Rodríguez-Fernández, A.; Castillo, D. Caffeine Ingestion Improves Performance During Fitness Tests but Does Not Alter Activity During Simulated Games in Professional Basketball Players. *Int. J. Sports Physiol. Perform.* **2021**, *16*, 387–394. [CrossRef]
28. Krustrup, P.; Mohr, M.; Amstrup, T.; Rysgaard, T.; Johansen, J.; Steensberg, A.; Pedersen, P.K.; Bangsbo, J. The Yo-Yo Intermittent Recovery Test: Physiological Response, Reliability, and Validity. *Med. Sci. Sports Exerc.* **2003**, *35*, 697–705. [CrossRef]
29. Akyildiz, Z.; Yıldız, M.; Clemente, F. The Reliability and Accuracy of Polar Team Pro GPS Units. *Proc. Inst. Mech. Eng. Part P J. Sports Eng. Technol.* **2020**, *236*, 83–89. [CrossRef]
30. Sánchez-Medina, L.; González-Badillo, J.J. Velocity Loss as an Indicator of Neuromuscular Fatigue during Resistance Training. *Med. Sci. Sports Exerc.* **2011**, *43*, 1725–1734. [CrossRef]
31. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed.; Hillsdale, N.J., Ed.; Lawrence Erlbaum Associates: Mahwah, NJ, USA, 1988; ISBN 978-0-8058-0283-2.
32. Nuzzo, J.L.; McBride, J.M.; Cormie, P.; McCaulley, G.O. Relationship between Countermovement Jump Performance and Multijoint Isometric and Dynamic Tests of Strength. *J. Strength Cond. Res.* **2008**, *22*, 699–707. [CrossRef]
33. Wisløff, U.; Castagna, C.; Helgerud, J.; Jones, R.; Hoff, J. Strong Correlation of Maximal Squat Strength with Sprint Performance and Vertical Jump Height in Elite Soccer Players. *Br. J. Sports Med.* **2004**, *38*, 285–288. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.

APPENDIX 2. THE INFORMED CONSENT

ANEXO II
INFORMED CONSENT

I, ... with DNI/NIE/Passport: .....

DECLARE:

Have been informed of the study and procedures of the research of the Project entitled: Effects of Different Strength and Conditioning Programs Variations on Performance Variables in Professional Female Soccer Players

The researchers who will access my personal data and test results are: Luis Manuel Martínez Aranda (IP) and Sefika Pelin Bal (PhD student)

Likewise, I have been able to ask questions about the study, understanding that I lend myself voluntarily to it and that at any time I can abandon it without prejudice of any kind.

I CONSENT:

1,-) To submit to the following tests:

- Collection of basic sociodemographic data
- Physical tests:
  - Speed and agility: Measurement of 10-30 m sprints and change of direction (COD) using standardised methods.
  - Jump capacity: Assessment of jump height through countermovement jump (CMJ) tests.
  - Physiological measurements: Evaluation of VO_2max and running economy using indirect tests.
  - In-game monitoring: Collection of GPS data on maximum speed, distance covered, and RSA using the Polar Team Pro system.
  - Injury risk assessment: Analysis of the chronic/acute ratio to identify risks associated with training loads.

2,-) The use of the data obtained as indicated in the following paragraph:
In compliance with Regulation (EU) 2016/679 of the European Parliament and of the Council, of April 27, 2016, and Organic Law 3/2018, of December 5, on the Protection of Personal Data and Guarantee of Digital Rights, we inform you that the information you have provided and that obtained as a result of the tests to which you are going to submit will become part of the automated file INVESALUD, whose owner is the FUNDACIÓN UNIVERSITARIA SAN ANTONIO, with the purpose of RESEARCH AND TEACHING IN THE AREAS OF KNOWLEDGE EXPERIMENTAL SCIENCES AND HEALTH SCIENCES. You have the right to access this information and cancel or rectify it, by going to the address of the entity, at Avda. de los Jerónimos de Guadalupe 30107 (Murcia). This entity guarantees the adoption of the appropriate measures to ensure the confidential treatment of said data.

In..... on ..... of ..... of 202....

The participant,

Fdo: .....

The researcher,

Fdo: .....

APPENDIX 3. THE ETHICAL COMMITTEE APPROVAL

UCAM
UNIVERSIDAD CATÓLICA SAN ANTONIO

UCAM ETHICS COMMITTEE

Universidad Católica San Antonio. Vicerrectorado de Investigación. Salida nº 7870 25/06/2021 18:34:28

PROJECT DATA

Title:	"Effects of Different Strength and Conditioning Programs Variations on Performance Variables in Professional Female Soccer Players"	
Principle Researcher	**Name**	**Email**
PhD.	Luis Manuel Martínez Aranda	lmmartinez2@ucam.edu

COMITTEE REPORT

Date	**25/06/2021**	**Code**	**CE062112**

Type of Experimentation

Experimental clinical research involving human subjects	
Non-clinical experimental research with humans	X
Using human tissues from patients, healthy people, embryonic or fetal tissue	
Using human tissues, embryonic or fetal tissue from banks or tissue samples	
Observational research with humans or use of personal data	X
Animal studies	
Use of biological agents of risk to human health, animal or plant	
Use of genetically modified organisms (GMOs)	

Comments regarding the type of experimentation
No comments

Comments regarding the methodology of experimentation
No comments

UNIVERSIDAD CATÓLICA SAN ANTONIO · UCAM · COMITÉ DE ÉTICA · MURCIA ·

UCAM
UNIVERSIDAD CATÓLICA SAN ANTONIO

UCAM ETHICS COMMITTEE

Suggestions for the researcher

In view of the application of the attached report by the Researcher and the above mentioned recommendations, the opinion of the Committee is to:

Issue a favorable report	X
Issue an unfavorable report	
Issue a favorable report with subject to correction	

MOTIVATION
It will increase knowledge in this area

Approved by the President,

Sig.: José Alberto Cánovas Sánchez

UNIVERSIDAD CATÓLICA SAN ANTONIO UCAM COMITÉ DE ÉTICA MURCIA

Approved by the Secretary,

Sig.: José Alarcón Teruel