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COIMBRA

Joel Ignacio Barrera Díaz

FUNCTIONAL AND ACTIVITY PROFILES OF PROFESSIONAL FOOTBALL PLAYERS IN PORTUGAL - A MULTIDIMENSIONAL ANALYSIS.

Thesis for the degree of Doctor of Sport Sciences in the branch of Sports Training supervised by Prof. Dr. António José Barata Figueiredo and Prof. Dr. Hugo Miguel Borges Sarmento, submitted to the Faculty of Sport Sciences and Physical Education of the University of Coimbra.

March 2023

Faculty of Sport Sciences and Physical Education

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“Much of what I found by following my curiosity and intuition,
it later turned out to be invaluable.”

Steve Jobs, 2005

To me, to my family, friends, and Professors.

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Abstract

This thesis has been divided into four sections and the main objective was to generate a multidimensional characterization of the Portuguese soccer player, in order to obtain greater objectivity and effectiveness in the training processes of planning and control, allowing the maximization of performance in competitions. The four studies developed provided: (i) an exhaustive description of the systematic reviews and meta-analyses that have been previously conducted on injury prevention in professional soccer players; (ii) an evaluation of the physical performance in competition of Portuguese professional soccer players in different positional and contexts; (iii) the evaluating strength and power variables and their relationship with sprint performance (time) in Portuguese professional players; and, (iv) an exhaustive research concerning the contemporary practices of professional soccer physical trainers (PTs), to identify the methodologies used in the evaluation of physical capacities, monitoring and control of training and injury prevention.

The analysis of the information obtained in the different studies allowed us to suggest that; (i) the prevention programs focused on strength and proprioception prevent the incidence and severity of injuries; the dynamic warm-ups may decrease injury incidence, but the influence of static stretching on the susceptibility to subsequent injury is less well known; (ii) physical demands are different for each playing position and suggest that situational variables influence physical performance. It is suggested that physical training position-specific to prepare players for the specific demands of each playing position; (iii) at faster speeds, strength and power variables are associated with linear sprint performance. Professional soccer players with greater torque at 180°- s^{-1} had faster sprint times at 10, 20, and 30 m; and, (iv) the assessment of physical capabilities is based on scientific evidence; PTs prioritizes monitoring and controlling of training load and injury prevention; however, at times, contextual factors may influence adherence to working strictly within scientific guidelines.

This study allowed to determine different factors that can condition performance in competition, from injury prevention, optimization of physical abilities and contemporary methodological practices of physical trainers. In addition, I provide valuable evidence on the profiles of Portuguese players, in competition, strength, power and linear speed. However, the characterization proposed at the beginning of this project could not be fully developed due to the contingencies associated with the COVID-19 pandemic. Future research could continue the development of this characterization by adding information that strengthens the findings presented in this thesis.

Keywords: Soccer, masculine, elite, monitoring, evaluation, sports performance.

Resumo

Esta tese foi dividida em quatro secções e o objetivo principal foi gerar uma caracterização multidimensional do futebolista português, de forma a obter maior objetividade e eficácia nos processos de planeamento e controlo do treino, permitindo a maximização do desempenho nas competições. Os quatro estudos desenvolvidos forneceram: (i) uma descrição exaustiva das revisões sistemáticas e meta-análises que já foram realizadas sobre prevenção de lesões em jogadores masculinos de futebol; (ii) uma avaliação do desempenho físico em competição de futebolistas profissionais portugueses em diferentes posicionamentos e contextos; (iii) a avaliação das variáveis de força e potência e sua relação com o desempenho do *sprint* (tempo) em jogadores profissionais portugueses; e, (iv) uma pesquisa exaustiva sobre as práticas contemporâneas de preparadores físicos (PFs) profissionais de futebol, para identificar as metodologias utilizadas na avaliação das capacidades físicas, monitorização e controle do treino e prevenção de lesões.

A análise da informação obtida nos diferentes estudos permitiu-nos sugerir que; (i) os programas de prevenção com foco em força e propriocepção previnem a incidência e gravidade de lesões; os aquecimentos dinâmicos podem diminuir a incidência de lesões, mas a influência do alongamento estático na suscetibilidade a lesões subseqüentes é menos conhecida; (ii) os requisitos físicos são diferentes para cada posição de jogo e sugerem que variáveis situacionais influenciam o desempenho físico. Sugere-se o treinamento físico específico da posição para preparar os jogadores para os requisitos específicos de cada posição de jogo; (iii) em velocidades mais rápidas, as variáveis de força e potência estão associadas ao desempenho do *sprint* linear. Jogadores profissionais de futebol com maior torque em 180°-s^{-1} tiveram tempos de *sprint* mais rápidos em 10, 20 e 30 m; e, (iv) a avaliação das capacidades físicas é baseada em evidências científicas; PFs prioriza monitorização e controle da carga de treino e prevenção de lesões; no entanto, às vezes, fatores contextuais podem influenciar a adesão ao trabalho estritamente dentro das diretrizes científicas.

Este estudo permitiu determinar diferentes fatores que podem condicionar o desempenho em competição, desde a prevenção de lesões, otimização das capacidades físicas e práticas metodológicas contemporâneas dos preparadores físicos. Além disso, fornece valiosas evidências sobre os perfis dos jogadores portugueses, em competição, força, potência e velocidade linear. No entanto, a caracterização proposta no início deste projeto não pôde ser totalmente desenvolvida devido às contingências associadas à pandemia de COVID-19. Pesquisas futuras poderiam dar continuidade ao desenvolvimento dessa caracterização, acrescentando informações que fortaleçam os achados apresentados nesta tese.

Palavras-Chave: Futebol, masculino, elite, monitorização, avaliação, desempenho desportivo.

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List of Abbreviations

GNSS = Global Navigation Satellite System.

GPS = Global Positioning System.

TD = Total distance.

M = Media.

SD = Standard deviation.

ICC = Intraclass correlation coefficients.

SEM = Standard error of the mean.

CI = Coefidence interval.

SPSS = Statistical Package for the Social Sciences.

Kg = Kilogram.

cm = Centimetre.

m = Meter.

h = Hora.

s = Second.

MBI = Body mass index.

mL = Milligram.

Min = Minuto.

Vo2max = Cantidad máxima de oxígeno (O2) que el organismo puede absorber, transportar y consumir en un tiempo determinado.

1RM = 1 repetition maximum.

CPX = Combination training that alternates biomechanically similar high load weight training exercises with lighter load power exercises.

CNT = Combination training where all high load strength exercises are performed at the beginning of the session and all lighter load power exercises at the end.

COD = Change of direction.

VBT = Velocity-Based Training.

° = Grados.

PT = Peak torque.

N = Newton.

GK = Goalkeepers.

SB = Side backs.

CB = Central backs.

CDM = Central defending midfielders.

CAM = Central attacking midfielders.

FW = Forwards.

QB = Quarterbacks.

K/P = Kickers/Punters.

OL = Offensive linemen.

HB = Halfbacks.

WR = Wide receivers.

DL = Defensive linemen.

LB = Linebackers.

DB = Defensive backs.

Ext.CPT = Maximum concentric torque of the extender.

Ext.EPT = Maximum eccentric torque of the extensor.

Flx.CPT = Maximum concentric flexor torque.

Flx.EPT = Flexor eccentric peak torque.

CMJ = Countermovement jump.

SJ = Squat jump.

ACL = Anterior cruciate ligament.

NHE = Nordic hamstring exercises.

STE = Stretching Technique Employed.

SSP = Standard Stretch Protocol.

SHT = Static stretch holding time.

HSF = Hamstring stretch frequency or repetitions per session.

PNF = Proprioceptive Neuromuscular Facilitation.

CA = Copenhagen adduction.

km = Kilometer.

WD = Wide defenders.

CD = Central defenders.

CM = Center midfielder.

OA = Open attackers.

CF = Center forward.

Hz = Hertz.

TD m = Total distance.

TDP m = Total distance by parts.

ZD1 m = Zone 1 distance / standing. walking very low intensity.

ZD2 m = Zone 2 distance / low intensity walking.

ZD3 m = Zone 3 distance / jog at low intensity.

ZD4 m = Zone 4 distance / running at medium intensity.

ZD5 m = Zone 5 distance / running high speed.

ZD6 m = Zone 6 distance / Sprint.

ΣD m (1,2,3) = Sum distances (1,2,3).

ΣD m (4,5,6) = Sum distances (4,5,6).

Acc1 m/s/s = Acceleration 1.

Acc2 m/s/s = Acceleration 2.

Acc3 m/s/s = Acceleration 3.

ΣAcc (1,2,3) m/s/s = Sum Acceleration (1,2,3).

Des1 m/s/s = Deceleration 1.

Des2 m/s/s = Deceleration 2.

Des3 m/s/s = Deceleration 3.

ΣDes (1,2,3) m/s/s = Sum Deceleration (1,2,3).

MS km/h = Maximum speed.

L = Local.

V = Visit.

SBA = Sprints based in accelerations.

Q1 = Quartile 00-15 min.

Q2 = Quartile 16-30 min.

Q3 = Quartile 31-45 min.

Q4 = Quartile 46-60 min.

Q5 = Quartile 61-75 min.

Q6 = Quartile 76-90 min.

Q7 = Quartile More of 45.

Q8 = Quartile More of 90.

D = Draw.

L = Lose.

W = Win.

BD = Bilateral difference.

T = Torque.

KE = Knee extension.

KF = Knee flexion.

RCT = Randomized controlled trial.

NRCT = Non-randomized controlled trials.

CD = Cohort designs.

NCG = Non-equivalent control group.

TS = Series of time.

QS = Qualitative study.

RD = Retrospective design.

FIFA = Federation International Football Association.

NWP = New Warm-up Program.

BEP = Bounding Exercise Program.

ACL = Anterior cruciate ligament.

LL = Lower limb.

SR = Systematic review.

SRMA = Systematic review with meta-analysis.

N/A = Not applicable.

PTs = Physical Trainers

MC = Microcycle.

IMTP = Isometric Mid-Thigh Pull.

CK = Creatine kinase.

RPE = Rate of perceived exertion.

EEG = Electroencephalogram.

CORE = Central strengthening.

TRX = Total-body Resistance Exercise.

FMS = Functional movement screen.

RM =Real Madrid.

Chapter I:

General introduction, Investigation objectives, Structure of the thesis and Theoretical framework

Chapter I

General introduction

Chapter I

1.1 General introduction

Soccer has undoubtedly become the most important sport worldwide. It is undergoing a quiet revolution driven by the increasing availability of athlete quantification data and advanced analytics (Pettersen, Johansen, Baptista, Halvorsen, & Johansen, 2018).

Soccer is a team sport that includes frequent fluctuations between high and low exercise intensities (Drust, Atkinson, & Reilly, 2007), in which, a significant evolution in terms of physical and technical performance has been noted, with an increase in the number of high-intensity activities (Barnes, Archer, Hogg, Bush, & Bradley, 2014). Despite this, it is estimated that players spend most of the matches (80-90%) performing low and medium intensity activities, while the decisive moments of a match typically require high speed and sprint actions (Bangsbo, 1994; Stølen, Chamari, Castagna, & Wisløff, 2005), where players have to be skilled with the brief moments of ball possession (Dellal, Wong, Moalla, & Chamari, 2010), even though each of the positions has a different profile of sprint performance (Di Salvo et al., 2007b; Sporis, Jukic, Ostojic, & Milanovic, 2009). Considering these differences in performance by playing position, it has been shown that all positions have evolved and increased their physical demands in total distance, high intensity running and sprinting in the English Premier League (Bush, Barnes, Archer, Hogg, & Bradley, 2015); being wing and attacking position players, the ones who increased more than central defenders and central midfielders between 2006-07 and 2012-13, in terms of both high-intensity distance run and running. On the other hand, central players increased both the number of passing and pass completion rates over the same period (Bush et al., 2015). This states clearly that each position has unique and specific demands, which should be considered by coaches when, designing and planning training (Ade, Fitzpatrick, & Bradley, 2016). Additionally, other elements such as ball speed, game speed and tactical elements have also evolved over the past few years (Wallace & Norton, 2014).

For this reason, players require a wide range of motor skills such as jumping, kicking, turning, tackling, changing pace, accelerating and decelerating (Carling, Williams, & Reilly, 2007; Rennie et al., 2020). These movements are considered unorthodox and that they increase energy expenditure with respect to normal motion

(Reilly & Bowen, 1984) as well as depending on the efficiency of the neuromuscular system, particularly of the lower limbs (Cometti, Maffiuletti, Pousson, Chatard, & Maffulli, 2001). In parallel, there is the need to quickly resolve different game situations, by making decisions and executing them in a context that changes between the offensive and defensive process. This decisions also correspond to a tactical framework (coach's game model) which can be adapted according to the opponent, environmental conditions and location in the ranking (Wallace & Norton, 2014). Thus, soccer is not considered a continuous type of game, because the sport demands require a variety of intense anaerobic movement interspersed with a large number of low-intensity aerobic activities (Drust et al., 2007). For this reason, when analyzing the physical demands of the players, their pathway should be detailed as well, since simplifying the information with performance averages would greatly underestimate the energy cost of the players, by not considering the frequent changes in speed, movement direction and the skills of the game (Reilly, 1976). On the other hand, a very important and overlooked element is the game structure, which involves periods of offensive and defensive play interspersed with stoppages in the game for different situations; despite the fact that there is no variation in the number of stoppages, an increase in the time of almost all stoppage events has been observed. This is important because they have a direct impact on the potential proportions of work and recovery, influencing the opportunities for rest and determining the intensity with which players can compete during subsequent periods of play (Wallace & Norton, 2014).

Additionally, there is evidence on some contextual elements -that can alter the sport performance of players-, such as the result, playing as a home or visitor team, first and second half, level of the opponent, effective playing time and duration of the microcycle (Barrera, Sarmento, Clemente, Field, & Figueiredo, 2021; Castellano, Blanco-Villaseñor, & Alvarez, 2011; Minano-Espin, Casais, Lago-Penas, & Gomez-Ruano, 2017; Oliva-Lozano, Rojas-Valverde, Gómez-Carmona, Fortes, & Pino-Ortega, 2020b, 2021). Likewise, it has been shown that contextual variables can influence the use of different playing styles, which in turn has an impact on the tactical behavior of players (Fernandez-Navarro, Zubillaga, & McRobert, 2018) and, consequently, on their physical performance. In this sense Fernandez-Navarro et al. (2020), determined that the higher the quality of the opponent, the lower the ball recovery options in advanced areas of the opponent's field are, which conditions the strategy and therefore the tactical behaviors. On the other hand, when comparing the best club in the world in the XX century (Real Madrid), named as such by the International Federation of Soccer History and Statistics, with their domestic competitors, it was observed that they covered shorter distances in high-speed running and sprinting, and executed fewer sprints than the players of the opposing team, which could be explained by the ability to impose and maintain their pattern of play, despite the variables alteration throughout the match (Minano-Espin et al., 2017). On the other hand, elements such as the need to maintain the category increase the total distance traveled as the possibility of relegation approaches, but only in the first part of the matches, while in the second part no differences were observed. This may be associated with the need to win to avoid relegation, therefore players make greater trips to try to obtain a favorable result as soon as possible (García-Unanue et al., 2018).

On the other hand, in addition to the high performance demands, which match by match push players to the limit of their capabilities and, as a consequence, characterizes professional soccer by a high risk and large number of injuries (Pérez-Gómez, Adsuar, Alcaraz, & Carlos-Vivas, 2020), players are forced to play a large number of matches in a season, where rest and recovery periods are short and insufficient (Vasileiadis, 2020). The literature has shown that the occurrence of match injuries in adults was up to 30 per 1000 hours, and training injuries which were approximately 5 per 1000 hours of exposure (Gerhardt et al., 2012). In professional clubs, this situation generates three major problems; the first one is the sport-related problem, by not having the injured players available to the coach; the second one is the economic cost involved, which is approximately € 20,000 per day in European elite teams (Ekstrand, 2016b); and third one is the sporting performance and the final ranking in both domestic as well as international competitions (Hägglund, Waldén, Magnusson, et al., 2013).

Considering the above, performance should not be approached and analyzed from a simplistic perspective, since many elements can affect performance in competition, such as the extent to which physical abilities have been developed, the sport context and injuries. For this reason and based on the evidence presented above, the present thesis seeks to obtain more clarity in terms of some important aspects of performance, both at individual and collective level in Portuguese soccer players. Thus, in the broad field of scientific research related to professional soccer, we consider it relevant to understand certain situations that occur in more specific contexts. In this manner, conducting studies focusing on professional soccer players in Portugal seems important in order to understand whether the findings made in other country leagues are similar to what happens in this one, in terms of competition performance, physical abilities evaluation, and injury prevention. In addition, to collect the knowledge of different coaches with working experience in elite soccer teams will be important to understand (a) how the scientific literature is used in this sport context, (b) what lessons are learned from the practices of what was done "yesterday" and (c) how this learning helps to proceed "today". The aim is that coaches can optimize the performance of their players as well as minimizing errors and loss of resources associated with the problems that may occur during a season.

1.2 Research objectives

In consequence, the general objective of this thesis was to generate a multidimensional characterization of the professional Portuguese soccer player, in order to obtain greater objectivity and effectiveness in the training processes of planning and control, allowing the maximization of performance in competitions. To do this, each study included in this process needed to meet their own specific objective(s), which are presented below.

- To provide an overview of the systematic reviews and meta-analyses that have been previously conducted on injury prevention in professional soccer players.
- To compile all available evidence, to report on the effectiveness of different prevention programs, to identify heterogeneity among studies and possible gaps in the literature, and to provide recommendations for future research on injury prevention programs in male soccer players.
- To evaluate the physical performance of Portuguese professional soccer players in different positional roles. The interactive effects between match half, location and match status on physical performance metrics in Portuguese official matches were also analyzed.

- To evaluate strength and power variables and their relationship with sprint performances (time) in professional players competing in the second highest professional division in Portugal to determine predictors of linear sprint performance.
- To research contemporary practices of professional soccer physical trainers in two continents.
- To identify methodologies used in the evaluation of physical capacities, monitoring and control of training and injury prevention to support the development of applied and practical research.

1.3 Thesis structure

As for secondary objectives, the present research thesis had three topics related to the performance of professional soccer players in Portugal, which responded to the central objective.

Thus, the structure of this thesis was constructed as follows: (1) the objective was focused on conducting a retrospective study on injuries during the 2019-2020 season, which had to be modified due to the absence of information from the medical team of the club and the early end of the season due to COVID-19. Due to this, the objective was focused on conducting an umbrella review of injuries in professional soccer players; (2) an evaluation study was conducted on competition performance, using GNSS devices during the 2019-2020 season, which was affected by two external events (departure of a coaching staff and COVID-19), this limited the number of matches that could be used for this analysis; (3) to determine the level of prediction and the relationship between laboratory tests and performance with the linear sprint of two clubs in the second division of Portugal; (4) a qualitative study was conducted, aiming to understand the contemporary practices of physical trainers in today's soccer. To do this, several interviews focusing on three topics were conducted: (1) evaluation of physical capacities; (2) monitoring and control of competition and training; and, (3) injury prevention. Thus, the structure of the thesis was formed by four studies that aim to be a contribution to the work of soccer coaches in Portugal and the world.

1.4 Theoretical framework

Soccer is a sport of confrontation between two teams in numerical equality, where the defending team deploys the nobility of its resources against the rival attack, with the objective of disarming and recovering of the ball. On the other hand, the attacking team uses its offensive resources to try to cause technical, tactical, physical, and psychological imbalances in the opponent, hoping that they will be quantified in the scoreboard to achieve success.

Soccer is practiced by 4% of the world's population, which are children and adults, men and women (Kunz, 2007) of which only 0.04% play in a professional league, suggesting that achieving sporting success is difficult and there is also great competition (Haugaasen & Jordet, 2012). At a scientific level, the lines of research in soccer have adopted different paths with a great increase in recent years (Kirkendall, 2020). This phenomenon is due to the fact that analyzing performance in this sport involves a large number of individual and collective aspects (Fernandez-Navarro, Fradua, Zubillaga, & McRobert, 2019; Folgado, Goncalves, & Sampaio, 2018). Therefore, the professionals in charge of the players need objective evidence to optimize the training process (Chrismas, Taylor, Thornton, Murray, & Stark, 2019). For all these reasons, next, the theoretical framework will have a sequence that progresses from physical performance in competition, to physical evaluations that are applied in the professional context and finally to the use and effectiveness of injury prevention programs, with the aim of evidencing the elements that are relevant to achieve the objectives of this research.

1.4.1 Soccer injuries

Professional soccer is considered stressful, which increases the likelihood of developing burnout or fatigue symptoms, especially when not balanced with an optimal recovery process (Hassmen, Kentta, Hjalm, Lundkvist, & Gustafsson, 2019), therefore affecting the ability to perform and tolerate the different training loads prescribed by their coaches (Chrismas et al., 2019). Due to this, it is essential to maintain an effective communication between the different members of the club (medical team, coaching staff and managers) to try to control the injury rate, training attendance and availability for matches (Ekstrand, Lundqvist, Davison, D'Hooghe, &

Pensgaard, 2019). Thus, it is essential to create strategies that allow recovery time, such as winter break in the middle of the season. As it has been shown, the absence of a scheduled winter break was associated with an increased injury burden, both before and during the periods following this break (Ekstrand, Spreco, & Davison, 2019).

Soccer is considered a high-velocity contact sport with a high risk of injury (Arliani et al., 2017), which can be considered a critical issue, as they are highly common in elite professional athletes and many of these players will suffer multiple injuries during their career (Finch, Cook, Kunstler, Akram, & Orchard, 2017). This negatively affects the performance of teams in professional soccer (Hägglund, Waldén, Magnusson, et al., 2013), resulting in large economic losses for clubs and, on the sporting side, conditions the coach's decisions for training and official matches of the season (Ekstrand, 2016a). According to different authors (Hägglund, Waldén, Magnusson, et al., 2013), this could directly affect the sporting performance and the final ranking of the team in the different competitions.

Injuries occur mainly during competition (Jones et al., 2019; López-Valenciano et al., 2020). Ekstrand et al. (2011b) conducted a prospective study of seven seasons (2001 to 2008) with the top 50 European teams from different leagues. This study yielded a total of 4,483 injuries during 566000 hours of exposure, giving an injury incidence of 8,0 per 1000 hours, which was higher during matches than in training (27.5 vs 4.1, $p<0.0001$). These results are in agreement with the ones presented by Wong and Hong (2005) and proved to be consistent over the seven seasons of the study, where a player suffers an average of 2,0 injuries per season, and a team with 25 players can expect around 50 injuries each season (Ekstrand et al., 2011b). As for the incidence and nature of injuries, after evaluating 51 soccer teams and a total of 2,299 players during the 2001 and 2009 period, it yielded a total of 2,908 muscle injuries and an average injury per player of 0.6 muscle injuries per season. Muscle injuries amounted to 31% of all injuries, also caused 27% of the total injury absence and 92% of them affected the four main muscle groups of the lower extremities: hamstrings (37%), adductors (23%), quadriceps (19%) and calf muscles (13%) (Ekstrand, Hägglund, & Waldén, 2011a).

Hamstring injuries are the most common injury in soccer and account for about 17% of all soccer injuries (Ekstrand, Walden, & Hagglund, 2016), with an incidence rate varying from 0.87 to 0.96 per 1000 hours of exposure (training and match) (Hägglund, Waldén, Magnusson, et al., 2013). This results in an average of 90 days of absence per injury and between 15 and 20 matches per team per season (Hägglund, Waldén, & Ekstrand, 2013; Hägglund, Waldén, Magnusson, et al., 2013). Moreover, in soccer, the majority of quadriceps femoris injuries (~88 %) involve the rectus femoris (Hägglund, Waldén, & Ekstrand, 2013; Hägglund, Waldén, Magnusson, et al., 2013). The risk of thigh muscle injury is 1.6/1000 hours of exposure, which means that a team with 25 players on the roster can expect 10 said injuries each season (on average), with a dominance of quadriceps strains in the dominant leg (60%) (Ekstrand, 2008) and an average of three rectus femoris injuries per season, resulting in a total time loss of about 50 days (Hägglund, Waldén, & Ekstrand, 2013; Hägglund, Waldén, Magnusson, et al., 2013). 62% of rectus femoris injuries are recorded during the first half of the game, and the peak risk is observed between minutes 16 and 45 of play (Bengtsson, Ekstrand, & Hägglund, 2013; Hägglund, Waldén, Magnusson, et al., 2013). Additionally, adductor injuries account for 23% of all muscle injuries in soccer, with a recurrence rate of 18%, affecting mainly the age range of 22-30 years (Ekstrand et al., 2011a, 2011b). Finally, soleus-gastrocnemius (calf) injuries are common in sports involving high-speed running, high total running loads and a large number of accelerations/decelerations, which frequently occur when a player is fatigued (Bisciotti et al., 2019). The recorded incidence in soccer matches is 0.84 per 1000 hours of exposure (Carling, Le Gall, & Orhant, 2011; Orchard & Seward, 2010), being more likely to occur during critical periods of competition (e.g., the end of the season in soccer) (Mallo, González, Veiga, & Navarro, 2011), mainly affecting older players (over 25.8 ± 4.5 years) and those with a history of injuries sustained in this anatomical area (Hägglund, Waldén, & Ekstrand, 2013; Hägglund, Waldén, Magnusson, et al., 2013). This information is essential, since the first step in injury prevention is to assess injury epidemiology and establish injury risk patterns as well as injury circumstances, using a multifactorial approach, in order to design more effective prevention strategies (Bahr, 2016; Bittencourt et al., 2016; Pfirrmann, Herbst, Ingelfinger, Simon, & Tug, 2016; Van Mechelen, Hlobil, & Kemper, 1992).

1.4.1.1 Effectiveness of injury prevention work

Understanding both the phenomenon of injuries in professional soccer and the mechanisms that trigger them or the most affected areas are essential parts of building more appropriate prevention programs tailored to these specific needs of soccer (Bahr, 2016; Bittencourt et al., 2016; Pfirrmann et al., 2016; Van Mechelen et al., 1992).

Similarly, finding the optimal point of duration of injury prevention work is essential to avoid subjecting players to unnecessary volumes that may detract from the player's performance. In this sense, when trying to determine the effectiveness of a 10 min versus a 20 min prevention program, the evidence shows that there are no significant differences in the incidence of injury per 1000 hours of exposure, as well as for lower limbs injuries, the location, type, severity or mechanism of injury, this suggests that 10 mins of preventive exercises are no less effective than 20 min in young soccer players (Rahlf & Zech, 2020).

Another aspect to consider is the timing of the application of the prevention program (start, end or mixed) and its impact on overall injury incidence, initial injury, recurrent injury, and injury severity. Both pre- and post- application reduced the total number of injuries and the incidence of initial injury more than the pre application of program by itself. However, the odds of recurrent injury did not differ between groups, nor did the level of injury severity, suggesting that the application of a pre- and post-program reduces the overall injury rate in amateur soccer players (Al Attar, Soomro, Pappas, Sinclair, & Sanders, 2017). Similarly, the application of both pre- and post-training sessions of Nordic hamstring exercises (NHE) showed a 92% reduction in injuries compared to the year prior to the intervention, where the prevention protocol prior to the training sessions showed an 80% decrease only; this clearly shows that the use of NHE as a prevention protocol is effective in reducing all hamstring injuries and that the application of a combined NHE program during pre- and post-training has a greater effect than using one of them on its own (Elerian, El-Sayyad, & Dorgham, 2019).

Thus, in terms of the programs' application of injury prevention, we can conclude that the amount of time of the prevention protocol does not seem to be relevant in the incidence of injury, but the frequency of application of the program does. A high compliance and control of these prevention programs is recommended so to optimize the results, which will decrease the injuries suffered, as well as the time lost (Silvers-Granelli, Bizzini, Arundale, Mandelbaum, & Snyder-Mackler, 2018). Considering the above, the main suggestion is to deepen the different means of application in order to enhance their effectiveness and determine which can be the best application for each sport context.

1.4.2 Performance evaluation in competition.

The evaluation of sport performance is increasingly common in modern soccer. In this context, the profile of players and the impact of contextual variables can be obtained by means of a Global Navigation Satellite System (GNSS) (Barrera, Sarmento, et al., 2021). The use of GNSS devices has both increased significantly and been widespread as a means to measure training and competition loads in professional soccer (Wehbe, Hartwig, & Duncan, 2014). At a scientific level, during the last few years the systematic reviews conducted on GNSS are abundant and have addressed various research topics (Cummins, Orr, O'Connor, & West, 2013; Gómez-Carmona, Bastida-Castillo, Ibáñez, & Pino-Ortega, 2020; Hands & Janse de Jonge, 2020; Haycraft, Kovalchik, Pyne, & Robertson, 2017; Johnston, Black, Harrison, Murray, & Austin, 2018; Principe, Vale, & Nunes, 2020; Rago et al., 2020; Whitehead, Till, Weaving, & Jones, 2018). Currently, GNSS devices are the most widely used in high performance sports in Europe, the United States, and Australia (Akenhead & Nassis, 2016), as it is a tool from which valid data are obtained (Reinhardt, Schwesig, Lauenroth, Schulze, & Kurz, 2019); data that is reliable and relevant to track external load in professional soccer, either collectively or individually (Rave, Granacher, Boullosa, Hackney, & Zouhal, 2020), allowing the measurement of the position, velocity and movement patterns of players (Cummins et al., 2013).

In recent years, the literature with professional soccer players has been documenting that: training load is considered essential for a proper training periodization, for performance optimization and to reduce the risk of injury (Rossi et al., 2016). Given that the performance in different elements as total distance (TD) in running can differ according to different factors, such as positions on the field, Al Haddad et al. (2018) found differences in TD > 13-18 km/h 3.4% for second strikers vs. 14.2% for forwards and 14.9% for open defenders vs. 9.7% for open midfielders. In TD, variations have been observed in different leagues such as the Australian and

Italian leagues with a record of 10,274 and 11,389 m respectively (Hands & Janse de Jonge, 2020). These same authors indicated that central defenders covered the lowest TD 10,178 m, while open midfielders covered the highest 11,654 m. On the other hand, in-matches information related to midfielders and TDs was established between 10,537 and 12,009 m, where 41% of the analyzed athletes showed an average higher than 12,000 m, 8% between 11,000-11,999 m and 51% lower than 10,999 m; finally, European athletes showed higher values than South American athletes (Dias, Soncin, & Navarro, 2015).

Additionally, despite a growing increase in studies in recent years, a relatively under-studied element is accelerations in different positions (Dalen, Loras, Hjelde, Kjosnes, & Wisloff, 2019), which acts as an element of external workload monitoring in invasion team sports (Gómez-Carmona et al., 2020). In this sense, the evidence of the position-based performance in relation to the accelerations depends on the range: in range 1 (0 to 13 km-h-1 and without reaching 18 km-h-1), indicates that the lateral defenders perform a greater number of accelerations compared to the other game demarcations and achieving an intensity ~ 95% of their maximum acceleration. In range 2 (0 to 13 km-h-1 and reaching 18 km-h-1), defenders and lateral midfielders performed more accelerations than central defenders and forwards, with midfielders achieving an approximated intensity of 95% of their maximum acceleration. In range 3 (13 km-h-1 up to 18 km-h-1), midfielders performed a higher amount of accelerations than the rest of the groups, while forwards achieved an intensity of approximately 78% of their maximum acceleration; finally, in range 4 (acceleration starting at a speed >18 km-h-1) only LD and CD performed an acceleration (Sánchez, Bendala, Arrones, Cabrera, & De Hoyo Lora, 2019). Along these lines, but in relation to the frequency of accelerations, it has been determined that there is a decrease in the number of accelerations in the last part of each of the game halves, being the first 15 minutes of each half those with the highest activity (Barrett et al., 2016; Dalen et al., 2019).

On the other hand, in relation to running speed, different thresholds have been stated: very low intensity running (0-7 km-h-1), low intensity running (7-13 km-h-1), medium intensity running (13-18 km-h-1), high intensity running (18-21 km-h-1), and very high intensity running (>21 km-h-1). Within these parameters, 30% of players achieve 80-90% of their peak speed in matches, and 2.5% reaches 90-100% of their peak speed (Sanchez, Bendala, Vazquez, & Arrones, 2017). However, there is no scientific consensus on the different thresholds, which may vary according to the GPS manufacturer or the software configuration options, i.e. consider high-speed running (> 14.0 km - h-1;> 14.1 km - h-1;> 14.4 km - h-1) and very high-speed running (> 19.1 km - h-1;> 19.8 km - h-1;> 21.0 km - h-1); in the meantime, the general trend was for central defenders to cover less high intensity running and the wide midfielder to cover more very high-speed running, (Hands & Janse de Jonge, 2020). Additionally, and after evaluating both high-speed running and high-speed sprinting performance for a six season period in Real Madrid, Miñano-Espin et al. (2017) concluded that players covered shorter distances in high-intensity running and sprinting, players performed fewer sprints than their counterparts and also that no differences were found in terms of the opposing team' strength. These findings can be explained by the fact that Real Madrid was able to impose and maintain its pattern of play despite the alterations throughout the matches.

Finally, an attempt was made to also determine the demands of the players in relation to the various positions in different game systems, which implies differences due to the objectives to be fulfilled in each of them. It was found that the 3-5-2 formation in relation to the 4-4-2; 4-3-3; 3-4-4 and 4-2-3-1 formations elicited: greater TD (10,528 ± 565 m, p = 0.05), greater high-speed running (642 ± 215 m, *p* =0.001) and greater high metabolic load distance (2025 ± 304 m, p =0. 001) than all other formations; accelerations and decelerations (≥ 3 m/s/s/s) were also above average (34 ± 7, p = 0.036 and 57 ± 10, p = 0.006), with 4-2-3-1 eliciting the highest accelerations and decelerations (38 ± 8 and 61 ± 12) (Tierney, Young, Clarke, & Duncan, 2016).

Thus, and as the evidence shows, there are different performance profiles depending on the position played by each player on the field and, despite the differences that may exist between different competitions, the trends are more or less similar. However, this performance is a consequence of a broader and more complex process of periodization, where different elements emerge, some of which will be discussed below.

1.4.3 Evaluation of physical abilities in soccer

Keeping players at a high physical level throughout the season is a complex task, due to the fact that many factors are relevant in determining the success of a soccer player and the requirements for high-level play are multifactorial (Reilly, Bangsbo, & Franks, 2000), where both factors and requirements are still being analyzed to this day (Bennett, Novak, Pluss, Coutts, & Fransen, 2020) and are often conditioned by the position that players occupy on the field (Sporis et al., 2009). For this reason, achieving high levels of endurance, strength, speed, agility, and optimal levels of body composition are considered key to achieving athletic success (Cabell, Zahalka, Maly, & Mala, 2019; Haycraft et al., 2017; Johnston et al., 2018). The different assessments used within the training process and competition allow identifying different work profiles in players considering variables such as positions on the field, which shows that training programs should be individualized for each position (Slimani & Nikolaidis, 2019). In this sense, during a sport season different evaluations with different objectives are usually performed; some of these will be presented below.

1.4.3.1 Body composition.

Body composition is considered to be relevant in preparing players for competitive performance and it can be negatively affected in periods of inactivity, such as the off-season, non-selection or when players are injured (Carling & Orhant, 2010). Due to this, the body composition of soccer players is likely to change during the course of the competitive season as a result of both training and competition, but also habitual activity and diet (Ostojic, 2003). It is important to note that body composition is a critical component of fitness because an excess of adipose tissue acts as dead weight in common game activities, such as running and jumping, where body mass must be repeatedly lifted against gravity (Reilly & Doran, 2003).

The measurement of body composition in elite soccer players has received widespread attention, especially with respect to playing positions and describing changes throughout the playing season (Carling & Orhant, 2010). For example, after evaluating 306 top-level professional players from Iceland, Arnason et al. (2004a) obtained mean height values of 180.6 ± 5.4 cm, body mass of 76.5 ± 6.6 kg and fat percentage of 10.5 ± 4.3 %. When classifying the players by position, the tallest ones were goalkeepers 185.2 ± 4.7 cm, followed by defenders 181.1 ± 5.4 cm, forwards 180.2 ± 5.3 cm and finally midfielders 179.3 ± 5.2 cm. The heaviest ones were goalkeepers 81.4 ± 7.0 kg, followed by defenders 76.9 ± 6.1 kg, midfielders 75.9 ± 7.0 kg and forwards 75.3 ± 5.9 kg. Additionally, the soccer players with the highest body fat percentage were goalkeepers 12.3 ± 5.3 %, followed by midfielders 10.7 ± 4.2 %, defenders 10.6±3.6 % and forwards 9.6 ± 5.1 %. Sporis et al. (2009) evaluated elite Croatian soccer players and presented similar values for height 181.4 ± 2.5 cm, body mass 78.4 ± 3.1 kg and fat percentage 11.9 ± 3.1%. As for the classification by positions, goalkeepers were the tallest ones (185.0 ± 3.1 cm), heaviest ones 81.0 ± 2.3 kg and with the highest fat percentage of them all 14.2 ± 1.9%; whereas the shortest ones 169.4 ± 5.6 cm, lightest ones 64.4 ± 3.2 kg and with the lowest fat percentage of them all 8.4 ± 2.9 % were midfielders. On the other hand, the data obtained from the English Premier League positions goalkeepers with the greatest height 190.0 ± 0.03 cm, weight 91.2 ± 4.6 kg and with the highest fat percentage 12.9 ± 2.0 %, while defenders are positioned with a height of 184.0 ± 0.06 cm, body composition of 86. 0 ± 7.3 kg and fat percentage of 10.6 ± 2.1 %, showing a clear difference with the Icelandic and Croatian leagues in terms of height and weight, but with the same tendencies as for who occupies the taller and heavier positions (Sutton, Scott, Wallace, & Reilly, 2009). Evidence clearly shows that body composition in a group of professional soccer players varied substantially according to the specific positional roles of the players and that there were significant variations throughout the season, with changes depending on the positional group but not on the time of exposure (Carling & Orhant, 2010).

Table 1.4.3.1.1. Evidence with general sample of height, weight, body mass index and percentage of body fat

Author	Country	N	Ege M ± SD	Level	Heigth (cm) M ± SD	Weight (kg) M ± SD	MBI (kg/m2) M ± SD	Body Fat (%) M ± SD
Masanovic, Milosevic and Bjelica (2019)	Serbia	26	23.2 ± 3.4	Professional	182.1 ± 6.7	80.1 ± 7.1	24.1 ± 1.1	9.6 ± 1.6
Corluka et al. (2019)	Bosnia and Herzegovina Montenegro	28 30	24.4 ± 4.1 22.7 ± 4.3	Professional Professional	182.6 ± 4.8 182.0 ± 5.9	78.9 ± 5.8 78.0 ± 8.5	23.6 ± 1.1 23.5 ± 1.5	8.8 ± 3.2 10.0 ± 2.8
Parpa & Michaelides (2022)	Eastern Mediterranea n	308	25.4 ± 4.7	Professional	178.9 ± 6.1	76.7 ± 7.1	-	11.2 ± 1.8
Joksimović et al. (2019)	Serbia	29	26.8 ± 3.9	National Team	185.8 ± 7.5	77.2 ± 7.5	22.4 ± 1.1	-
Bloomfield et al. (2005)	4 European countries	2085	26.4 ± 4.4	First level	181 ± 6.0	75.5 ± 6.3	23.0 ± 1.2	-
Gardasevic et al. (2019)	Montenegro	70	22.8 ± 4.5	First League of Montenegro	182.7 ± 6.2	78.5 ± 7.6	23.5 ± 1.3	10.0 ± 3.0
Cossio-Bolanos et al. (2012)	Peru	68	27.2 ± 5.0	Elite soccer players	178.0 ± 6.0	75.9 ± 7.9	-	11.4 ± 2.9
Kashani et al. (2013)	Iran	220	25.9±4.1	First Professional Iranian Soccer League	180.1±6.0	75.6 ± 7.6	23.3 ± 1.4	10.2 ± 3.5
Gardasevic & Bjelica (2020)	Kosovo	53	22.8 ± 4.2	Superleague of Kosovo	180.3 ± 5.6	75.2 ± 7.2	23.1 ± 1.6	9.8 ± 3.2
Vasileios et al. (2018)	Greece	25	23.0 ± 4.0	First division	182.3 ± 5.4	78.2 ± 4.7	-	7.7 ± 1.1
Metaxas et al. (2021)	Greece	14	27.1 ± 4.4	Second division	180.0 ± 6.0	76.3 ± 5.6	-	8.6 ± 2.3
Najafi et al. (2015)	Ahwaz - Irán	60	24.31±4.20	Iran soccer league	179.0 ± 6.0	75.4 ± 7.1	23.3 ± 1.42	11.1 ± 1.5
Boone et al. (2012)	Belgium	289	25,4 ± 4,9	First division	182.4 ± 6.0	77.4 ± 7.1	-	11.0 ± 2.5

Author	Country	N	Ege M ± SD	Level	Heigth (cm) M ± SD	Weight (kg) M ± SD	MBI (kg/m2) M ± SD	Body Fat (%) M ± SD
Haugen et al. (2013)	Noruega	939	26.8 ± 3.4	National Team	184.0 ± 5.6	83.0 ± 7.8 79.0 ±	24.8 ± 1.8	-
			23.4 ± 4.3	First division	182.9 ± 6.2	7.1	23.6 ± 1.6	-
			23.4 ± 3.7	Second division	181.7 ± 6.0	80.1 ± 7.9	24.3 ± 1.7	-
Boraczyński et al. (2020)	-	25	25.1 ± 4.6	First division	180.6 ± 5.5	75.2 ± 5.9	-	14.0 ± 3.47

M = mean; SD = standard deviation; MBI = body mass index; kg = kilograms; cm = centimeter; % = Percentage.

Table 1.4.3.1.2. Evidence with general sample of height, weight, of body fat

Author	Country	N	Ege M ± SD	Level	Playing position	*n* - Position	Height (cm) M ± SD	Weight (kg) M ± SD	Body fat (%) M ± SD
Parpa &					Defenders	(n=69)	182.8 ± 5.8	79.8 ± 6.9	11.4 ± 3.1
Michaelides	Eastern				Midfielders	(n=87)	177.3 ± 5.6	75.1 ± 5.5	11.3 ± 2.3
(2022)	Mediterranea	308	25.4 ± 4.7	Professionals	Full-backs	(n=53)	177.2 ± 4.3	74.4 ± 5.7	11.6 ± 2.7
	nl				Forwards	(n=40)	182.7 ± 6.0	81.9 ± 7.5	11.5 ± 3.4
					Wingers	(n=41)	174.5 ± 4.3	73.6 ± 7.0	11.5 ± 3.6
Hernández-					Goalkeeper	(n=20)	180.8 ± 5.4	79.0 ± 7.3	22.2 ± 3.3
Mosqueira et al	Chile	158	24.1 ± 4.7	Professionals	Defender	(n=46)	177.9 ± 5.0	77.9 ± 5.4	20.8 ± 3.2
(2022)					Frills	(n=58)	170.8 ± 4.7	70.5 ± 6.5	22.4 ± 3.4
					Forwards	(n=34)	178.3 ± 5.2	76.5 ± 7.0	21.3 ± 3.1
									-
Joksimović et al.	Serbia	29	26.8 ± 3.9	National Team	Goalkeeper	(n=4)	194.3 ± 5.3	85.8 ± 7.4	-
(2019)					Defender	(n=10)	187.5 ± 5.4	78.9 ± 5.4	-
					Midfielder	(n=11)	181.7 ± 5.4	72.3 ± 5.4	-
					Forward	(n=4)	184.0 ± 7.4	75.5 ± 9.9	
									-
Bloomfield et al.	England	2085	26.4 ± 4.4	Premier League	Goalkeeper	(n=68)	188.0 ± 4.0	83.3 ± 6.9	-
(2005)					Defender	(n=185)	182.0 ± 6.0	76.3 ± 6.6	-
					Midfielder	(n=202)	179.0 ± 5.0	72.0 ± 6.0	-
					Forward	(n=123)	181.0 ± 6.0	74.6 ± 6.5	
	Spain								-
				La Liga	Goalkeeper	(n=56)	185.0 + 4.0	81.1 + 4.3	-
					Defender	(n=167)	180.0 + 5.0	75.5 + 5.2	-
					Midfielder	(n=201)	179.0 + 5.0	73.6 + 4.6	-
					Forward	(n=104)	179.0 + 6.0	73.8 + 6.4	
	Italy								-
				Serie A	Goalkeeper	(n=60)	186.0 + 4.0	79.1 + 5.5	-
					Defender	(n=163)	181.0 + 5.0	74.9 + 4.8	-
					Midfielder	(n=180)	178.0 + 6.0	71.7 + 4.4	-
					Forward	(n=96)	181.0 + 6.0	75.2 + 5.3	
	Germany								-
				Bundesliga	Goalkeeper				-

Author	Country	N	Ege M ± SD	Level	Playing position	*n* - Position	Height (cm) M ± SD	Weight (kg) M ± SD	Body fat (%) M ± SD
					Defender	(n=50)	189.0 + 4.0	85.5 + 6.0	-
					Midfielder	(n=150)	184.0 + 5.0	78.4 + 5.2	-
					Forward	(n=164)	179.0 + 6.0	74.3 + 5.4	
						(n=116)	182.0 + 6.0	77.2 + 6.1	
Aguilera et al. (2013)	Chile	406	-	12 1st Division	Goalkeeper	(n=48)	181.2 ± 3.8	81.4 ± 5.9	-
				3 2nd Division	Defender	(n=124)	178.1 ± 5.5	77.1 ± 6.2	-
					Frills	(n=134)	172.9 ± 5.6	71.7 ± 6.0	-
					Forwards	(n=93)	176.6 ± 6.1	75.2 ± 7.2	-
Moghadam et al. (2012)	Iran	85	26.0 ± 4.9	premium league	Goalkeepers	(n=9)	187.2 ± 3.8	84.0 ± 7.6	-
					Defenders	(n=25)	178.1 ± 5.5	76.6 ± 7.3	-
					Halfbacks	(n=36)	172.9 ± 5.6	72.8 ± 6.2	-
					Strikers	(n=15)	176.6 ± 6.1	74.2 ± 6.0	-
Sutton et al. (2009)	England	64	26.2 ± 4,0	English Premier League	Midfield	(n=22)	178.0 ± 5.0	78.0 ± 5.8	10.2 ± 1.8
					Forwards	(n=14)	180.0 ± 8.0	82.7 ± 5.6	9.9 ± 2.0
					Goalkeepers	(n=8)	190.0 ± 3.0	91.2 ± 4.6	12.9 ± 2.0
					Defenders	(n=20)	184.0 ± 6.0	86.0 ± 7.3	10.6 ± 2.1
Cossio-Bolanos et al. (2012)	Peru	68	27.2 ± 5.0	Elite soccer players	Goalkeepers	(n=8)	185.0 ± 3.0	82.6 ± 7.5	11.8 ± 2.5
					Defenders	(n=18)	179.0 ± 6.0	76.5 ± 7.7	11.3 ± 2.7
					Midfielders	(n=27)	174.0 ± 5.0	72.5 ± 7.9	11.8 ± 3.4
					Attackers	(n=15)	179.0 ± 6.0	77.8 ± 5.3	10.7 ± 2.9
Kashani et al. (2013)	Iran	220	25.9 ± 4.1	First Professional Iranian Soccer League	Goalkeepers	(n=16)	188.6 ± 3.9	86.0 ± 5.5	11.5 ± 4.3
					Defenders	(n=62)	181.6 ± 5.6	78.3 ± 7.3	10.8 ± 3.5
					Midfielders	(n=92)	178.2 ± 5.3	72.8 ± 6.0	9.1 ± 3.5
					Attackers	(n=50)	179.1 ± 5.7	74.1 ± 7.3	11.0 ± 2.6

M = mean; SD = standard deviation; kg = kilograms; cm = centimeter; % = Percentage.

1.4.3.2 Oxygen consumption.

A high level of aerobic fitness is believed to improve recovery from high intensity exercise (Bell, Snydmiller, Davies, & Quinney, 1997; Cooke, Petersen, & Quinney, 1997; Gharbi, Dardouri, Haj-Sassi, Chamari, & Souissi, 2015; R. M. Jones et al., 2013), because the ability to recover from repeated maximal exercise is positively related to several metabolic indicators of aerobic capacity, such as a higher capillary density (Tesch & Wright, 1983), higher mitochondria volume (Meyer, 1988), oxidative enzymes (Jansson, Dudley, Norman, & Tesch, 1990) and higher tolerance to exertion as well as to high training loads (Windt & Gabbett, 2017). In this sense, it is suggested that VO_2max is not a clearly distinguishing variable that separates male players of different competitive standards (Tønnessen, Hem, Leirstein, Haugen, & Seiler, 2013; Wells, Edwards, Winter, Fysh, & Drust, 2012). In disagreement with the previous statement, a recent meta-analysis considers VO_2max performance to be the most powerful discriminator between high and low level soccer players and that individualized position-specific training programs should be designed for its optimization (Slimani, Znazen, Miarka, & Bragazzi, 2019). However, despite these differences, VO_2max values between 62-64 $mL·kg^{-1}·min^{-1}$ are believed to satisfy aerobic capacity demands in men's professional soccer (Tønnessen et al., 2013).

Oxygen consumption in professional soccer players can be determined by different tests, both laboratory tests, for which the use of ergospirometry is recommended, in order to accurately estimate aerobic capacity in soccer players; and field tests such as the Yo-Yo test, which should be used by coaches because they are easy and useful tools in establishing the training program and for monitoring players during the playing season (Metaxas, Koutlianos, Kouidi, & Deligiannis, 2005).

In this sense, Arnason et al. (2004a) determine the oxygen consumption of soccer players by means of the laboratory Treadmill test, which consists of an incremental-type test in terms of the running speed and treadmill angle. With this procedure, the authors presented oxygen consumption values for soccer players of 62.5 ± 4.8 ($mL*kg^{-1}*min^{-1}$), which, when classified by position, left the highest values for midfielders with 63.0 ± 4.3 $mL*kg^{-1}*min^{-1}$, followed by forwards 62.9 ± 5.5 $mL*kg^{-1}*min^{-1}$, defenders 62.8 ± 4.4 $mL*kg^{-1}*min^{-1}$ and goalkeepers with the lowest values 57.3 ± 4.7 $mL*kg^{-1}*min^{-1}$. Using the same procedure and after evaluating 270 players, Sporis et al. (2009) obtained lower values reaching 60.1 ± 2.3 ($mL*kg^{-1}*min^{-1}$); a sample that when grouped by positions yielded the highest values for midfielders with 62.3 ± 3.1 $mL*kg^{-1}*min^{-1}$, followed by defenders 59.2 ± 1.5 $mL*kg^{-1}*min^{-1}$, then forwards 58.9 ± 2.1 $mL*kg^{-1}*min^{-1}$ and finally goalkeepers 50.5 ± 2.7 $mL*kg^{-1}*min^{-1}$. As it can be seen, these values are significantly lower than the ones in the previous study. Similar to Arnason et al. (2004a) and using the Treadmill running protocol but with a fixed inclination of 5.5% on the treadmill, Chamari et al. (2005) obtained values for adult professional players of 66.6 ± 5.2 ($mL*kg^{-1}*min^{-1}$). In turn, Oliveira et al. (1998) evaluated 115 field players, concluding that wingers and midfield players performed significantly better than other defenders and forwards in the Yo-Yo test of intermittent endurance. Therefore, the evidence suggests that a player's positional role is related to his physiological capacity. Thus, midfielders and wingers have the highest intakes of oxygen (> 60 mL*kg-1*min-1) and perform better in intermittent exercise tests (Reilly et al., 2000).

Table 1.4.3.2.1 Evidence of oxygen consumption in professional players

Author	Country	N	Ege M ± SD	Level	VO2max (ml/Kg/min) M ± SD
Vasileios et al. (2018)	Greece	25	23.0 ± 4.0	1st division	64,4 + 5,7
Metaxas (2021)	Greece	14	27.1 ± 4.4	2nd division	58.8 + 5.2
Najafi et al. (2015)	Iran	60	24.3 ± 4.2	Iran soccer league	59.0 ± 3.7
Boone et al. (2012)	Belgium	289	25.4 ± 4.9	1st division	57,7 ± 4,7
Boraczyński et al. (2020)	-	25	25.1 ± 4.6	1st division	64.2 ± 3.6
Sporis et al. (2009)	-	270	28.3 ± 5.9	Professional	60.1 ± 2.3

M = mean; SD = standard deviation; ml = milligram; kg = kilograms; min = minute.

1.4.3.3 Strength

Strength plays a fundamental role in soccer (Hlavonova, Jan, Kalina, Dominik, & Hammerova, 2017), being crucial for sports performance and injury prevention (Bangsbo, 1994; Case, Knudson, & Downey, 2020) and enhancing post-competition recovery (Johnston, Gabbett, Jenkins, & Hulin, 2015; Komi, 1984). Strength combines different morphological and neural factors, such as muscle cross-section, muscle architecture, tendon distensibility, motor unit recruitment with their neuromuscular synchronization and inhibition (Christian, Ivan, Alejandra, & David, 2020; Cormie, McGuigan, & Newton, 2011). For this reason, various power strength training strategies are used, the first one is the complex training program (CPX), which is a combined training that alternates biomechanically similar high-load training exercises with lighter-load power exercises, set by set (e.g., squats followed by countermovement lunges). Secondly, a combined contrast training (CNT), where all high load strength exercises are performed at the beginning of the session and all lighter load power exercises at the end. This is an effective methods that increases lower body strength, vertical jump height, sprint performance and the ability to change direction (COD) in team sports and it can be used by strength and conditioning professionals (Cormier, Freitas, Rubio-Arias, & Alcaraz, 2020). Finally, and despite being an old method, velocity-based training (VBT) is being used more and more nowadays, which allows an accurate and objective prescription of training intensities and volumes (Weakley et al., 2021). This requires an inertial measurement unit to measure velocity in linear trajectories, which have been shown to be valid and reliable (Clemente, Akyildiz, Pino-Ortega, & Rico-González, 2021). Some results have shown significant gains in the strength and power in jumping rates, generating a transfer digitalization in the maximum speed achieved in competition in young soccer players (Rodríguez & López, 2018). Additionally, it was proved that VBT can lead to an improvement in absolute and relative power in concentric phases of half squat in professional soccer players of the Spanish second division (Ramírez, Núñez, Lancho, Poblador, & Lancho, 2015). This transforms VBT into a fundamental tool for strength and conditioning coaches to monitor and prescribe exercise intensity.

On the other hand, kicking and cutting skills in soccer are clearly unilateral (Reilly & Williams, 2003); they require asymmetric motor patterns and lead to the development of asymmetric adaptations in lower extremity musculoskeletal function, which seems to be more balanced in players with longer professional training time (>11 years) (Fousekis, Tsepis, & Vagenas, 2010). This results in high complexity, since, strength asymmetries in soccer have been related to lower extremity injuries (Dauty, Menu, Fouasson-Chailloux, Ferreol, & Dubois, 2016; E. Tsepis, Vagenas, Giakas, & Georgoulis, 2004; Elias Tsepis, Vagenas, Ristanis, & Georgoulis, 2006).

From what has been pointed out above, strength measurement, power and the asymmetry of the lower limbs are important to monitor strength development and injury risk (Redden, Stokes, & Williams, 2018). In this regard, isokinetic dynamometer assessment is one of the most widely used assessment methods for a wide range of strength assessments, due to its high scientific validity (Drouin, Valovich-mcLeod, Shultz, Gansneder, & Perrin, 2004) and preferably using angular velocities of 60° s^{-1}, 180° s^{-1} and 300° s^{-1} in professional soccer players, to represent slow, medium and fast dynamic isokinetic force (Bogdanis & Kalapotharakos, 2016). This allows determining muscle performance profiles of soccer players and possible asymmetries between limbs or between muscle groups of the limb itself, which is relevant both for performance optimization, as well, as for injury prevention (Sliwowski, Marynowicz, Grygorowicz, Wieczorek, & Jadczak, 2021).

The evidence has been presented in different ways in the scientific literature, some of which are presented below in Tables 4, 5 and 6.

Table 1.4.3.3.1. Peak torque in flexion and extension of the knees (right and left) at different angular velocities

Author	Country	N	Ege M ± SD	Level	Velocidad angular	PT Right ($N*m*kg^{-1}$)	PT Left ($N*m*kg^{-1}$)
Parpa & Michaelides (2017)	Chipre 1st Division and 2nd Division	N=429	1st Division	1st Division	Extensor		
			25.5 ± 4.7		60 °/sec	239.7 ± 33.5	234.8 ± 36.1
		1st Division			300 °/sec	125.1 ± 17.4	122.7 ± 17.9
		245	2nd Division	2nd Division	60 °/sec	228.6 ± 32.5	224.9 ± 35.4
			25.0 ± 4.9		300 °/sec	119.6 ± 17.2	117.8 ± 16.5
		2nd Division					
		184			Flexor		
				1st Division	60 °/sec	176.7 ± 27.6	170.6 ± 25.8
					300 °/sec	178.9 ± 27.0	171.7 ± 29.5
					60 °/sec	104.7 ± 15.8	99.7 ± 17.0
				2nd Division	300 °/sec	106.1 ± 15.6	100.9 ± 16.9
Zakas (2006)	Greece	N=42	Right leg dominant	1st Division	Right leg dominant		
			(26.0 ± 3.1)		Extensor		
		Right leg dominant			12 °/sec	258.6 ± 45.8	249.7 ± 50.6
		(n=15)	Left leg dominant		60 °/sec	228.3 ± 39.7	228.2 ± 41.3
			(26.5 ± 3.0)		180 °/sec	163.1 ± 30.6	162.2 ± 28.8
		Left leg dominant			300 °/sec	110.7 ± 21.6	114.7 ± 21.3
		(n=12)	Bilateral legs				
			dominant (26.6 ± 3.3)		Right leg dominant		
		Bilateral legs			Flexor		
		dominant (n=15)			12 °/sec	132.5 ± 36.5	136.8 ± 31.0
					60 °/sec	126.5 ± 28.9	126.7 ± 31.3
					180 °/sec	89.5 ± 18.9	86.7 ± 22.5
					300 °/sec	61.0 ± 13.4	58.5 ± 13.0
					Left leg dominant		
					Extensor		
					12 °/sec	270.1 ± 44.3	265.5 ± 38.7
					60 °/sec	248.0 ± 47.5	246.5 ± 32.3
					180 °/sec	172.6 ± 26.2	172.2 ± 22.8
					300 °/sec	120.7 ± 19.3	120.7 ± 15.8
					Left leg dominant		
					Flexor		
					12 °/sec	139.2 ± 20.2	139.4 ± 20.3
					60 °/sec	127.9 ± 18.1	133.9 ± 24.9
					180 °/sec	94.4 ± 16.9	95.7 ± 17.5
					300 °/sec	62.8 ± 9.7	63.5 ± 13.5

Author	Country	N	Ege M ± SD	Level	Velocidad angular	PT Right (N*m*kg-1)	PT Left (N*m*kg-1)
					Bilateral legs Extensor		
					12 °/sec	273.0 ± 46.4	261.6 ± 56.1
					60 °/sec	239.9 ± 47.0	229.2 ± 41.9
					180 °/sec	161.6 ± 32.7	159.7 ± 29.9
					300 °/sec	113.6 ± 24.3	112.7 ± 18.4
					Bilateral legs Flexor		
					12 °/sec	144.7 ± 35.3	144.3 ± 35.5
					60 °/sec	129.1 ± 29.4	132.7 ± 29.9
					180 °/sec	92.7 ± 20.9	90.8 ± 20.5
					300 °/sec	60.7 ± 13.7	58.6 ± 11.3

N=newton; m = meter; kg = kilograms.

Table 1.4.3.3.2. Peak torque in flexion and extension of the knee joint at different angular velocities. In addition to the peak eccentric torque. Some grouped by position and others by injuries suffered. All variables divided into dominant and non-dominant leg

Authors	Level and country	N	Age years	Velocidad angular	Playing position	Quadriceps concentric peak torque (N*m*kg-1)		Hamstrings concentric peak torque (N*m*kg^{-1})		Hamstrings eccentric peak torque (N*m*kg^{-1})	
				60 °, 120°, 180°, 240°, 300°		Preferred	Non-preferred	Preferred	Non-preferred	Preferred	Non-preferred
Ruas et al. (2015)	Professional – Brazil	All = 79	All = 26.1±5.3	60°·s- 1	GK	299.5±30.6	277.9±33.3	173.8±33.1	150.8±31.5	235.6±51.2	197.1±36.5
		GK = 8	GK = 26.4±6.9		SB	252.8±48.3	267.7±35.4	157.1±20.8	162.2±24.7	194.0±46.2	206.0±34.8
		SB = 13	SB = 27.0±4.9		CB	262.5±47.3	264.8±50.4	172.4±33.8	164.4±36.0	211.8±39.8	202.1±45.6
		CB = 14	CB = 26.4±5.7		CDM	264.6±26.5	257.3±42.3	154.3±35.5	162.0±33.3	210.4±43.1	199.1±53.8
		CDM = 12	CDM = 28.1±4.6		CAM	248.9±31.7	253.2±17.2	152.5±26.2	149.7±22.4	193.6±35.2	192.0±27.4
		CAM = 15	CAM = 24.5±5.8		FW	257.8±42.4	250.6±42.4	146.2±37.2	141.4±39.1	197.4±41.8	190.3±39.9
		FW = 17	FW = 25.0±4.7								
Ruas et al. (2015)	Professional – Brazil	All = 102	All = 26 ± 5	60°·s- 1	GK	302±34	294±37	182±35	162±31	247±54	211±36
		GK = 12	GK = 26±6		SB	256±46	269±36	157±19	162±23	198±45	206±32
		SB = 15	SB = 26±5		CB	270±42	268±46	170±34	162±33	206±37	197±45
		CB = 20	CB = 26±5		CDM	266±27	263±40	159±34	163±31	218±43	206±50
		CDM = 15	CDM = 28±4		CAM	244±36	248±27	150±26	149±22	191±35	191±30
		CAM = 19	CAM = 24±6		FW	258±39	256±44	152±38	148±40	204±41	194±42
		FW = 21	FW = 25±5								
Severo-Silveira et al. (2017)	Elite – Brazil	All = 72	All = 25±6	60°·s- 1	QB	193-312	194-300	113-156	113-162	175-204	150-234
		QB = 3	QB = 18-27		K/P	268-282	284-303	149-179	129-162	177-211	165-253
		K/P = 2	K/P = 24-30		OL	327±57	328±60	164±18	176±71	252±41	253±40
		OL = 13	OL = 26±7		HB	238±41	228±27	137±45	117±19	205±43	185±36
		HB = 10	HB = 28±6		WR	260±39	262±51	161±57	147±31	223±50	230±52
		WR = 11	WR = 25±6		DL	286±47	288±60	167±45	143±23	227±26	227±51
		DL = 11	DL = 26±6		LB	268±75	279±48	145±26	157±48	222±38	223±51
		LB = 10	LB = 25±4		DB	268±40	259±49	135±20	133±20	201±28	133±20
		DB = 12	DB = 23±3								
Moreno-Pérez et al. (2013)	Professional – Spain 2nd Division	All = 20	All = 27.1 ± 3.6	Extcon 240°·s- 1	All	156.2±23.7	155.2±29.9				
				Flexexc 30°·s- 1						189.8±34.8	185.6±41.5
		Injured = 5		Extcon 240°·s- 1	Injured	162.6±17.2	166.3±36.6				
				Flexexc 30°·s- 1						183.0±31.8	157.2±53.1
		Not injured = 15		Extcon 240°·s- 1	Not injured	154.1±25.7	151.5±27.8				
				Flexexc 30°·s- 1						193.4±37.1	193.7±33.4

GK=goalkeepers; SB=side backs; CB=central backs; CDM=central defending midfielders; CAM=central attacking midfielders; FW=forwards; QB = Quarterbacks; K/P = Kickers/Punters; OL = Offensive linemen; HB = Halfbacks; WR = Wide receivers; DL = Defensive linemen; LB = Linebackers; DB = Defensive backs.

Table 1.4.3.3.3. Concentric and eccentric isokinetic peak torque of knee flexors and extensors, for each playing position and age category; with normalised by body mass means and SD; Ext.CPT, Extensor Concentric Peak Torque; Ext.EPT, Extensor Eccentric Peak Torque; Flx.CPT, Flexor Concentric Peak Torque; Flx.EPT, Flexor Eccentric Peak Torque.

Authors	Pais	N	Position		17–20 years Mean±SD	21–24 years Mean±SD	25–28 years Mean±SD	29–32 years Mean±SD	33+ years Mean±SD
Scoz et al. (2021)	Elite – Brazil	Goalkeepers n = 45	Goalkeepers	Ext.CPT	331.69±46.16	329.98±31.48	331.33±32.37	281.73±44.55	249.83±48.04
				Ext.EPT	396.90±66.88	387.20±65.64	426.22±51.76	360.60±91.56	319.04±79.60
				Flx.CPT	193.00±26.01	188.09±16.36	215.01±18.64	169.12±42.77	149.44±16.03
				Flx.EPT	242.45±57.30	238.73±36.32	245.22±57.04	167.12±35.37	183.64±39.61
		Defenders n = 102	Defenders	Ext.CPT	321.36±44.61	317.88±51.26	302.90±46.46	301.73±50.34	310.59±61.12
				Ext.EPT	418.65±54.23	396.36±93.67	400.85±54.08	442.16±64.73	410.36±83.27
				Flx.CPT	171.34±35.00	191.97±38.47	181.51±32.20	204.19±35.97	195.62±23.26
				Flx.EPT	228.47±47.59	215.45±44.10	221.35±51.42	262.23±63.25	218.96±21.05
		Sidebacks n = 78	Sidebacks	Ext.CPT	355.02±40.49	315.14±42.81	312.43±57.51	297.35±54.51	310.88±37.13
				Ext.EPT	426.07±64.50	359.70±49.90	382.21±77.19	367.98±70.80	306.48±02.94
				Flx.CPT	188.54±25.81	166.36±34.68	177.64±41.09	192.85±35.85	218.51±12.19
				Flx.EPT	228.52±36.49	219.29±32.54	202.01±54.62	203.12±59.84	204.01±03.64
		Midfielders n = 180	Midfielders	Ext.CPT	317.62±40.38	320.81±54.98	308.62±43.09	262.95±64.41	187.23±40.17
				Ext.EPT	375.32±77.84	394.49±78.06	385.25±59.21	344.04±87.48	240.69±51.46
				Flx.CPT	176.41±30.89	183.75±26.04	168.65±29.80	169.37±33.24	177.04±23.78
				Flx.EPT	224.60±45.41	211.54±43.89	210.29±38.58	206.67±38.04	185.44±36.55
		Forwards N = 165	Forwards	Ext.CPT	318.15±44.45	315.55±38.98	297.03±40.13	286.77±50.23	280.78±54.51
				Ext.EPT	389.30±78.51	367.45±59.58	382.24±48.90	361.53±54.16	365.51±41.11
				Flx.CPT	175.18±34.29	188.13±31.24	191.80±32.28	182.53±23.97	186.54±32.67
				Flx.EPT	217.07±47.78	208.37±38.60	217.40±36.29	195.80±41.17	179.55±20.33

Ext.CPT, maximum concentric torque of the extender; Ext.EPT, maximum eccentric torque of the extensor; Flx.CPT, maximum concentric flexor torque; Flx.EPT, flexor eccentric peak torque.

1.4.3.4 Leg power tests

Jumping tests in professional soccer are commonly used nowadays, since the contact mat and a digital timer are the reliable and valid tests for the estimation of the explosive power of the lower limbs (Markovic, Dizdar, Jukic, & Cardinale, 2004). Additionally, this allows to predict the performance of linear sprint in professional soccer players in 20 and 30 m (Barrera, Figueiredo, Duarte, Field, & Sarmento, 2022) and in child players of different categories in 10 and 30 m and agility (Zig-Zag 20 m) (Barrera, Valenzuela-Contreras, et al., 2021). The countermovement jump (CMJ) and squat jump (SJ) are considered to be the most reliable and valid field tests for the estimation of lower limb explosive power in physically active men (Markovic et al., 2004), as well as it is suggested that the CMJ and Abalakov jump (AJ) are the most reliable tests for the estimation of explosive strength in soccer and basketball players in different age categories (Rodríguez-Rosell, Mora-Custodio, Franco-Márquez, Yáñez-García, & González-Badillo, 2017), which, justifies its use for the determination of lower limb power in elite athletes.

Cometti et al. (2001), presented comparative data between first division and second division soccer players in the squat jump (SJ) and countermovement jump (CMJ) 1st 38.48 ± 3.80 - 2nd 33.86 ± 7.47 and 1st 41.56 ± 4.18 - 2nd 39.71 ± 5.17 cm respectively, which meant significant differences between both groups. Meanwhile and after evaluating 214 professional players, Arnason et al. (2004a) presented the following values for SJ 37.6 ± 4.8 cm and the following ones for CMJ 39.2 ± 5.0 cm. Additionally, the author detailed the performance by positions, where the best results in SJ were for forwards 37.8 ± 4.4 cm, followed by defenders 37.7 ± 4.9 cm, midfielders 37.6 ± 4.8 cm and goalkeepers 35.8 ± 5.3 cm. As for the CMJ, the forwards had the best performance again 39.4 ± 4.2, followed by midfielders 39.3 ± 4.9 cm, defenders 39.3 ± 5.5 cm and finally goalkeepers with 38.0 ± 5.6. None of these variables showed significant differences between the different positions.

Subsequently and in attempting to define physical fitness profiles in Croatian professional players, Sporis et al. (2009) obtained significantly higher values than those previously exposed in SJ 44.1 ± 1.3 cm and CMJ 45.1 ± 1.7 cm. Another big difference is related to the performance of goalkeepers, who presented the lowest values in the previous studies, but in this one, they are the best performers in both tests

SJ 46.8 ± 1.4 cm and, CMJ 48.5 ± 1. 5 cm, with significant differences in SJ with defenders obtaining 42.3 ± 2.1cm, midfielders 41.49 ± 4.0cm and forwards44.2 ± 3.2 cm; while in the CMJ, defenders obtained a 44.2 ± 1.9 cm, midfielders a 44.26 ± 2.1 cm and forwards 45.3 ± 3.2 cm.

In a study with German players at the second division, Keiner et al. (2015) presented results of SJ 38.7 ± 4.0 cm and CMJ of 41.2 ± 3.8 cm. These data were relatively similar to the one obtained by Pivovarnicek et al. (2015), in Slovakian first and second division players where in SJ, defenders obtained 36.3 ± 4.0 cm, midfielders 37.1 ± 4.4 cm and forwards 36.7 ± 2.9 cm; but was higher in CMJ, where defenders obtained 37.3 ± 4.4 cm, midfielders 37.8 ± 5.9 cm and forwards 36.8 ± 3.6 cm. On the other hand, Requena et al. (2009) evaluated 21 professional soccer players and classified them into the fastest and the slowest, they declared a CMJ height 40.3 cm in the fastest and 35.6 cm in the slowest, while in the SJ obtained 36.9 cm in the fastest athletes and 32.8 cm in the slowest athletes.

Table 1.4.3.4.1. Evidence of lower limb power in professional players, determined by the countermovement jump (CMJ)

Author	Country	N	Ege M ± SD	Level	CMJ Height Cm M ± SD
Boone et al. (2012)	Belgium	289	25.4 ± 4.9	1st Division	43,1 ± 4,9
Haugen et al. (2013)	Norway	939	26.8 ± 3.4	National Team	39.4 ± 5.2
			23.4 ± 4.3	1st Division	39.0 ± 4.6
			23.4 ± 3.7	2nd division	38.8 ± 4.6
Boraczyński et al. (2020)	-	25	25,1 ± 4,6	1st Division	46.0 ± 4.6
Sporis et al. (2009)	-	270	28.3 ± 5.9	Professional	45.1 ± 1.7
Northeast et al. (2019)	England	26	25.0 ± 4.0	Premier League	39.0 ± 4.0

M = mean; SD = standard deviation; CMJ = countermovement jump.

1.4.3.5 Running speed

In high performance soccer, high speed actions such as agility, acceleration, changes of direction, deceleration and sprinting are known to be relevant in player performance (Cabell et al., 2019; Little & Williams, 2005). Evidence has shown that, elite soccer players cover between 0.7 and 3.9 km of distance at high speed (Bradley et al., 2009; Rampinini, Impellizzeri, Castagna, Coutts, & Wisløff, 2009) and between 0.2 and 0.6 km of sprint distance (Mohr, Krustrup, & Bangsbo, 2003; Morgans, Orme, Anderson, Drust, & Morton, 2014). On the other hand, decisive moments of a match largely require high speed and sprint actions (Bangsbo, 1994; Stølen et al., 2005), with direct sprinting being the most frequent action in goal situations (Loturco et al., 2017). Additionally and considering the predictive forward model a 1% increase in distance run >24 km/h increases by 4.08% the odds of winning in subsequent seasons (Konefał et al., 2020), reflecting the relevance of high and very high intensity running to achieve sporting success, despite the fact that successful and less successful soccer teams are able to obtain similar maximum running speeds during matches throughout the season (Del Coso et al., 2020).

In the 10 m acceleration test and after evaluating 106 professional players, a mean of 1.83 ± 0.08 s was obtained (Little & Williams, 2005). After evaluating 27 U21 players, Coratella et al. (2018) obtained 10 m acceleration data of 1.77 ± 0.10 s and in the 30 m speed test, values of 4.23 ± 0.19 s; while Barrera et al. (2022) evaluated 33 Portuguese professional players obtaining times of 1.57 ± 0.13 s in the 10 m tests, of 2.99 ± 0.03 s in the 20 m and of 4.55 ± 0.24 s in the 30 m tests.

Additionally, a significant correlation has been observed between them, but the coefficients of determination were low, suggesting that they are specific and relatively unrelated qualities (Cabell et al., 2018; Little & Williams, 2005). For this reason, it is relevant to determine the performance of these abilities separately.

Table 1.4.3.5.1. Evidence of linear sprint performance of different lengths in professional soccer players

Author	Country	N	Ege M ± SD	Level	5m S. M ± SD	10m S. M ± SD	20m S. M ± SD	30m S. M ± SD
Boone et al. (2012)	Belgium	289	25.4± 4.9	1st Division	1.46±.07	-	-	-
Haugen et al. (2013)	Norway	939	26.8± 3.4	National Team	-	1.51±.05	-	-
			23.4± 4.3	1st Division	-	1.52±.06	-	-
			23.4± 3.7	2nd division	-	1.53±.05	-	-
Boraczyński et al. (2020)	-	25	25,1± 4,6	1st Division	1.04±.03	-	-	4.22±.11
Lahti et al. (2020)	Finland	32	24,1± 5,1	1st Division	1.36±.04	2.10±.04	3.37±.08	4.56±.11
Sporis et al. (2009)	-	270	28.3± 5.9	Professional	1.44±.50	2.27±.40	3.38±.70	-
Northeast et al. (2019)	England	26	25.0±4.0	Premier League	1.02±.07	1.72±.09	2.94±.11	-

M = mean; SD = standard deviation; m = meter; S = second.

Chapter II:

Results

Chapter II

Study 1

Chapter II

2.1 Study 1

Injury Prevention Programmes in Male Soccer Players: An Umbrella Review of Systematic Reviews

Reference: *Barrera, J., Figueiredo, A. J., Clemente, F. M., Field, A., Valenzuela, L & Sarmento, H. (2022) Injury Prevention Programmes in Male Soccer Players: An Umbrella Review of Systematic Reviews. Journal of Men's Health, 18(10), 200.*

2.1.1 Abstract

Background: The incidence of lower-extremity injuries in soccer is high, with effective injury prevention programmes shown to reduce injury rates. Over the past decades, an exponential growth has occurred in the number of scientific publications including review articles on injury prevention programmes in male soccer. Accordingly, it is timely to summarise findings from potential systematic reviews and meta-analyses in the form of an umbrella review. Objective: This umbrella review was conducted to review, synthesise and appraise the findings of the published systematic reviews and meta-analyses that investigated the effects of injury prevention programs in male soccer players. Methods: Following pre-registration on the International Platform of Registered Systematic Review and Meta-analysis Protocols (https://inplasy.com/inplasy-2021-9-0066/) and according to PRISMA guidelines, a search of databases (Web of Science, Scopus, SPORTDiscus and PubMed) was conducted for studies published before June 2021. Studies were eligible if they included male (amateur to professional) soccer players, included studies that incorporated injury prevention programs with a control and intervention group(s), and adopted the form of a systematic review (with or without a meta-analysis). The methodological quality of the evidence was assessed using the AMSTAR 2 tool. Results: Eight systematic reviews (no meta-analyses) were included in the umbrella review. The review articles retained for analyses primarily focused on the prevention of injuries in the lower limbs, with primary focus on the hamstrings. Prevention programs principally incorporating strengthening, proprioception and multi-component protocols (balance, core stability, functional strength and mobility) revealed positive effects on injury incidence and severity. Implementing eccentric hamstring protocols demonstrated efficacy in decreasing hamstring injury and proprioception exercises reduced the risk of ankle sprains. It was also revealed that dynamic warm-ups were effective in reducing incidence, but not severity of injuries. Conversely, the evidence from the current umbrella review suggests that programs focusing on static stretching showed inconclusive injury preventative effects. Articles were of mixed methodological quality with one demonstrating high quality, two indicating low quality and five were of critically low quality. Conclusions: The systematic reviews in this area suggests that prevention programs developing muscle strength and proprioception are effective in reducing the incidence and severity of injury (time out). Dynamic movements performed before a match are effective in reducing injury incidence, whilst the effects of warm-ups incorporating static stretching are unclear. Future original studies on this topic with improved methodological quality and consistency among experimental study designs should be conducted to evaluate the benefits of different programs over longer periods in male soccer players.

Keywords: football; effectiveness; methodological quality; synthesis.

2.1.2 Introduction

Soccer is a physically demanding sport, in which players compete in a large number of matches in a season, with limited recovery time separating each match (Konefal et al., 2019). In view of the challenge of contemporary fixture congested match scheduling (Julian, Page, & Harper, 2021), injury incidence has increased in professional soccer over recent years (Pérez-Gómez et al., 2020). Injuries have great financial implications for professional clubs, with each player lost due to injury costing approximately € 20,000 per day for elite clubs europeans (Ekstrand, 2016a), and availability correlating with team success (Hägglund, Waldén, Magnusson, et al., 2013). Since injury propensity in soccer is high (Ekstrand et al., 2011b), costly (Ekstrand, Lundqvist, et al., 2019) and impacts success (Eirale, Tol, Farooq, Smiley, & Chalabi, 2013), several strategies to reduce injury occurrence have been developed to address this concern. These include, but are not limited to, warm-up and cool down strategies (Small, Mc Naughton, & Matthews, 2008), the warm-ups can include running in different directions, arm swings, skipping, trunk rotation, jumps and counter jumps, among others, and for an approximate period of 20 minutes (Ayala et al., 2017), while cooling strategies can be by immersion in cold water (Machado et al., 2016) or a low-intensity aerobic run as an active recovery mode (Meyer, Wegmann, Poppendieck, & Fullagar, 2014) among others (Ribeiro, Sarmento, Silva, & Clemente, 2021), the provision of protective equipment (i.e., shin pads) (Junge & Dvorak, 2004), movement screening (McCunn, aus der Fünten, Fullagar, McKeown, & Meyer, 2016) and injury prevention programs (Van Beijsterveldt, van der Horst, van de Port, & Backx, 2013).

Additionally, the available systematic reviews (SR) with and without meta-analyses have showed some contradictions about the real impact of specific prevention programs: (i) Olsen et al. (2004), pointed out that prevention strategies seem promising but lack proper evaluation in young soccer players; (ii) Rogan et al. (2013) obtained some similar results, as no scientific evidence could be found on the effects of static stretching in preventing hamstring injuries; (iii) finally, Shadle and Cacolice (2017) considered the evidence supporting the use of eccentric hamstring exercises to prevent a hamstring injury in elite adult male soccer players. However, despite some systematic reviews with meta-analyses claiming a 50% injury risk reduction with Nordic hamstring exercise (NHE) (Al Attar, Soomro, Sinclair, Pappas, & Sanders, 2017;

Van Dyk, Behan, & Whiteley, 2019), a recent meta-analysis published by Impellizzeri et al. (2021) noted that the evidence supporting the protective effect of NHE so far remains inconclusive and is mainly derived from randomized controlled trial (RCT) with high risk of bias.

The Federation International Football Association (FIFA) Medical and Research Centre developed the FIFA '11' prevention programme in 2003, with the '11+' later developed in 2006 (Al Attar, Soomro, Pappas, Sinclair, & Sanders, 2016). These soccer-specific injury prevention protocols have also included eccentric exercises to reduce hamstring strain injuries (Arnason, Andersen, Holme, Engebretsen, & Bahr, 2008; Petersen, Thorborg, Nielsen, Budtz-Jørgensen, & Hölmich, 2011), neuromuscular training strategies and strength, flexibility, stability and balance exercises to prevent anterior cruciate ligament injuries in male soccer players (Alentorn-Geli et al., 2009; Mandelbaum et al., 2005). The 11+ consists of three parts and different levels depending on the level of the player, beginning with running exercises (part I), followed by six exercises to develop strength, balance, muscle control and core stability (part II), and ending with advanced running exercises (part III) (Soligard et al., 2008). Multifaceted protocols comprise varying exercises targeting modifiable risk factors to reduce occurrence of the most common injuries in soccer players. Preventative training programs have shown to reduce the risk of non-contact musculoskeletal injuries by 23% in professional soccer players (Lemes et al., 2021), which may include, warm-up, muscle activation, balance, strength (concentric or eccentric) and core stability (Kiani, Hellquist, Ahlqvist, Gedeborg, & Byberg, 2010). These preventative exercise protocols can be integrated within the applied environment by professional soccer practitioners. However, given the large number of preventative training programs and the influx of contrasting interpretations from the varying original and review articles, it may be difficult to apply such findings in the field. Therefore, an easily accessible umbrella review summarising the current state of knowledge on this topic is required.

The purpose of this umbrella review article is to provide an overview of the systematic reviews and meta-analyses that have previously been conducted on injury prevention in professional soccer players. Considering the lack of consensus on the topic of interest, this umbrella review appears warranted to compile all the available evidence, report the effectiveness of the differing prevention programs, identify heterogeneity among studies and possible gaps within the literature, and provide recommendations for future research on injury prevention programs in male soccer players.

2.1.3. Methods

The umbrella review was conducted to evaluate the systematic reviews and meta-analyses that have been undertaken on injury prevention programmes in male soccer players. Programs included specific strengthening, balance, and jumping/landing exercises (Thorborg et al., 2017), and can be applied before, after or before and after the specific training session in the field (Al Attar, Soomro, Sinclair, et al., 2017). This umbrella review was developed and reported in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) statement (http://www.prisma-statement.org) (Page et al., 2021). The review was pre-registered on INPLASY (International Platform of Registered Systematic Review and Meta-analysis Protocols) prior to the searches (https://inplasy.com/inplasy-2021-9-0066/).

Eligibility criteria

The eligibility criteria for this umbrella review are presented in Table 1. To be in included within the current review, articles were required to meet the following criteria: (1) included professional, semi-professional, university level or amateur male soccer players, (2) contained injury prevention programs, (3) incorporated both a control and intervention group(s), and (4) took the form of a systematic review (with or without a meta-analysis). Studies were omitted if they violated the following criteria: (1) articles are excluded if they were about female soccer players, (2) incorporated training programmes that did not target injury prevention, (3) did not implement a control group, (4) failed to include relevant data on injury prevention, and (5) were original studies, narrative reviews, conference proceedings or book chapters.

Table 2.1.3.1. Inclusion and Exclusion Criteria

	Inclusion	Exclusion
Population	Male professional football players	Female footballers
Intervention	Injury prevention programme	Incorporated other topics in their intervention programmes
Comparator	Programmes with control group and intervention group	Studies without a control group
Outcomes	Number of injuries	Does not include relevant data on injury prevention
Study design	Only systematic review with or without a meta-analysis	Studies that are not systematic reviews or meta-analyses

Search strategy

The searches were carried out independently by two researchers (JB and HS) using the Web of Science (all data bases), Scopus, SPORTDiscus, and PubMed. All searches were conducted in June 2021, with the following search terms used: ((Soccer OR football) AND (Injur* OR "Injur* prevention" OR "Injur* characteristics" OR "Injur* prediction" OR "Injur* reduction" OR "game Injur*" OR "training Injur*" OR "prevention strategies" OR "muscle injur*" OR "joint injur*" OR "contusion injur*" OR "Anterior cruciate ligament" OR ACL) AND ("Systematic Review" OR "Meta-analysis")). The search strategy for each database is presented in Electronic Supplementary Material Tables S1. Reference lists of the retained studies were also evaluated for any additional articles that fulfilled the selection criteria. Additionally, relevant studies that were previously known to the authors but not found during the searches were also incorporated in the umbrella review.

Table 2.1.3.2. Electronic Supplementary Material Table S1. Full search strategies for each database.

Database	Search strategy
PubMed	Search: ((Soccer OR football) AND (Injur* OR "Injur* prevention" OR "Injur* characteristics" OR "Injur* prediction" OR "Injur* reduction" OR "game Injur*" OR "training Injur*" OR "prevention strategies" OR "muscle injur*" OR "joint injur*" OR "contusion injur*" OR "Anterior cruciate ligament" OR ACL)) AND ("Systematic Review" OR "Meta-analysis")
Scopus	(TITLE-ABS-KEY (soccer OR football) AND TITLE-ABS-KEY (Injur* OR "Injur* prevention" OR "Injur* characteristics" OR "Injur* prediction" OR "Injur* reduction" OR "game Injur*" OR "training Injur*" OR "prevention strategies" OR "muscle injur*" OR "joint injur*" OR "contusion injur*" OR "Anterior cruciate ligament" OR ACL) AND TITLE-ABS-KEY ("Systematic Review" OR "Meta-analysis"))
SPORT Discus	(Soccer OR football) AND (Injur* OR "Injur* prevention" OR "Injur* characteristics" OR "Injur* prediction" OR "Injur* reduction" OR "game Injur*" OR "training Injur*" OR "prevention strategies" OR "muscle injur*" OR "joint injur*" OR "contusion injur*" OR "Anterior cruciate ligament" OR ACL) AND ("Systematic Review" OR "Meta-analysis")
Web of Science	Soccer OR football (All Fields) and Injur* OR "Injur* prevention" OR "Injur* characteristics" OR "Injur* prediction" OR "Injur* reduction" OR "game Injur*" OR "training Injur*" OR "prevention strategies" OR "muscle injur*" OR "joint injur*" OR "contusion injur*" OR "Anterior cruciate ligament" OR ACL (All Fields) and "Systematic Review" OR "Meta-analysis" (All Fields)

Data extraction

For data extraction, a Microsoft Excel sheet (Microsoft Corporation, Readmon, WA, USA) was prepared in accordance with the data extraction template of the Cochrane Consumers and Communication Review Group (Consumers, Ryan, Synnot, & Hill, 2018). The Excel spreadsheet was used to evaluate the inclusion requirements. Articles were screened initially by titles, then abstracts and finally full texts were examined for their relevance. The full-text articles that were excluded were also recorded, along with the reason for non-inclusion. The process was carried out independently by two of the authors (JB and HS). A third author (FMC) helped resolve article eligibility if disagreements ensued between the first two authors. For each eligible review article, the following items were extracted: citation details, research purpose, type of analysis, matching background, personal and environmental limitations, and main results.

Risk of bias assessment of studies

The overall reliability of the results from the eligible articles proposed by the AMSTAR-2 tool was defined as: (1) high — no, or a non-critical weakness: the systematic review provides an accurate and complete summary of the results, (2) moderate — more than one non-critical weakness but no critical flaws: the systematic review provides an accurate summary of the results, (3) low — a critical flaw, with or without non-critical weaknesses: the systematic review may not provide an accurate and complete summary of the results, (4) critically low — more than one critical flaw, with or without non-critical weaknesses: the systematic review should not be relied upon to provide an accurate and complete summary of the results (Shea et al., 2017).

Data elements

The following information was extracted from the eligible studies: (1) number of articles included (n), age group (children, youth or adults), sex (males), competitive level (if available), design (systematic review and/or meta-analysis) and type of original articles included (experimental, observational, analytical or multiple designs); (2) identification of effectiveness, anatomical region targeted by the prevention program (trunk, groin, hamstrings, knee and/or ankle), results and main findings.

Assessment of methodological quality

The assessment of the methodological quality of systematic reviews (AMSTAR-2) tool was used to assess the methodological quality of the eligible studies included in this umbrella review (Shea et al., 2017). The evaluation of eligible articles was carried out by two investigators (JB and HS) separately. If ambiguity around methodological quality occurred, then constructive debate ensued with a third author (FMC) until a consensus was reached.

2.1.4 Results

Identification and selection of studies

The searches yielded a total of 1252 titles. The studies were exported to reference management software (EndNoteTM X9, Clarivate Analytics, Filadelfia, PA, EE. UU.). Duplicates were omitted automatically or manually (176 references). The remaining 1034 articles were reviewed for their relevance based on titles and abstracts, leading to the elimination of 1003 studies. Following this trimming, 31 articles were selected for in-depth reading and analysis. After reading the full texts, 22 were excluded for failing to align with the selection criteria and one article was removed for not being written in English (Figure 1). Of the 8 articles included in this umbrella review, all were systematic reviews, with 7 of 8 articles (86%) being published between 2015 and 2021, and one article published in 2004 (16 years ago). This demonstrates a recent and growth in this area of research.

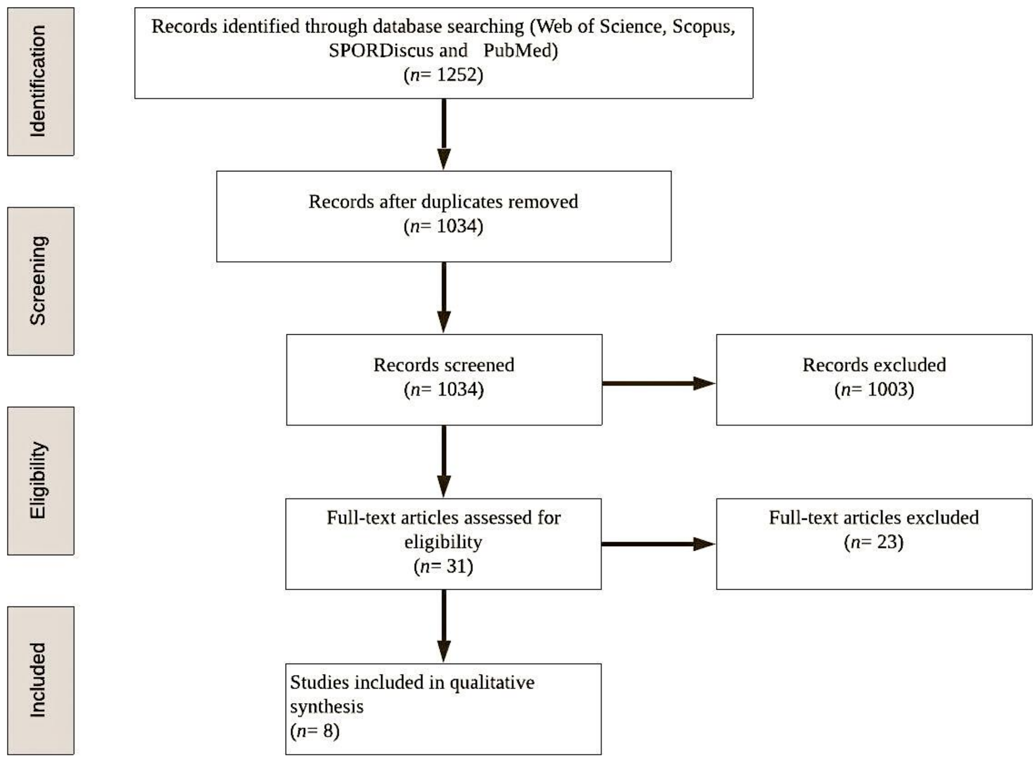

Fig 2.1.4.1. PRISMA flow chart highlighting the selection process of the studies included in the umbrella review

Characteristics of the study and qualitative synthesis

The characteristics of the eight eligible articles included in the umbrella review can be found in Table 2. The summary of the main evidence found in each review article is outlined in Table 3. There were 60 articles included in the eight systematic reviews, with 20 being repeated, two of which included female soccer players (Espinosa et al., 2015; Kraemer & Knobloch, 2009), two focused on injury prediction (Croisier, Ganteaume, Binet, Genty, & Ferret, 2008; Fredberg, Bolvig, & Andersen, 2008), one with a mixed sample (Elias, Roberts, & Thorson, 1991), three systematic reviews, of which one was already within this review (Rogan et al., 2013), another was mixed (Athanasiou & Stergioulas, 2016) and the last jointly involved risk factors, detection and prevention tests with articles that were already included in the other reviews (McCall et al., 2015), five of optimisation (A. Daneshjoo, A. Mokhtar, N. Rahnama, & A. Yusof, 2013; Daneshjoo, Mokhtar, Rahnama, & Yusof, 2012; Ghareeb, McLaine, Wojcik, & Boyd, 2017; Naclerio et al., 2013; Naclerio, Larumbe-Zabala, Monajati, & Goss-Sampson, 2015), one developed in Australian soccer (Verrall, Slavotinek, & Barnes, 2005) and one not available (Sebelien, Stiller, Maher, & Qu, 2014). In total, 25 articles remained accessible among the eight systematic reviews, which incorporated male soccer players of different competitions, levels, and ages. The intervention period for the different intervention protocols ranged from four weeks to four years. Most of the studies included in the reviewed systematic reviews were randomized controlled trials (RCT) (n = 14) (Askling, Karlsson, & Thorstensson, 2003; de Hoyo et al., 2015; Ekstand & Gillquist, 1984; Engebretsen, Myklebust, Holme, Engebretsen, & Bahr, 2008; Harøy et al., 2019; Hölmich, Larsen, Krogsgaard, & Gluud, 2010; Mohammadi, 2007; Petersen et al., 2011; Silvers-Granelli, Bizzini, Arundale, Mandelbaum, & Snyder-Mackler, 2017; Silvers-Granelli et al., 2015; Tropp, Askling, & Gillquist, 1985; van Beijsterveldt et al., 2012; van de Hoef et al., 2019; van der Horst, Smits, Petersen, Goedhart, & Backx, 2015), five were non-randomized controlled trials (NRCT) (Arnason et al., 2008; Elerian et al., 2019; Izzo, Giovannelli, & D'Isanto, 2019; Melegati et al., 2013; Owen et al., 2013), two cohort designs (CD) (Grooms, Palmer, Onate, Myer, & Grindstaff, 2013; Junge et al., 2011), one non-equivalent control group (NCG) (Caraffa, Cerulli, Projetti, Aisa, & Rizzo, 1996), one series of time (TS) (Lehnhard, Lehnhard, Young, & Butterfield, 1996), one qualitative study (QS) (Dadebo, White, & George, 2004), and one retrospective design (RD) (Cross & Worrell, 1999).

Table 2.1.4.1. Summary of the eligible articles' characteristics included in the umbrella review

Reference	Type of Review (SR, SRMA)	Original studies included (N)	Type of included studies (RCT, NRCT, QS, RD, CD)	Systematic review topic	Analysis of injury prevention programs						Types of programs used				Outcome		Risk of bias		
					Injury Prevention (Hamstrings)	injury prevention (ACL tear)	injury prevention (knee)	injury prevention (ankle)	injury prevention - (Groin)	LL - general	Strengthening	Mobility - flexibility	Propioception	Multi-component training / 11+	Reduces the number of injuries	Little enlightening	High	Half	Low
Olsen et al. (2004)	SR	4	1 RCT 1 NCG 1 TS	Prevention of injuries in general		x				x	x		x	x	x		N/A	N/A	N/A
Rogan et al. (2013)	SR	4	1 RD 1 QS 1 NRCT	Static Stretching of the Hamstring Muscle for Injury Prevention	x					x		x			x	x	x		
Cruz-Ferreira et al. (2015)	SR	5	4 RCT 1 NRCT	Prevention of injuries in general	x		x	x	x	x	x	x		x	x	x	N/A	N/A	N/A
Porter and Rushton (2015)	SR	8	8 RCT	Various Hamstring Injury Prevention Topics	x		x	x	x	x	x	x	x	x	x	x	x		
Shadle and Cacolice (2017)	SR	3	2 RCT 1 NRCT	Hamstring Strains	x						x				x		N/A	N/A	N/A
Fanchini et al. (2020)	SR	15	4 RCT 5 NRCT	Various Hamstring Injury Prevention Topics	x		x	x	x	x	x	x	x	x	x	x	x		
Pérez-Gómez et al. (2020)	SR	11	7 RCT 2 NRCT 2 CD	Various Hamstring Injury Prevention Topics	x	x		x	x	x	x	x	x	x	x		N/A	N/A	N/A

Reference	Type of Review (SR, SRMA)	Original studies included (N)	Type of included studies (RCT, NRCT, QS, RD, CD)	Systematic review topic	Analysis of injury prevention programs						Types of programs used				Outcome		Risk of bias		
					Injury Prevention (Hamstrings)	injury prevention (ACL tear)	injury prevention (knee)	injury prevention (ankle)	injury prevention - (Groin)	LL - general	Strengthening	Mobility - flexibility	Propioception	Multi-component training / 11+	Reduces the number of injuries	Little enlightening	High	Half	Low
Rosado-Portillo et al. (2021)	SR	10	4 RCT	Hamstring Strains	x					x	x		x	x	x		N/A	N/A	N/A

SR - systematic review; SRMA - systematic review with meta-analysis; N/A - not applicable; RCT - Randomized controlled trial; NRCT - non-randomized-controlled trials; NCG - Nonequivalent control group; TS - Time series; RD - Retrospective design; QS - Qualitative study; CD - Cohort design; NHE - Nordic Hamstrings Exercise; FIFA - Fédération International de Football Association; NWP - New Warm-up Program; BEP - Bounding Exercise Program; ACL - Anterior cruciate ligament; LL - Lower limb.

Table 2.1.4.2. Summary of the main findings published in the eligible articles included in the umbrella review

Reference	Type of study (SR - SRMA)	Included studies	Type of included studies (RCT, NRCT, TS, QS, RD, CD, ED)	Objectives of the studies	Age	Level	Instruments used to assess variables	Results	Conclusions
Olsen et al. (2004)	SR	4	1. RCT (Ekstand & Gillquist, 1984) 2. NCG (Caraffa et al., 1996) 3. TS (Lehnhard et al., 1996)	Examine the evidence on the effectiveness of current soccer injury prevention strategies, determine the applicability of the evidence to children and youth, and make recommendations on policy, programming, and future research.	1. 17 to 38 2. N/A. 3. N/A.	1. Community soccer league 2. Semi-professional and amateur teams 3. College soccer team	1. Injury history and persistent symptoms of past injuries, and by the stability of the knee and ankle joints. Lower limb strength and range of motion test 2. a careful clinical examination, KT-1000 measurement, standard X-ray, magnetic resonance imaging (MRI), or computed tomography (CT)-scan. 3. Recorded.	A total of 44 potentially relevant articles from electronic (n = 37) and hand (n = 7) searches yielded four that met inclusion criteria. Some of the strategies look promising but lack adequate evaluation or require further research among younger players.	There is a serious lack of prevention research targeting soccer players.
Rogan et al. (2013)	SR	4	1. NRCT (Arnason et al., 2008) 2. RD (Cross & Worrell, 1999) 3. QS (Dadebo et al., 2004)	The aim of this review is to determine if static stretching reduces hamstring injuries in soccer codes.	1. N/A 2. 18.6±1.5 3. N/A	1. Professional 2. Professional 3. University	1. Continuous injury registration protocol during the study period. 2. The clinical evaluation of a single certified athletic trainer. 3. Questionnaire.	35 studies were selected. Thirty-one articles were excluded after the review and 4 met the eligibility criteria and were analyzed. Studies with low qualitative and quantitative characteristics. The effects of static stretching in preventing hamstring injuries cannot be determined.	Study protocols vary in terms of duration of intervention and follow-up. No RCT studies are available, however RCT studies should be conducted in the near future.

Reference	Type of study (SR - SRMA)	Included studies	Type of included studies (RCT, NRCT, TS, QS, RD, CD, ED)	Objectives of the studies	Age	Level	Instruments used to assess variables	Results	Conclusions
Cruz-Ferreira et al. (2015)	SR	5	1. RCT (Askling et al., 2003) 2. NRCT (Arnason et al., 2008) 3. RCT (Engebretsen et al., 2008) 4. RCT (Petersen et al., 2011) 5. RCT (van Beijsterveldt et al., 2012)	To know the scientific evidence on the effectiveness of exercise programs in the prevention of hamstring injuries in male soccer players.	1. 25.0±2.9 2. N/A 3. N/A 4. 23.3±4.0 5. 24.8±4.2	1. Professional 2. Professional 3. Professional 4. Professional and amateur 5. Amateur	1. The coaches, physical therapists and physicians register and report all hamstring injuries. 2. Continuous injury registration protocol during the study period). 3. The injury reports from each physiotherapist. 4. Ultrasound examination. 5. Questionnaire plus reported weekly by coaches.	The review identified 1920 studies. 1892 excluded. There were 23 studies considered potentially included of which 5 met the eligibility criteria. and that they were analyzed.	Heterogeneity of the duration and frequency of the exercise program; Small number of experimental studies with a control group carried out in male soccer players; Lack of follow-up study designs. More studies of high methodological quality should be conducted.
Porter and Rushton (2015)	SR	8	1. RCT (Askling et al., 2003) 2. RCT (Engebretsen et al., 2008) 3. RCT (Hölmich et al., 2010) 4. RCT (Mohammadi, 2007) 5. RCT (Petersen et al., 2011) 6. RCT (Tropp et al., 1985) 7. RCT (van Beijsterveldt et al., 2012)	To carry out a systematic review to evaluate the efficacy of exercise in the prevention of injuries in adult male soccer.	1. 25.0±2.9 2. N/A 3. N/A 4. 24.6 ± 2.6 5. 23.3±4.0 6. N/A 7. 24.8±4.2	1. Professional 2. Professional 3. Professional 5. Professional 6. Professional and amateur 7. Semi-professional 8. Amateur	1. The coaches, physical therapists and physicians register and report all hamstring injuries. 2. The injury reports from each physiotherapist. 3. N/A 4. The injury diagnosis was made within 1 hour of the injury event by 1 of the medical practitioners 5. Ultrasound examination 6. Coach reported every ankle injury. 7. Questionnaire plus reported weekly by coaches.	Eight trials (n = 3,355) from five countries met the inclusion criteria. Two trials reported statistically significant reductions in hamstring injuries with eccentric exercise and two reported statistically significant reductions in recurrent ankle sprains with proprioceptive exercise. Four trials showed no statistically significant difference in injury incidence with exercise interventions targeting a variety of injuries.	Limitations in the context of study quality and heterogeneity resulted in the inability to reach a clear conclusion regarding the efficacy of exercise for injury prevention in adult male soccer.

Reference	Type of study (SR - SRMA)	Included studies	Type of included studies (RCT, NRCT, TS, QS, RD, CD, ED)	Objectives of the studies	Age	Level	Instruments used to assess variables	Results	Conclusions
Shadle and Cacolice (2017)	SR	3	1. RCT (Askling et al., 2003) 2. RCT (Petersen et al., 2011) 3. NRCT (Arnason et al., 2008)	To determine the effect of eccentric exercises in preventing hamstring strain in adult male soccer players.	1. 25.0±2.9 2. 23.3±4.0 3. N/A	1. Professional 2. Professional and amateur 3. Professional	1. The coaches, physical therapists and physicians register and report all hamstring injuries. 2. Ultrasound examination. 3. Continuous injury registration protocol during the study period.	3 articles met the inclusion criteria. Two were randomized controlled trials and one was a cohort study. There is strong evidence to support the implementation of eccentric hamstring exercises to prevent injury in elite adult male soccer players.	There is strong supporting evidence that eccentric hamstring exercises can prevent a hamstring injury in an elite adult male soccer player.
Fanchini et al. (2020)	SR	15	1. RCT (Askling et al., 2003) 2. RCT (de Hoyo et al., 2015) 3. RCT (Engebretsen et al., 2008) 4. RCT (Harøy et al., 2019) 5. NRCT (Arnason et al., 2008) 6. NRCT (Elerian et al., 2019) 7. NRCT (Owen et al., 2013) 8. NRCT (Melegati et al., 2013) 9. NRCT (Izzo	To assess the effectiveness of exercise-based muscle injury prevention strategies in elite soccer for adults.	1. 25.0±2.9 2. 17 ± 1 3. N/A 4. 22 to 24 5. N/A 6. N/A 7. 28.6±3 8. 21 to 35 9.26,1±4,5.	1. Professional 2. Youth soccer 3. Professional 4. Professional 5. Professional 6. Professional 7. Professional 8. Professional 9. Professional	1. The coaches, physical therapists and physicians register and report all hamstring injuries. 2. Medical team registration. 3. The injury reports from each physiotherapist. 4. The OSTRC Overuse Injury. Questionnaire. 5. Continuous injury registration protocol during the study period. 6. Clinical diagnosis and magnetic resonance imaging (MRI). 7. N/A 8. Clinical diagnosis and magnetic resonance imaging (MRI). 9. The Australian football association injury form was used to collect incidence of injuries).	15 studies. Three systematic reviews showed inconsistent results, one supporting (high risk of bias) and two showing insufficient evidence (low risk of bias) to support exercise-based strategies to prevent muscle injury in elite players. Five RCTs and seven NRCTs support eccentric exercise, proprioception exercises, and a multidimensional component of an injury prevention program; however, all were at high / critical risk of bias. Only one RCT was found to be at low risk of bias and supported eccentric exercise to prevent groin problems.	Limited scientific evidence to support exercise-based strategies to prevent muscle injury in elite soccer players.

Reference	Type of study (SR - SRMA)	Included studies	Type of included studies (RCT, NRCT, TS, QS, RD, CD, ED)	Objectives of the studies	Age	Level	Instruments used to assess variables	Results	Conclusions
			et al., 2019)						
Pérez-Gómez et al. (2020)	SR	11	1. NRCT (Arnason et al., 2008) 2. RCT (Askling et al., 2003) 3. CD (Grooms et al., 2013) 4. RCT (Harøy et al., 2019) 5. CD (Junge et al., 2011) 6. RCT (Mohammadi, 2007) 7. NRCT (Owen et al., 2013) 8. RCT (Petersen et al., 2011) 9. RCT (Silvers-Granelli et al., 2017) 10. RCT (Silvers-Granelli et al.,	Carry out a systematic review of published studies on injury prevention programs for adult male soccer players, identify points of common understanding and establish recommendations that should be considered in the design of injury prevention strategies.	1. N/A 2. 25.0±2.9 3. 18 to 25 4. 22 to 24 5. 14 to 65 6. 24.6 ± 2.6 7. 28.6±3 8. 23.3±4.0 9. 18 to 25 10. 18 to 25 11. 18 to 40	1. Professional 2. Professional 3. University 4. Professional 5. Amateurs 6. Professional 7. Professional 8. Professional and amateur 9. University 10. University 11. Amateurs	1. Continuous injury registration protocol during the study period. 2. The coaches, physical therapists and physicians register and report all hamstring injuries. 3. Team doctor and imaging studies. 4. The OSTRC Overuse Injury. Questionnaire. 5. Injury reports. 6. Team doctor. 7. N/A 8. Ultrasound examination. 9. Internet-based injury surveillance system (HealtheAthlete; Cerner Corporation, Overland Park, KS, USA). 10. Internet-based injury surveillance system (HealtheAthlete; Cerner Corporation, Overland Park, KS, USA). 11. Medical team registration.	2512 studies, 11 met the inclusion criteria. Injury prevention programs in soccer have focused on strength training, proprioceptive training, multi-component programs (balance, core stability, and functional strength and mobility), and warm-up programs.	Soccer players can reduce the incidence of injury in games and training sessions by participating in dynamic warm-up programs that include preventive exercises before games or during training sessions.

Reference	Type of study (SR - SRMA)	Included studies	Type of included studies (RCT, NRCT, TS, QS, RD, CD, ED)	Objectives of the studies	Age	Level	Instruments used to assess variables	Results	Conclusions
			2015) 11. RCT (van der Horst et al., 2015)						
Rosado-Portillo et al. (2021)	SR	10	1. RCT (van de Hoef et al., 2019) 2. RCT (van der Horst et al., 2015) 3. RCT (Silvers-Granelli et al., 2015) 4. RCT (Petersen et al., 2011)	To review the exercise programs used to prevent acute hamstring injuries in eleven-player soccer players and their effectiveness.	1. 18 to 45 2. N/A 3. 18 to 40 4. 22 ± 2,6 5. 18 to 25 6. 19 to 39 7. 23,8 ± 3,1 8. 18,9 ± 1,4 9. 18 to 21 10. 23.3±4.0	1. Amateurs 2. Amateurs 3. University 4. Professional and amateur	1. Medical team and players registration) 2. Medical team registration) 3. Internet-based injury surveillance system (HealtheAthlete; Cerner Corporation, Overland Park, KS, USA). 4. Ultrasound examination.	Ten studies were selected considering 14 interventions, including nine different programs: FIFA11 + (11+), Harmoknee, Eccentric Nordic Hamstring Exercise (NHE) exclusively, with eccentric exercises, with stretching or proprioceptive, New Warm-up Program (NWP), Bounding Exercise Program (BEP), the only one without positive results, and proprioceptive exercises.	The exercise programs discussed were effective in preventing acute hamstring injuries in soccer players, except BEP and partially Harmoknee. The exercises most used to reduce the risk of hamstring injuries are eccentric strength exercises due to their functionality, especially the NHE.

SR - systematic review; SRMA - systematic review with meta-analysis; N/A - not applicable; RCT - Randomized controlled trial; NRCT - non-randomized-controlled trials; NCG - Nonequivalent control group; TS - Time series; RD - Retrospective design; QS - Qualitative study; CD - Cohort design; NHE - Nordic Hamstrings Exercise; FIFA - Fédération International de Football Association; NWP - New Warm-up Program; BEP - Bounding Exercise Program.

Olsen et al. (2004) included young soccer players, while the remainder of the studies incorporated adult professional, semi-professional, amateur and college/university soccer players (Cruz-Ferreira et al., 2015; Fanchini et al., 2020; Pérez-Gómez et al., 2020; Porter & Rushton, 2015; Rogan et al., 2013; Rosado-Portillo et al., 2021; Shadle & Cacolice, 2017). Despite two systematic reviews including two studies with female athletes and one with mixed genders, 95% of the included studies focused on male players. Four systematic reviews included a generalised lower-limb injury prevention programme (Fanchini et al., 2020; Olsen et al., 2004; Pérez-Gómez et al., 2020; Porter & Rushton, 2015) and four assessed the efficacy of training programs on hamstring injury prevention (Cruz-Ferreira et al., 2015; Rogan et al., 2013; Rosado-Portillo et al., 2021; Shadle & Cacolice, 2017). Two of the systematic reviews focusing on lower-limb injury prevention programmes questioned the quality of the evidence obtained in the studies (Fanchini et al., 2020; Porter & Rushton, 2015). Porter and Rushton (2015) and Fanchini et al. (2020) identified that the use of eccentric hamstring exercises may be effective in preventing hamstring injuries and that proprioceptive training may be effective in preventing recurrent ankle sprains. Rosado-Portillo et al. (2021) suggested that soccer players can reduce the incidence of injury in games and training sessions by participating in dynamic warm-ups, including, strength, balance and mobility training exercises. Olsen et al. (2004) demonstrated that the prevention strategies used in young soccer players appear effective, but further evaluation is required before robust inferences can be drawn. Programmes that focused on the prevention of hamstring muscle injuries (Cruz-Ferreira et al., 2015; Rosado-Portillo et al., 2021; Shadle & Cacolice, 2017) were shown to be efficacious when containing eccentric contraction force (Nordic) exercises. Injury prevention programmes utilising static stretching did not present quality scientific evidence to support its use (Rogan et al., 2013).

Methodological quality

The methodological quality of the 8 included articles is summarized in Table 4. Five articles were rated as 'critically low' methodological quality, two reviews were rated as 'low' quality and one study was rated as 'high' quality.

Table 2.1.4.3. AMSTAR 2 evaluation of each of the eligible studies included in the umbrella review

Study	AMSTAR 2 - ITENS																Overall Items
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Olsen et al. (2004)	Yes	No	Yes	Yes	No	Yes	Yes	Yes	No	No	No MA	No MA	No	No	No MA	No	Critically low
Rogan et al. (2013)	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No MA	No MA	Yes	Yes	No MA	Yes	Low
Cruz-Ferreira et al. (2015)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No MA	No MA	No	Yes	No MA	Yes	Critically low
Porter & Rushton, (2015)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No MA	No MA	Yes	Yes	No MA	Yes	High
Shadle and Cacolice, (2017)	Yes	No	Yes	Yes	No	No	No	Yes	No	No	No MA	No MA	No	No	No MA	No	Critically low
Fanchini et al. (2020)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No MA	No MA	Yes	Yes	No MA	No	Low
Pérez-Gómez et al. (2020)	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No MA	No MA	No	No	No MA	Yes	Critically low
Rosado-Portillo et al.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No MA	No MA	No	Yes	No MA	Yes	Critically low

Yes, Complies; NO, Fails; No MA, No metanalysis.

In total, 63% of the articles included in this umbrella review (n = 5) did not adopt a satisfactory technique to assess the risk of bias in the individual studies that were included in the systematic review articles. Four of the systematic reviews had not been pre-registered. despite calls for more transparency around research practices (Caldwell et al., 2020).

The correct analysis of the RoB of the individual studies included in the SRs plays an important role when interpreting and discussing their results, which can profoundly affect the conclusions derived from the reviews, both qualitatively and quantitatively. Also, observing heterogeneity in the results, the authors should provide a satisfactory explanation and critical discussion on the subject. Our umbrella review is supported by the growing need to improve the quality of SRs, as well as the studies published on this matter, in order to avoid fragile conclusions or recommendations or those without strong scientific support.

Synthesis of results

The synthesis of results obtained and extracted from the systematic reviews is presented in Table 5.

Table 2.1.4.4. Synthesis of results - evidence map

	Type of study	Article review process					Study design %									Leves sports %				Injury prevention			
Reference	**SR ou SRMA**	**Total articles**	**Duplicates**	**1st revision articles**	**2st revision articles**	**Included studies**	**RCT**	**NRCT**	**NCG**	**QS**	**RD**	**ED**	**CD**	**TS**	**SR**	**Professional players**	**Amateur Players**	**University Players**	**Youth Players**	**General lower limbs**	**Hamstrings**	**Built-in programs**	**Conclusions**
Olsen et al. (2004)	SR	44		5		4	25		25					50 (25)			25		75	x		Various programs	Serious lack of evidence in young players. No specific practical recommendations for young soccer players are generated.
Rogan et al. (2013)	SR	502		35	21	4		25		25	25	-25				50		25			x	Static stretching	Studies with low qualitative and quantitative characteristics. There are no RCT studies available. Therefore, it is not possible to find documentation on the effects of static stretching in preventing hamstring injuries.
Cruz-Ferreira et al. (2015)	SR	1910		1892	23	5	80	20								70	30				x	Various programs	Limited and moderate evidence in the various programs analyzed, but concentric and eccentric force to be effective in reducing the incidence of injuries to the hamstrings as well as the Nordic hamstrings appear to be effective in reducing the incidence of new injuries.
Porter & Rushton (2015)	SR	1942	1179	763	19	8	100 (13)													x		Various programs	Very low-quality evidence on the efficacy of exercise in preventing injuries in adult men's soccer, suggests some support for the use of eccentric exercises for the hamstrings and proceptive training for ankle sprains.

	Type of study	Article review process					Study design %									Leves sports %				Injury prevention			
Reference	**SR ou SRMA**	**Total articles**	**Duplicates**	**1st revision articles**	**2st revision articles**	**Included studies**	**RCT**	**NRCT**	**NCG**	**QS**	**RD**	**ED**	**CD**	**TS**	**SR**	**Professional players**	**Amateur Players**	**University Players**	**Youth Players**	**General lower limbs**	**Hamstrings**	**Built-in programs**	**Conclusions**
Shadle and Cacolice (2017)	SR	3		3		3	67	33								83	17				x	Eccentric exercises	There is strong supporting evidence that eccentric hamstring exercises can prevent a hamstring injury in an elite adult male soccer player.
Fanchini et al. (2020)	SR	8382	4207	15		12	33 (7)	47 (13)							(20)	92			8	x		Various programs	Level 1, 2, 3 and 4 evidence limited in injury prevention programs and at high or unclear risk of bias. Therefore, it is considered useful evidence for professionals.
Pérez-Gómez et al. (2020)	SR	2512	1597	1505	92	11	64	18					18			50	23	27		x		Various programs	Supports prevention programs carried out in training and match warm-ups (FIFA 11+, NHE, balance, mobility end strength at least twice a week.
Rosado-Portillo et al. (2021)	SR	923	625	298	11	10	100 (60)									25	35	20	10		x	Various programs	Supports the use of different programs such as NHE, NHE + eccentrico, FIFA 11+, NWP and proprioception except BEP and Harmoknee.

SR - systematic review; SRMA - systematic review with meta-analysis; N/A - not applicable; RCT - Randomized controlled trial; NRCT - non-randomized-controlled trials; NCG - Nonequivalent control group; TS - Time series; RD - Retrospective design; QS - Qualitative study; ED - Experimental Design; CD - Cohort design; NHE - Nordic Hamstrings Exercise; FIFA - Fédération International de Football Association; NWP - New Warm-up Program. Note: Within parenthesis we presented the percentages of articles eliminated for deviating from the objectives of this research.

2.1.5 Discussion

The present umbrella review aimed to synthesise the current evidence from the previously published systematic reviews on injury prevention programmes. Up to the present time, no articles are available that have specifically evaluated the current state of knowledge of injury prevention programmes in soccer through the analysis of systematic reviews and meta-analyses on this topic. This article is topical given the increasingly demanding competitive schedules and subsequent potential of increasing injury incidence in professional soccer. Given these contemporary factors the current article is specific to the systematic reviews focusing on programmes targeted at the prevention of lower limb injuries and, the prevention of hamstring injuries.

Lower limb injury prevention programmes

This umbrella review showed that among the eight systematic reviews included, four focused on lower-limb injury prevention (general). One of these reviews included young soccer players (Olsen et al., 2004) and the other three included senior players of different ages and competitive levels (Fanchini et al., 2020; Pérez-Gómez et al., 2020; Porter & Rushton, 2015).

Among the most common injuries declared in one of the studies included by Olsen et al. (2004), in young athletes, 177 lower limb injuries were documented, of which 69% were trauma and 29% sprains, which resulted in 93% of them involving the ankle 59% and the knee 34% (Ekstand & Gillquist, 1984). Despite these findings, Olsen et al. (2004), point out that at the time of the review, there was a serious lack of research in the area, which could have been due to the time of publication of the study, since it is the oldest article included in this umbrella review.

The most common injuries in adult players are hamstring strains (Arnason et al., 2008; Askling et al., 2003; de Hoyo et al., 2015; Elerian et al., 2019; Engebretsen et al., 2008; Petersen et al., 2011; van Beijsterveldt et al., 2012; van der Horst et al., 2015), therefore, it is recommended that prevention programs should incorporate eccentric exercises, neuromuscular training program that includes core stabilization exercises, eccentric quadriceps exercises and eccentric hamstring exercises (Athanasiou & Stergioulas, 2016). Haroy (2019), used a programme based on the Copenhagen adduction exercise (CA). This study reported that the male soccer players that completed the CA programme showed a reduced prevalence of groin injuries. Hölmich et al. (2010) also used a prevention programme based on six exercises, (1) isometric adduction with a ball between the feet (2) isometric adduction with a ball at the knees, (3) combined abdominal and hip flexion, (4) coordination of a flexed leg "cross country skiing on one leg", (5) hip adduction versus partner hip abduction, and (6) iliopsoas muscle stretch. Despite these exercises reducing the risk of groin injury by 31%, the changes did not reach statistical significance. It was also found that having suffered a previous groin injury almost doubles the risk of a recurrent groin injury and playing at a higher level increases the risk of developing a groin injury three-fold. A common recurrent injury is the knee sprain, Engebretsen et al. (2008) proposed the use of exercises for instability on the balancing equipment, and unilateral activities. However, these individualised programmes did not reduce injury-risk, which could be attributed to the low participation in the programme, which varied between 19 and 30% during the intervention period. Compliance is an important factor in the effectiveness of an injury prevention programme and should be reported by the authors of scientific articles investigating injury prevention training protocols.

Ankle sprains have been studied by several authors. Mohammadi (2007) compared three injury prevention programmes to determine their effectiveness. The groups either completed a proprioceptive programme, strength training programme, orthosis, or a control group. The results showed that the incidence of recurrent ankle sprain injuries was significantly lower for the group that used the proprioceptive programme compared to the control group. However, there were no significant differences for the strength training programme and orthosis groups. Tropp et al. (1985) compared three groups, including an orthosis group, a group that completed co-ordination on an ankle disc and a control group (no intervention). The intervention groups proved to be effective in reducing functional instability in players with a previous ankle sprain injury, with both techniques also decreasing reccurent ankle injuries. Therefore, it appears that propioception and balance exercises are effective in reducing ankle sprains.

Owen et al. (2013) used a multicomponent prevention programme, including, balance exercises on different surfaces, functional strength, core stability, and mobility. A reduction in solely muscle injuries were observed during an entire season where players performed the structured intervention programme bi-weekly versus a control season (no intervention). Other multi-component interventions are FIFA programmes (Grooms et al., 2013; Junge et al., 2011; Silvers-Granelli et al., 2017; Silvers-Granelli et al., 2015), whose application has shown to decrease injury-risk in matches and training, and a reduction in time-loss from training and competition. These programmes have also been shown to substantially reduce the chances of suffering an ACL injury. Melegati et al. (2013) and Engebretsen et al. (2008) incorporated both individualised and group programmes based on previous injuries. Melegati et al. (2013) demonstrated that group and individualised injury prevention programmes are effective in reducing the number of muscle injuries and days absent from competition. Engebretsen et al. (2008) reported no differences for injury-risk between the intervention and control groups, perhaps given the low engagement with both group and individual protocols. Izzo et al. (2019) used an injury prevention programme based on dynamic movements and preventative work. It was determined that this programme significantly reduced the occurrence of muscle strain injuries.

Hamstring-Targeted Muscle Injury Prevention Programmes

Hamstring strain injuries are common in sports involving sprinting, kicking, and high-speed movements or extensive muscle lengthening-type maneuvers with hip flexion and knee extension (Erickson & Sherry, 2017). Training-related hamstring injury rates have markedly increased over the last 20 years, but game injury rates have remained constant (Ekstrand, Waldén, & Hägglund, 2016). A major factor that can influence hamstring injuries is fatigue, which can last up to 72 hours after a game (Nédélec et al., 2012). Therefore, if players do not return to pre-performance strength values (high speed movements / high load / accelerations / decelerations) after 72 hours or more, this could result in injury (Rhodes, McNaughton, & Greig, 2019).

The injuries can cause an initial loss of flexibility and strength (Askling, Saartok, & Thorstensson, 2006; Erickson & Sherry, 2017), which combined with an insufficient recovery time and premature return to sport, can lead to a risk of acute and chronic injuries (Sherry, Johnston, & Heiderscheit, 2015). for example, for central tendon disruption the median recovery time was 91 days. Nerveless, the median recovery times for biceps femoris injuries with and without central tendon disruption were 21 and 72 days respectively (Comin, Malliaras, Baquie, Barbour, & Connell, 2013).

On the other hand, it is essential to use some procedures based on the recommendations of the rehabilitation protocols based on exercises of progressive agility and stabilization of the trunk and ice (PATS) and static stretching, isolated progressive resistance exercise of the hamstrings and ice application (PRES) based on three phases; phase 1, minimizing pain and edema, restructuring neuromuscular control at slower speeds and preventing excessive scar tissue; phase 2, increases the intensity of the exercises, the neuromuscular training is carried out at greater speed and amplitude, in conjunction with the start of eccentric resistance training; phase 3, high-speed neuromuscular training and an eccentric resistance training in a lengthened position in preparation for the return to sport (Erickson & Sherry, 2017; Sherry & Best, 2004; Silder et al., 2013).

The above-mentioned procedures can help the injury process recovery, reducing the risk of injury relapse given the complexity that characterizes the hamstring injury. Therefore, it is essential to review, analyze and understand the benefits of the different intervention plans available in scientific literature.

Rogan et al. (2013) were the first —included in the umbrella review — to perform a systematic review on the prevention of hamstring injuries. This article attempted to determine whether static stretching reduced hamstring injuries in soccer players. However, due to the heterogeneity of the intervention programme methods included in the studies, the data were considered inconclusive. A systematic review incorporated in the current review article assessed the effectiveness of different protocols on the prevention of hamstring injuries (2015). The programme included proprioceptive, balance, neuromuscular and postural control training, with heterogeneity in the duration and frequency of the programmes. It was established that a combined concentric and eccentric strength programme was most effective in reducing the incidence of recurrent hamstring injuries, whereas the Nordic hamstring eccentric strength programme decreased the incidence of new hamstring injuries. However, the evidence was limited, and the authors suggested that follow-up studies, with higher methodological quality, are required. Askling et al. (2003) used a control group and an experimental group, with the training group performing additional hamstrings strength training (concentric and eccentric YoYotm wheel ergometer) once every five days for the first 4 weeks and every four days for the last six weeks of the programme. The addition of specific strength training for the hamstrings was beneficial for injury prevention and performance in elite soccer players. Petersen et al. (2011) performed a 10-week intervention with a total of 27 sessions of Nordic hamstring eccentric strength exercises. The study observed a reduction in the incidence of recurrent injuries, new injuries and recovery time from injury with the intervention programme. Arnason et al. (2008) included Nordic hamstring eccentric strength exercises, a stretching-based warm-up and elasticity exercises three times a week in preseason and 1-2 times during the season, in addition to the regular training regime. The evidence suggests that there was a decrease in the incidence of injuries, but not in severity or recurrence. However, the programme not incorporating the Nordic hamstring strength programme did not obtain differences in incidence, recurrence and severity of injuries (Arnason et al., 2008). Engebretsen et al. (2008) identified that completion of a Nordic hamstring eccentric strength exercise programme for 10 weeks did not reduce injury-risk, which could be due to low compliance (19—30%). van Beijsterveldt et al. (2012) incorporated an exercise programme (thigh eccentric exercises, proprioceptive training, dynamic stabilisation and plyometric exercises) in the warm-up phase for 9 months, twice a week for 10-to-15 minutes each time. However, the programme did not influence the overall injury incidence or severity versus the control group.

Rosado-Portillo et al. (2021) conducted a systematic review assessing the effectiveness of acute hamstring injury prevention programmes in soccer players. The exercises programmes incorporating eccentric exercises, especially Nordic hamstring exercises were most effective. Programmes involving concentric and isometric contraction exercises were also effective in improving strength and injury reduction. Naclerio et al. (2015) implemented two different injury prevention programmes. One group completed eccentric knee flexor exercises, including Nordic hamstring exercises, and a separate group performed proprioceptive exercises (both 18 sessions in 6 weeks). It was found that both protocols reduced hamstring and ACL injury incidence. Additionally, a four-week resistance training programme that included a stable eccentric open kinetic chain and two unstable closed kinetic chain exercises was shown to significantly alter the isometric ratio of the hamstrings between the angle of the knee and torsion by improving the maximum torque produced in a more closed position (80°). These adaptations are considered positive for the prevention of injuries as they protect athletes from both muscle and joint injuries (Naclerio et al., 2013). Daneshjoo et al. (2012) and Daneshjoo et al. (2013) analysed the effects of the 11+ and HarmoKnee injury prevention programmes on knee strength in male soccer players. The first study focused on the conventional force ratio, the dynamic control ratio and the fast/slow speed ratio. It was identified that the 11+ improved the conventional force ratio and fast/slow speed ratio and reduced the rate of knee injuries in soccer players. However, the HarmoKnee programme showed no improvement. It was also found that programmes 11+ and HarmoKnee are useful warm-up protocols to improve concentric hamstring strength in soccer players, but programme 11+ yielded greater improvements in concentric hamstring strength. However, in the study of Daneshjoo et al. (2013) the authors tried to determine the effects of 11+ and Harmoknee on performance measures in professional football players, concluding that carrying out the 11+ heating program for 8 weeks can improve jump height, agility and football skill. On the other hand, the HarmoKnee program only improves football skill in young professional men's football players.

Rogan et al. (2013) suggest that the effects of static stretching programmes are unclear concerning the prevention of the hamstring injury incidence. Cruz-Ferreira et al. (2015) suggest that eccentric and concentric strength programmes appear to be effective in reducing the incidence of hamstring injuries in male soccer players, as are Nordic exercise eccentric strength programmes. Shadle and Cacolice (2017) performed a systematic review that incorporated evidence obtained from Arnason et al. (2008), Askling et al. (2003), and Petersen et al. (2011), which were previously described. These studies conclude that eccentric hamstring exercises can prevent hamstring injuries in elite adult male soccer players.

Limitations of current research on injury prevention

The existing systematic reviews included in the present article have revealed primarily low methodological quality. However, it must also be noted that there are large differences in quality ratings for the same study between systematic reviews, potentially due to different methodological quality criteria tools being used and subjective interpretations of quality ratings. Few articles pre-registered the systematic reviews at inception to reduce duplication and facilitate comparisons between reported review methodologies. Another commonality between studies was inadequate procedures used to identify sources of bias. There are no meta-analyses that qualified for the current review to evaluate the quality and strength of the evidence, thus, no statistical conclusions have been established across studies (Impellizzeri, McCall, & van Smeden, 2021). The umbrella review does not incorporate other team sports, which may have given interesting perspectives. However, a decision was taken to limit the analyses to solely soccer given its unique activity profile.

Directions for Future Research on Injury Prevention

There are a number of future research avenues that should be explored. Considering the low methodological quality across studies, future articles in this area should address this by conducting research superior in quality to the reviews previously conducted. Longitudinal studies should be conducted (i.e., minimum of one season) to determine the impact of injury prevention programmes over longer periods of time. This could allow adaptations to the different programmes to take effect to determine if there is a genuine difference between players participating in prevention programmes compared with those who do not partake in such protocols. Moving forward, research avenues should also assess different team sports and explore to what extent the same types of prevention programmes have an effect, based on the notion that the demands will differ between each team sport (i.e., lower and upper limbs). Exploring how psychological processes (emotional well-being, motivation, etc.) link with injury prevention could help established a more comprehensive depiction of athlete health, not only in competitive football, but also in recreational football (Sarmento et al., 2020). Researchers should prospectively and publicly record systematic reviews and meta-analyses on an appropriate platform to avoid others completing a review on the same topic.

2.1.6 Conclusions

Injury prevention programmes are becoming increasingly important in competitive soccer, and in recent years evidence has shown that injury rates are associated with team success (Hägglund, Waldén, Magnusson, et al., 2013). There have been many systematic reviews conducted on this topic mainly over the last decade, and as such, it appears warranted that an umbrella is undertaken to summarise the findings of all previous review articles. In general, there is low methodological quality in the systematic reviews included and, consequently, any inferences drawn must be interpreted with caution. Despite the lack of consistency in the literature and the absence of meta-analyses, the existing evidence suggests that prevention programmes focused on strength and proprioception prevent the incidence and severity of injuries. The systematic reviews included also revealed that dynamic warm-ups can decrease injury incidence, but the influence of static stretching on subsequent injury susceptibility is less well known. These findings collate a grouping of evidence that can inform future research endeavors enabling flaws and gaps to be addressed. Reducing injury rates and increasing player availability can lesser the economic costs for professional soccer clubs and enhance success. Practitioners responsible for optimising prevention protocols could use the current comprehensive summary of the literature to direct their future practices. Soccer practitioners should implement injury prevention programmes in their weekly plans during the pre-competitive and competitive phases of the season to minimise injury and use some of the current data to inform their practices. To address the low methodological quality, future research should possess greater rigor, employ longer periods of intervention, incorporate a control group in their study design, and record the level of programme compliance.

Key Points

This umbrella review provides a comprehensive evidence synthesis of injury prevention programs in male soccer, including various beneficial practices for players, teams, and clubs.

Preventative programs targeted at enhancing muscle strength and proprioception reduce injury incidence and severity, particularly hamstring strains and ankle sprains.

Warm-ups implementing dynamic activity before soccer matches have shown to decrease incidence, while the impact of static stretching as an injury preventative strategy appears ambiguous.

There is a lack of consistency between the studies reporting on prevention programs in male soccer players. More homogenous research is required to elucidate the efficacy of injury prevention protocols to inform practice in the applied environment.

Registration

The umbrella review was pre-registered in the International Platform of Registered Protocols for Systematic Review and Meta-analysis (10.37766 / inplasy2021.9.0066).

Amendment to the information provided in the registry or in the protocol

Injury prevention programmes in male soccer players: an umbrella review of systematic reviews.

Ethics approval and consent to participate

NA

Chapter II

Study 2

2.2 Study 2

The Effect of Contextual Variables on Match Performance across Different Playing Positions in Professional Portuguese Soccer Players

Reference: *Barrera, J., Sarmento, H., Clemente, F. M., Field, A., & Figueiredo, A. J. (2021). The Effect of Contextual Variables on Match Performance across Different Playing Positions in Professional Portuguese Soccer Players. International journal of environmental research and public health, 18(10), 5175.*

2.2.1 Abstract

This study investigated the position-specific physical demands of professional Portuguese players. The effects of situational variables on the physical performance demands were also ana-lysed (match location, match half and match result). Match performance observations were collected using Global Navigation Satellite System devices across 11 matches during a competitive season (2019–2020). Data were analysed according to five playing positions: goalkeepers (n = 11), central defenders (n = 42), wide defenders (n = 31), central midfielders (n = 34), open attackers (n = 28), and centre forwards (n = 14). Central midfield players completed the greatest total distance (10,787 ± 1536 m), while central defenders covered the least distance (9272 ± 455; $p < 0.001$). Open attackers covered the greatest high and very-high-speed distance (1504 ± 363 m), number of high-speed decelerations per match (11 ± 4) and were the fastest players (30.6 ± 1.5 km/h), along with center forwards (30.6 ± 2.0 km/h), versus all other positions ($p < 0.05$). Greater distances were performed in teams that were winning (9978 ± 1963 m) or drawing (10,395 ± 875 m) versus losing (9415 ± 2050) $p = 0.036$ and $p = 0.006$, respectively. Increases in distance covered at walking speeds were observed during the 2nd half (1574 ± 179 m) compared with the 1st half (1483 ± 176; ($p < 0.003$). A higher number of decelerations across all speeds were performed in the 1st half (144 ± 39) versus the 2nd half (135 ± 37). The distance covered in home matches (10,206 ± 1926 m) far exceeded away matches (9471 ± 1932 m; $p < 0.001$). The number of faster accelerations were higher in away (7 ± 5) versus home matches (6 ± 4; $p < 0.049$). The data demonstrate the different physical demands of each playing position and suggest that situational variables influence physical performance. These findings suggest position-specific physical training is required to condition players for the bespoke demands of each playing position.

Keywords: football; monitoring; performance; professional team.

2.2.2 Introduction

The physical performance demands of soccer match-play have been researched extensively in English Premier League soccer players (Barnes et al., 2014; Di Salvo, Gregson, Atkinson, Tordoff, & Drust, 2009; Di Salvo, Pigozzi, González-Haro, Laughlin, & De Witt, 2013; J. J. Malone et al., 2015), and Australian, Italian (Hands & Janse de Jonge, 2020) and Spanish league players (Oliva-Lozano, Rojas-Valverde, Gómez-Carmona, Fortes, & Pino-Ortega, 2020a). Classic and contemporary match observations suggest professional soccer players cover between 9 and 14 km during match-play (Bangsbo, Nørregaard, & Thorsoe, 1991; Carling & Dupont, 2011; Rampinini et al., 2009). Studies primarily of English players also indicate that during competitive encounters, elite soccer players cover between 0.7–3.9 km high-speed distance (Bradley et al., 2009; Rampinini et al., 2009) and 0.2–0.6 km sprint distance (Mohr et al., 2003; Morgans et al., 2014), while Spanish players in friendly matches cover smaller distances in these same variables (Mallo, Mena, Nevado, & Paredes, 2015). English players are also reported to perform ~656 accelerations and ~612 decelerations during match-play (Russell et al., 2016), and Spanish players ~581 accelerations (Mallo et al., 2015). It is estimated that players spend the majority (80–90%) of matches performing low and medium intensity activities, whereas the decisive moments of a match largely require high-speed and sprint actions (Bangsbo, 1994; Stølen et al., 2005). However, whilst the match demands have been clearly outlined in professional English players, there remain few match-play studies evaluating the demands of professional Portuguese players. Therefore, elucidating the match demands of professional Portuguese players appears warranted.

During competitive English Premier League matches, there appear to be large differences in the physical running output of different playing positions (Bloomfield, Polman, & O'Donoghue, 2007). The greatest distance seems to be covered by midfield players (11.5 km) (Bangsbo, 1994; Rienzi, Drust, Reilly, Carter, & Martin, 2000), whilst forwards and defenders cover lesser distances during match-play (10–10.5 km) (Bangsbo, 1994). A major limitation of the studies discriminating between playing positions is that small samples are used; thus, findings are often difficult to accurately differentiate across varying positional roles. Therefore, while the running demands during matches appear to differ, there are few large-scale studies of professional players elucidating the match demands between different positional roles. Assessing the difference between positional demands may help tailor individual training processes towards improving training drills for the needs of individual playing positions.

Given that soccer is associated with many complex logistical factors, it is plausible that situational variables influence match running profiles. It has also been identified that performance metrics can differ according to specific match factors (Carling, Bloomfield, Nelson, & Reilly, 2012; Lago, 2009). One such contextual variable shown to influence physical performance is match half, with evidence suggesting that greater running distance is covered during the 1st half versus the 2nd half of matches (Barros et al., 2007; Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2007). Match location impacts technical performance (González-Rodenas et al., 2019), although few large-scale studies have assessed whether competing in home or away matches can influence the physical running metrics of soccer players. Another factor that has been investigated for its impact on performance is match status (Lago, 2009), which refers to whether a team wins, draws or loses a competitive match. Spanish La Liga soccer players are reported to cover greater distances when losing versus matches that are being drawn or won (Castellano et al., 2011). These findings are consistent with a separate study also evaluating the running profiles of Spanish La Liga players, which demonstrates that lesser high-speed running is performed when winning versus losing matches (Lago et al., 2010). Further research is required that develops an understanding of the influence of situational variables on soccer-specific running metrics across different leagues and countries. Considering the different cultures across European countries, it is logical to assume that the contextual variables influencing performance in some leagues may not apply to other countries. Therefore, assessing the influence that situational variables have on physical performance in professional Portuguese players will provide novel interpretations.

The aim of this study was to evaluate the physical performance of professional Portuguese soccer players across different positional roles. The interactive effects between match half, location, and status on physical performance metrics across official Portuguese matches were also assessed.

2.2.3 Methods

Experimental Approach to the Problem

A quasi-experimental design was used to evaluate the activity profile of different positional roles in competitive professional soccer matches. Those who played the entire 90 min (including added time) during the 2019–2020 (August to May) season were included for analyses. The matches were played between 11:00 am and 20:30 pm, and all players refrained from strenuous activity for 24 h prior to each match. All matches were played on natural turf. Given the observational nature of the research, no intervention or attempts were made to influence players performance, nor was any feedback provided to players throughout the entirety of data collection.

Participants

A total of 25 professional soccer players (age: 24.9 ± 4.2 years, stature: 180.9 ± 6.3 cm and body mass: 78.5 ± 8.5 kg) were monitored over 11 official matches in the Portuguese LigaPro (second tier). The players were classified into six different positions: goalkeepers (GK), wide defenders (WD), central defenders (CD), center midfielder (CM), open attackers (OA) and center forward (CF). The athletes who did not complete the entire duration of all 11 matches were excluded from analyses (n = 38). Each player provided informed consent, as did the leadership of the Coimbra Academic Association club. This study was approved by the scientific council and the ethics committee of the University of Coimbra (CE/FCDEF-UC/00692021). At the beginning of the season each player was evaluated by the club's medical staff and underwent the Portuguese Football Federation's mandatory medical examinations.

Experimental Procedure

Stature was determined using a SECA wall stadiometer (range 10–230 cm, division 1 mm). Body mass was determined through a multifrequency bioimpedance device (InBody770). Players voided their bowels and bladder before anthropometric characteristics were taken (Saunders, Blevins, & Broeder, 1998). Assessments were conducted ≥3 h after the last meal with each player consuming approximately 500 mL of water ~2 h before evaluation to standardise hydration. Matches were analysed both across halves (1st and 2nd) and 15-min segments (0–15, 16–30, 31–45, 46–60, 61–75, 76–90 min). Additional ('injury') time for the first and second halves were also separated for analyses. The data were filtered to exclude any activity before kickoff (warm-up), during and reactivation after half-time, and cool-down at the end of the match.

Match data were recorded using portable GNSS (SPI HPU, GPSports, Canberra, Australia) at a sampling frequency of 15 Hz. These devices have reported good inter-unit reliability (coefficient of variation [CV]: 1.9% for TD, 7.6% for speeds of 3.8–5.5 m/s/s and 12.1% for speeds ≥ 5.5 m/s/s). Previous models of the 15 Hz units have revealed a degree of error for TD (1.1%) and maximum speed running (< 1%) (Johnston, Watsford, Kelly, Pine, & Spurrs, 2014; Mara, Thompson, & Pumpa, 2016). At the end of each match, the data from the GNSS devices were extracted using the manufacturer's software (Team AMS, Canberra, Australia). Match activities were categorised as the following: standing, very low speed walking (0–5.9 km·h−1), low speed walking (6–11.9 km·h−1), low speed jogging (12–13.9 km·h−1), medium speed running (14–17.9 km·h−1), high speed running (18–23.9 km·h−1) and sprinting (24 km·h−1). The different speed thresholds form the 11 official matches are summarised in Table 1.

Table 2.2.3.1. Speed thresholds for the reported match variables

Variables	Abbreviation		Rank
Total distance	TD m		0 - ≤ 24 km/h
Total distance by parts	TDP m		0 - ≤ 24 km/h
Zone 1 distance	ZD1 m	standing. walking very low intensity	0 – 5.9 km/h
Zone 2 distance	ZD2 m	low intensity walking	6 – 11.9 km/h
Zone 3 distance	ZD3 m	jog at low intensity	12 – 13.9 km/h
Zone 4 distance	ZD4 m	running at medium intensity	14 – 17.9 km/h
Zone 5 distance	ZD5 m	running high speed	18 – 23.9 km/h
Zone 6 distance	ZD6 m	Sprint	≤ 24 km/h
Sum distances (1,2,3)	ΣD m (1,2,3)		0 – 13.9 km/h
Sum distances (4,5,6)	ΣD m (4,5,6)		14 - ≤ 24 km/h
Acceleration 1	Acc1 m/s/s		1.0 – 1.9 m/s/s
Acceleration 2	Acc2 m/s/s		2.0 – 2.9 m/s/s
Acceleration 3	Acc3 m/s/s		3.0 – 4.0 m/s/s
Sum Accelerations (1,2,3)	ΣAcc (1,2,3) m/s/s		1.0 – 4.0 m/s/s
Deceleration 1	Des1 m/s/s		1.0 – 1.9 m/s/s
Deceleration 2	Des2 m/s/s		2.0 – 2.9 m/s/s
Deceleration 3	Des3 m/s/s		3.0 – 4.0 m/s/s
Sum Deceleration (1,2,3)	ΣDes (1,2,3) m/s/s		1.0 – 4.0 m/s/s
Maximum speed	MS km/h		≤ 24 km/h

Statistical Analysis

Data were not normally distributed, and thus, non-parametric tests were used for analyses. Kruskal–Wallis was used to compare performance between the different positions and according to the match result. A Mann–Whitney U was performed for comparisons of match location and match half. Data were analysed using Statistical Package for the Social Sciences (IBM SPSS Statistics 24 for Windows; SPSS Inc., Chicago, IL, U.S.). Significance was accepted at $p \leq 0.05$ prior to analyses.

2.2.4 Results

Detailed results according to playing position are presented in Table 2 and be-tween-group comparisons in Table 3. The lowest TD was performed by CD, while the highest TD was covered by CM (10.787 ± 1.536 m; $p < 0.001$). The greatest high-speed distance in the sum of ZD4, 5 and 6 was performed by OA versus all other positions ($p < 0.001$). The WD, MC and OA demonstrated significantly higher values for the sum of accelerations and decelerations compared with CD and CF ($p < 0.001$).

Table 2.2.4.1. Distances covered across each speed threshold according to each playing position (Data are reported as mean ± SD)

Variables	GK *n* = 11			WD *n* = 31			CD *n* = 42			CM *n* = 34			OA *n* = 28			CF *n* = 14			Differences Between Positions	
	Mean		SD	Mean		SD	Mean		SD	Mean		SD	Mean		SD	Mean		SD	H de Kruskal-Wallis	Sig
TD m	4237.9	±	2342.1	10,582.4	±	504.4	9272.5	±	455.7	10,787.9	±	1536.8	10,640.6	±	1011.4	9336.9	±	673.6	90.451	0.0001
TDP m	2139.2	±	1243.9	5284.0	±	292.7	4636.2	±	263.9	5544.5	±	366.8	5320.3	±	535.8	4668.4	±	439.8	89.757	0.0001
ZD1 m	1320.5	±	139.8	1401.8	±	96.2	1672.0	±	129.1	1382.4	±	122.6	1679.6	±	98.6	1596.8	±	107.2	102.348	0.0001
ZD2 m	533.0	±	581.7	2010.8	±	149.3	1806.1	±	164.4	2175.2	±	209.0	1605.3	±	163.4	1764.3	±	206.4	95.502	0.0001
ZD3 m	92.9	±	158.9	533.6	±	77.8	433.8	±	84.0	692.0	±	144.0	529.5	±	100.7	375.2	±	63.7	92.521	0.0001
ZD4 m	126.4	±	260.6	707.3	±	115.2	475.6	±	102.7	853.9	±	194.3	741.8	±	172.2	479.4	±	56.9	94.934	0.0001
ZD5 m	55.7	±	162.4	472.2	±	110.0	211.8	±	58.3	380.9	±	95.1	561.4	±	143.2	338.4	±	71.2	107.543	0.0001
ZD6 m	8.5	±	28.3	155.1	±	76.5	33.9	±	23.9	56.9	±	41.1	199.6	±	89.9	110.9	±	64.9	102.121	0.0001
ΣD m (1,2,3)	1947.8	±	800.4	3947.8	±	222.4	3913.4	±	217.2	4251.2	±	246.7	3816.1	±	248.0	3737.8	±	310.3	63.108	0.0001
ΣD m (4,5,6)	191.4	±	451.0	1336.2	±	227.7	722.8	±	149.1	1293.3	±	251.1	1504.3	±	362.8	930.5	±	161.5	105.854	0.0001
Acc1 m/s/s	34.5	±	35.0	117.5	±	19.4	107.2	±	14.8	135.0	±	23.4	103.6	±	16.4	87.1	±	12.1	71.114	0.0001
Acc2 m/s/s	9.6	±	10.6	43.1	±	8.1	26.8	±	6.9	36.8	±	12.5	48.3	±	13.0	33.2	±	6.8	76.501	0.0001
Acc3 m/s/s	1.7	±	1.6	8.8	±	3.9	3.3	±	2.1	4.9	±	2.7	11.3	±	3.7	10.8	±	4.7	92.085	0.0001
ΣAcc (1,2,3) m/s/s	45.8	±	46.6	169.3	±	23.0	137.4	±	16.9	176.7	±	33.7	163.3	±	28.1	131.1	±	16.3	69.553	0.0001
Des1 m/s/s	31.7	±	28.0	99.3	±	15.5	95.5	±	12.7	116.1	±	17.8	83.1	±	12.5	74.9	±	10.7	81.279	0.0001
Des2 m/s/s	8.2	±	9.1	36.5	±	7.5	26.4	±	5.8	38.9	±	11.5	39.4	±	9.0	28.0	±	6.3	69.645	0.0001
Des3 m/s/s	2.5	±	4.6	17.9	±	5.2	10.4	±	4.2	12.9	±	5.2	25.6	±	7.7	19.8	±	4.1	90.250	0.0001
ΣDes (1,2,3) m/s/s	42.4	±	41.0	153.7	±	15.6	132.2	±	15.8	167.9	±	30.3	148.1	±	23.7	122.7	±	15.7	68.209	0.0001
MS km/h	20.2	±	3.1	29.7	±	1.9	27.4	±	2.2	28.0	±	2.1	30.6	±	1.5	30.6	±	2.0	70.830	0.0001

Note. Goalkeeper = GK Wide defenders = WD, central defenders = CD, center midfielder = CM, open attackers = OA) and center forward = CF.

Table 2.2.4.2. Comparisons between playing positions for each of the speed thresholds

Variables	WD >	CF >	CM >	OA >	CF >
TD m	CF**/CF**		WD**/CF**/CF**	CF**/CF**	
TDP m	CF**/CF**		WD**/CF**/CF**	CF**/CF**	
ZD1 m		WD**/CM**		WD**/CM**/CF**	WD**
ZD2 m	CF**/OA**/CF**	OA**	WD**/CF**/OA**/CF**		OA**
ZD3 m	CF**/CF**	CF*	WD**/CF**/OA**/CF**	CF**/CF**	
ZD4 m	CF**/CF**		WD**/CF**/CF**	CF**/CF**	
ZD5 m	CF**/CM**/CF**		CF**	WD**/CF**/CM**/CF**	CF**
ZD6 m	CF**/CM**/CF**		CF**	WD*/CF**/CM**/CF**	CF**/CM**
ΣD m (1,2,3)	OA*/CF**		WD**/CF**/OA**/CF**		
ΣD m (4,5,6)	CF**/CF**		CF**/CF**	WD**/CF**/CM**/CF**	CF**
Acc1 m/s/s	CF*/OA**/CF**	CF**	WD**/CF**/OA**/CF**	CF**	
Acc2 m/s/s	CF**/CM*/CF**		CF**	CF**/CM**/CF**	CF**
Acc3 m/s/s	CF**/CM**		CF**	WD*/CF**/CM**	CF**/CM**
ΣAcc (1,2,3) m/s/s	CF**/CF**		CF**/CF**	CF**/CF**	
Des1 m/s/s	OA** /CF**	OA**/CF**	WD**/CF**/OA**/CF**	CF*	
Des2 m/s/s	CF**/CF**		CF**/CF**	CF**/CF**	
Des3 m/s/s	CF**/CM**		CF*	WD**/CF**/CM**/CF**	CF**/CM**
ΣDes (1,2,3) m/s/s	CF**/CF**		CF**/OA*/CF**	CF**/CF**	
MS km/h	CF**/CM**			WD**/CF**/CM**	CF**/CM**

Note. GK comparisons are omitted from analyses. wide defenders = WD, central defenders = CD, center midfielder = CM, open attackers = OA) and center forward = CF. * $p \leq 0.05$; ** $p \leq 0.001$.

It was identified that TD was higher for the tied and won matches (10.395 ± 87 m, and 9.978 ± 1.962 m, respectively) versus lost matches (9.414 ± 2.050 m). Significant differences were found for TD between drawing and losing ($p = 0.036$) and winning and losing ($p = 0.006$) (Table 4).

Table 2.2.4.3. Distances covered across each speed threshold when the teams drew, lost, or won (Data reported as mean ± SD)

Variables	Draw $n = 14$			Lose $n = 76$			Win $n = 70$			Difference Between Groups		Difference Between Pairs		
	Mean		SD	Mean		SD	Mean		SD	H de Kruskal-Wallis	Sig	D >	L >	W >
TD m	10,395.1	±	875.0	9414.9	±	2050.2	9978.5	±	1962.5	9.342	0.009	*p**		*p* **
TDP m	5197.6	±	452.4	4707.5	±	1048.2	5062.4	±	899.2	9.170	0.010			*p* **
ZD1 m	1518.4	±	186.3	1496.6	±	185.7	1565.6	±	175.2	3.996	0.136			*p* *
ZD2 m	1905.3	±	270.2	1706.6	±	489.2	1875.5	±	428.5	10.052	0.007			*p* **
ZD3 m	533.1	±	95.8	475.1	±	196.8	511.7	±	177.6	3.518	0.172			
ZD4 m	675.3	±	183.1	597.3	±	251.9	642.3	±	259.0	1.361	0.506			
ZD5 m	433.5	±	165.0	339.4	±	183.0	367.0	±	178.3	3.209	0.201			
ZD6 m	128.9	±	104.7	89.4	±	83.8	97.1	±	89.9	2.443	0.295			
ΣD m (1,2,3)	3958.3	±	179.6	3679.8	±	680.1	3954.4	±	570.5	20.241	0.000			*p* **
ΣD m (4,5,6)	1239.2	±	423.4	1027.6	±	458.0	1108.0	±	462.7	2.312	0.315			
Acc1 m/s/s	116.6	±	22.2	103.0	±	34.0	111.1	±	28.7	4.960	0.084			*p* *
Acc2 m/s/s	36.9	±	11.2	34.6	±	13.7	35.6	±	15.4	0.151	0.927			
Acc3 m/s/s	7.9	±	4.9	6.6	±	4.8	6.4	±	4.4	1.019	0.601			
ΣAcc (1,2,3) m/s/s	161.4	±	27.2	144.2	±	45.1	153.1	±	41.0	2.851	0.240			
Des1 m/s/s	94.2	±	17.4	89.3	±	29.0	95.0	±	23.4	2.407	0.300			
Des2 m/s/s	33.7	±	6.8	31.3	±	12.2	32.9	±	12.4	0.665	0.717			
Des3 m/s/s	18.1	±	7.9	14.6	±	8.1	15.5	±	8.6	2.141	0.343			
ΣDes (1,2,3) m/s/s	146.0	±	21.5	135.2	±	42.2	143.4	±	35.3	2.586	0.274			
MS km/h	29.8	±	1.8	28.1	±	3.4	28.3	±	3.2	3.944	0.139	*p* *		

* $p \leq 0.05$; ** $p \leq 0.001$.

No significant differences were observed for average TD covered between the 1st (4942 ± 945 m) and 2nd (4868 ± 980) halves ($p = 0.432$). A decrease in the total number of decelerations in the 2nd half versus the 1st half was also identified ($p = 0.036$) (Table 5). Greater TD ($p = 0.0002$), TDP ($p = 0.0008$) and total displacements at low intensity ($p = 0.00003$) were observed in the home games in versus away matches. A higher num-ber of Acc3 ($p = 0.049$) was observed in the away matches. (Table 6).

Table 2.2.4.4. Distances covered across each speed threshold according to first and second half (data are reported as mean ± SD)

Variables	1st Part $n = 80$			2nd Part $n = 80$			Difference between 1st and 2nd part			
	Mean		SD	Mean		SD	U de Mann-Whitney	Sig	1st >	2nd >
TDP m	4942.7	±	945.2	4868.6	±	980.5	2969.5	0.432		
ZD1 m	1483.3	±	176.6	1574.1	±	179.3	2320.5	0.003		1st *
ZD2 m	1829.3	±	437.2	1766.5	±	471.0	2814.5	0.188		
ZD3 m	500.6	±	183.9	491.8	±	181.2	3124.0	0.795		
ZD4 m	639.9	±	254.0	607.7	±	246.5	2950.0	0.394		
ZD5 m	380.1	±	186.1	339.3	±	173.2	2776.0	0.148		
ZD6 m	106.5	±	91.9	86.0	±	84.3	2785.5	0.157		
ΣD m (1,2,3)	3814.7	±	585.8	3834.0	±	650.9	2987.0	0.467		
ΣD m (4,5,6)	1128.0	±	471.1	1034.6	±	444.0	2777.0	0.149		
Acc1 m/s/s	110.1	±	31.8	105.4	±	30.4	2819.0	0.193		
Acc2 m/s/s	36.1	±	15.2	34.4	±	13.3	3039.5	0.584		
Acc3 m/s/s	7.0	±	5.1	6.3	±	4.2	3072.5	0.663		
ΣAcc (1,2,3) m/s/s	153.1	±	43.1	146.1	±	41.2	2742.0	0.118		
Des1 m/s/s	94.5	±	26.5	90.0	±	25.1	2892.0	0.293		
Des2 m/s/s	33.6	±	12.5	30.7	±	11.2	2721.0	0.102		
Des3 m/s/s	16.3	±	9.0	14.3	±	7.5	2803.0	0.175		
ΣDes (1,2,3) m/s/s	144.4	±	38.7	135.1	±	36.7	2585.5	0.036	2nd *	
MS km/h	28.5	±	3.6	28.1	±	2.9	2761.5	0.134		

* $p \leq 0.05$; ** $p \leq 0.001$.

Table 2.2.4.5. Distances covered across each speed threshold when the teams competed home or away (Data reported as mean ± SD)

Variables	Local *n* = 60		Visit *n* = 100		Difference between groups			
	Mean	SD	Mean	SD	U de Mann-Whitney	Sig	L >	V >
TD m	10,208.0	± 1926.2	9470.8	± 1932.4	1948.0	0.0002	V **	
TDP m	5104.0	± 974.1	4786.6	± 937.4	2050.5	0.0008	V **	
ZD1 m	1549.8	± 190.3	1516.1	± 178.5	2719.0	0.3220		
ZD2 m	1892.5	± 476.4	1741.1	± 432.6	2109.5	0.0017	V **	
ZD3 m	530.5	± 193.3	475.6	± 172.7	2315.0	0.0158	V **	
ZD4 m	654.9	± 266.3	605.1	± 239.2	2648.0	0.2147		
ZD5 m	370.5	± 189.4	353.2	± 175.4	2866.0	0.6367		
ZD6 m	102.6	± 97.5	92.4	± 82.9	2896.0	0.7138		
ΣD m (1,2,3)	3974.3	± 625.1	3734.3	± 597.8	1666.0	0.000003	V **	
ΣD m (4,5,6)	1129.7	± 483.0	1052.3	± 443.4	2691.0	0.2761		
Acc1 m/s/s	111.7	± 32.1	105.3	± 30.4	2518.5	0.0896		
Acc2 m/s/s	34.4	± 15.5	35.7	± 13.5	2806.0	0.4940		
Acc3 m/s/s	5.6	± 4.0	7.3	± 4.9	2444.0	0.0493		L *
ΣAcc (1,2,3) m/s/s	151.8	± 44.4	148.3	± 41.0	2826.5	0.5408		
Des1 m/s/s	96.0	± 26.2	90.0	± 25.4	2464.0	0.0588		
Des2 m/s/s	34.1	± 12.9	31.0	± 11.2	2596.5	0.1547		
Des3 m/s/s	14.2	± 8.4	16.0	± 8.2	2603.5	0.1618		
ΣDes (1,2,3) m/s/s	144.3	± 39.4	137.0	± 36.9	2497.0	0.0762		
MS km/h	28.2	± 3.2	28.4	± 3.3	2906.0	0.7404		

L = local; V = Visit; * $p \leq 0.05$; ** $p \leq 0.001$.

The results revealed that the highest number of sprints were performed by OA (n = 5.39 ± 2.6), while the CD (n = 2.47 ± 1.5) showed the lowest values (p = 0.000). Furthermore, the highest number of sprints based in accelerations (SBA) were performed in Q1 (n = 5.04 ± 2.9), while the lowest frequencies were identified during Q4 (n = 3.77 ± 2.5) (table 7).

Table 2.2.4.6. Summary of each 15-min period of matches, playing positions, match result, first and second half and match location (Data reported as mean ± SD)

Variables		*n*	Mean	SD	H de Kruskal-Wallis	Sig	U de Mann-Whitney
Quartile	**00-15 = Q1 >**	378	5.04	±2.9	82.234	0.000	Q4 **/Q5 */Q7 **/Q8 **
	16-30 = Q2 >	360	4.68	±3.0			Q7 **/Q8 **
	31-45 = Q3 >	335	4.72	±2.8			Q4 */Q7 **/Q8 **
	46-60 = Q4 >	264	3.77	±2.5			Q7 **/Q8 **
	61-75 = Q5 >	287	3.99	±2.5			Q7 **/Q8 **
	76-90 = Q6 >	319	4.09	±2.2			Q7 **/Q8 **
	More of 45 = Q7 >	28	1.27	±0.5			
	More of 90 = Q8 >	106	2.12	±1.1			Q7 **
Positions	**GK >**	41	1.71	±1.0	107.057	0.000	
	WD >	526	4.78	±2.7			GK **/CD **
	CD >	301	2.47	±1.5			GK **
	CM >	444	4.11	±2.6			GK **/CD **/
	OA >	544	5.39	±2.6			GK **/CD **/CM **/CF *
	CF >	221	4.42	±2.8			GK **CD **
Result	**D >**	400	4.35	±2.9	1.091	0.579	No difference
	L >	761	3.90	±2.6			
	W >	916	4.02	±2.6			
Parts	**1st >**	1104	4.52	±2.9			27,322.0 / 0.001 / 2da **
	2nd >	973	3.59	±2.3			
Place	**Local**	702	3.84	±2.6			465,352.0 / 0.433 / No Dif
	Visit	1375	4.14	±2.7			

* $p \leq 0.05$; ** $p \leq 0.001$.

2.2.5 Discussion

The aim of this study was to analyse performance in professional Portuguese soccer players across different playing positions and contextual variables. Different positions require different physical demands, which are influenced by the location of the match and the result. Overall, players covered a mean TD of 9839 ± 1929 m, with midfielders covering the greatest distance and central defenders performing the least TD. Wingers covered the most high-speed distance, number of decelerations (3.0–4.0 m/s/s) and were the fastest players, along with center forwards. Players performed greater distances when their team drew or won, and reductions for some running metrics were observed in the 2nd half of matches. The number of faster accelerations (3.0–4.0 m/s/s) was higher in away versus home games. These data may be considered by coaches and physical practitioners as a guide for the training prescription for their teams.

The TD covered was similar with values reported by studies conducted in soccer players across other European countries (Barnes et al., 2014; Smpokos, Mourikis, & Linardakis, 2018). Specifically, the mean TD covered was similar in the present study for CM (10,788 ± 1537 m) and OA (10,641 ± 1537 1011 m), compared to the 2006–2007 (10,679 ± 956) and 2012–13 (10,881 ± 885 m) seasons in the English Premier League (Barnes et al., 2014). However, lower sprint distances across all playing positions were reported in the present study (≤ 199.6 ± 89.9 m) versus the English Premier League players (232 ± 114 (2006–2007 season) and 350 ± 139 m (2012–2013 season)). Therefore, this study presents novel evidence that soccer players competing in the second Portuguese league cover similar distances during competitive match-play with English Premier League players, but lesser sprint distances. The discrepancy in sprint distance may be reflective of the players across both studies competing in different countries (tactical modifications) and tiers (high-standard athletes). This is largely supported by evidence that suggests high-speed and sprint performance is superior in higher level soccer players during match-play (Mohr et al., 2003). These data indicate that practitioners may direct their focus on the development of sprint capacity to increase physical performance of lower division players during match-play, considering the specific demands of each position for the training prescription, optimizing the preparation process.

High-speed running performance is thought to be capable of discriminating between competitive levels and is a better indicator of physical performance versus TD alone (Barnes et al., 2014). However, a paucity of published information is available on the differences in high-speed running across playing positions in the Portuguese soccer leagues. In relation to high-speed running performance across different playing positions in the current investigation, it appears that CD perform considerably less high-speed activity versus all other positional roles (excluding the GK). This observation largely agrees with a previous study assessing English Championship and Premier League players (Di Salvo et al., 2013). The study found that English championship (540 ± 129 m) and Premier League players (482 ± 116 m) cover considerably less high-speed running distance compared with all other outfield positions, showing significant performance differences between positions. In relation to the WD and OA players, the results are consistent with players of wider positions in the English Premier League high-speed running values (Bush et al., 2015). These results suggest that training programmes for soccer players must be individualised and specific to the demands of the playing position to enhance physical performance during match-play.

The number of accelerations and decelerations present a similar pattern as identified in previous studies, with a greater quantity of actions reported in the 1st half versus the 2nd half (Dalen et al., 2019), but it differs in that the position that performs the greatest number of accelerations in the present study is the CM, while in preparation games in Spanish soccer it is the CD (Mallo et al., 2015), context that can influence these returns. Concerning the playing roles, the highest number of Acc1 (1.0–1.9 m/s/s) was performed by CM, who presented substantially higher values versus all positions. With reference to Acc2 (2.0–2.9 m/s/s), the highest quantity of actions was performed by the OA, who had differences with all positions except the WD, who also presented differences with CD, CF, and CM. Pertaining to Acc3 (3.0–4.0 m/s/s), the OA and CF achieved the highest performance and were considerably different compared to other positions (CM, CD, and WD). This suggests that the quantity of accelerations performed at different speeds varies depending on the demands of the position. These data can, therefore, be used as a guide to inform acceleration-based training paradigms that incorporate the different acceleration loads of each playing position.

Decelerations are also an important component to consider in soccer, since players must frequently decelerate at high speeds, placing lower-limb musculature under a high eccentric loading demand (Mair, Seaber, Glisson, & Garrett, 1996). The number of decelerations (1.0–4.0 m/s/s) performed by CM players was higher than CD, CF, and OA. These results may reflect the greater CM involvement in the game, both in offensive and defensive tasks. However, the OA players performed significantly more Dec3 (3.0–4.0 m/s/s) than other positions. This is possibly linked with the fact that OAs tend to run faster (30.6 ± 1.5) than other players, which necessitates a higher frequency of rapid decelerations. These demanding actions are associated with increased fatigue, which decreases locomotive efficiency at the end of each half in competitive football and thus increases the likelihood of injury incidence (Barrett et al., 2016). In this way, both accelerations and decelerations are another indicator that shows the variability of effort between the different positions; therefore, it is recommended that the functional specificity and movement drills incorporated within training programmes expose players to the quantity of accelerations and decelerations reported in the current data.

Lower performance was observed in the games played away from home, which may be influenced by tactical approaches and defensive strategies adopted to limit the opposition rather than providing an attacking threat (Staufenbiel, Lobinger, & Strauss, 2015). There may also be additional logistical issues involved with travelling that limits players preparation and reduces overall performance output and recovery (Fowler, Duffield, & Vaile, 2014). Thus, this specific aspect should be considered when scheduling the weekly planning and periodisation of training sessions (Kelly & Coutts, 2007). Greater very-low intensity (DZ1) activity was performed in the 2nd half versus the 1st half. This may be a subconscious self-pacing approach to conserve energy during the second half, to avoid significant reductions in high-speed capacity (Di Salvo et al., 2007a) or avoid fatigue-induced injury during the latter stages of match-play (Small, McNaughton, Greig, & Lovell, 2010). It is also possible that the reductions in intensity during the 2nd half are linked to a fatigue-induced inability to perform the actions rather than pacing strategies employed to maintain energy for the final moments of a match (Field et al., 2020). It is integral that physical capacity is maintained for the entire 90 min as approximately 57% of goals are scored in the 2nd half (Michailidis, Michailidis, & Primpa, 2013; Simiyu, 2013). Therefore, it is crucial that players are conditioned to be able to compete for an entire 90 min and that substitutions are utilised for the players incapable of performing the required running output across an entire match (Hills et al., 2018).

The SBA estimated in 6 blocks of 15 min showed a gradual decrease as the game progressed in the 1st half, while during the 2nd half the trend was the opposite and the lowest performance was presented at the beginning and increased during the game. This is perhaps associated with declines in body temperature that occur due to passive recovery in the changing rooms and a short and ineffective reactivation at the beginning of the 2nd half (Mohr, Krustrup, Nybo, Nielsen, & Bangsbo, 2004). This information should be used to better manage reactivation during matches and to create recovery contexts during training sessions that reflect what happens in competition. This may allow optimal adaptation to passive recovery and reduce insufficient performance during the start of each half. Adequate half-time re-warm-up and passive heat maintenance strategies may also enhance performance in the initial stages of the 2nd half (Silva, Neiva, Marques, Izquierdo, & Marinho, 2018). Thus, adherence to such protocols may gain soccer teams the competitive advantage during the early stages of the second half of matches.

2.2.6 Conclusions

The quantification of the demands of second-division Portuguese matches through GNSS devices presents novel perspectives. The current data suggest that the physical demands of each playing position are impacted by match location and result. The demands of each playing position are reported throughout the article, with mid-field players covering the most distance and largely performing the greatest quantity of actions throughout match-play. Players completed greater distances when their teams had a positive result (i.e., won or draw), and running performance largely de-creased in the 2nd half of matches, an observation that is consistent with the literature. Based on the current findings, training drills should be position-specific, where appropriate, to prepare players for the physical capacity and running output of the various positional roles during matches. Future studies are required to evaluate match running profiles across the major European Leagues (German Bundesliga, French Ligue 1 and the Spanish La Liga) to compare with the current data and the wealth of observations available on English Premier League players.

Patents

This section is not mandatory but may be added if there are patents resulting from the work reported in this manuscript.

Author Contributions:

J.B., H.S. and A.J.F. led the project, established the protocol, and wrote and revised the original manuscript. F.M.C. and A.F. wrote and revised the original manuscript. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement:

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

Conflicts of Interest:

The authors declare no conflict of interest.

Chapter II

Study 3

2.3 Study 3

Predictors of Linear Sprint Performance in Professional Football Players

Reference: *Barrera, J., Figueiredo, A. J., Duarte, J. P., Field, A., & Sarmento, H. (2022). Predictors of linear sprint performance in professional football players. Biology of Sport, 40(2), 359-364.*

2.3.1 Abstract

The purpose of this study was to analyze the relationship between sprint performance (time), and strength and power capabilities in football players. A total of 33 professional Portuguese football players performed isokinetic strength assessments, countermovement jumps (CMJ), squat jumps (SJ), and 10, 20 and 30 m sprints. Pearson's correlation (r) was used to determine the relationships between variables. Concentric knee extensor torque at 180 °· s^{-1} was largely-to-very largely correlated with 10 m (r = -0.726), 20 m (-0.657) and 30 m sprints (r = -0.823). Moderate inverse correlation were observed between CMJ (r = - 0.425 and r = -0.405) and SJ height (r = -0.417 and r = -0.430), and 20 m and 30 m sprint performance, respectively. Multiple linear regression combining KEcon 180 ° s^{-1} and KFcon 180 ° s^{-1} demonstrated that the model was significant for predicting 10 m sprint time (F (2, 8) = 5.886; R 2 = 0.595). The model combining SJ, CMJ and KEcon 180 ° s^{-1} was also significant for predicting 20 and 30 m sprint times (F (3, 7) = 2.475; R 2 = 0.515 and F (3, 7) = 5.282; R 2 = 0.562; respectively). In conclusion, peak torque at higher velocities and vertical jump performance correlates significantly with linear sprint performance (time). For practitioners seeking to improve linear sprint performance in football players, evaluation of high-speed strength and vertical jump indices should be undertaken.

Keywords: strength, speed, evaluation, football, professional players.

2.3.2 Introduction

Football matches involve activity of varying speeds, with high intensity efforts performed approximately every 60 seconds (Stølen et al., 2005) and accounting for ~10% of total match running. Matches elicit a greater demand on the aerobic system, although, the decisive 'game defining' moments are largely covered through sprint actions that require anaerobic metabolism energy delivery (Stølen et al., 2005). Previous research suggests that 83% of goals scored in the German Bundesliga were preceded by a powerful action from either the assisting or scoring player (Faude, Koch, & Meyer, 2012). The same study also found that players completed a straight-line sprint before 45% of goals scored in the highest competitive level of German football (Faude et al., 2012). Furthermore, coaches and sports scientists seek practical and time-efficient methods to improve top running sprint performance and acceleration capabilities in team sport athletes (Loturco et al., 2017). Accordingly, determining the important physical characteristics of professional football players will enhance understanding of the underlying determinants that influence their sprint performance.

Actions such as changes of direction, jumping, tackling, accelerating and decelerating (Rennie et al., 2020), require high-force muscular contractions (Stølen et al., 2005). These activities change every 5 seconds and are carried out around 1300 times per match with ~200 of these actions performed at high or maximum intensity (Bangsbo, Mohr, & Krustrup, 2006). Therefore, the sprint performance of the movement during competitive match-play is possibly associated with explosive strength and power production, but requires further investigation. To this end, identifying the key power and strength qualities that impact linear sprint performance could help inform individualized training programs that focus on improving the key elements that influence this variable.

Explosive force plays a fundamental role in football (Hlavonova et al., 2017), which is influenced by the interaction of different morphological and neural factors. These include muscle cross-sectional area, muscle architecture, motor unit recruitment, fibre type distribution, and neuromuscular inhibition (Christian et al., 2020). Measurable strength and power variables, such as knee flexor and extensor muscle strength and jumping performance may predict linear sprint performance and allow differentiation between professional and amateur players (Cometti et al., 2001). Laturco et al. (Loturco, Pereira, et al., 2020) demonstrated that vertical jump ability is significantly associated with linear and curvilinear sprint performance. A separate investigation also found that professional football players possessing higher lower extremity strength (i.e. maximum isometric knee extensor force and 1RM half squat) demonstrated superior sprint performance at 5 m and 30 m, and countermovement jump height (CMJ) (Boraczynski, Boraczynski, Podstawski, Wojcik, & Gronek, 2020). Similarly, a positive relationship was found between knee extensor force (240 ° s^{-1}) and 30-m sprint performance in elite football players (Hlavonova et al., 2017). Contemporary research suggests that professional players need to significantly increase their strength to obtain slight improvements in certain running-based actions (sprint and change of direction speed) (Silva, Nassis, & Rebelo, 2015), controlling for strength deficits which appear to impair sprinting performance (Loturco et al., 2021). This may be due to fixture congested contemporary schedules, making it difficult to periodize strength training programmes and apply appropriate loads (Weldon et al., 2021b). Therefore, due to equivocal data on predictors of linear sprint performance, more research is required.

Since the interaction between strength/power and speed is highly complex, further investigation seems warranted encompassing multiple predictor variables (e.g., jump measures and isokinetic measures) in the same multiple hierarchical linear regression models. Therefore, the objective of this study was to evaluate strength and power variables and their relationship with sprint performance (time) in professional players competing in the second highest professional division in Portugal to determine predictors of linear sprint performance.

2.3.3 Methods

Participants

A total of 33 professional male football players from Portugal's second highest football division (LigaPro) participated in the study (age: 26.4 ± 4.8 years, stature: 180.9 ± 6.4 cm and body mass: 77.4 ± 8.4 kg). All participants were informed of the procedures and purpose of the study and their written informed consent was obtained. The study was approved by the Ethics Committee of the University of Coimbra (CE / FCDEF-UC / 00692021) and was carried out in accordance with the Declaration of Helsinki (2013).

Body composition

The bioelectrical impedance measurements were conducted using a valid, segmental, multi-frequency bioelectrical impedance analyzer (InBody770; Biospace, Seoul, Korea). Bioelectrical impedance has been shown to be reliable in both men and women. The intraclass correlation coefficients for body fat percentage (BF) ≥0.98, fat mass (FM) ≥0.98 and fat free mass (FFM) ≥0.99 and with a low standard error of measurement for BF (0.77 % –0.99%), FM (0.54–0.87 kg) and FFM (0.58–0.84 kg) and a minimal difference for BF% (2.12% –2.73%), FM (1.49-2.39 kg) and FFM (1.60-2.32 kg). Participants' age, gender and height were initially input by the lead researcher. While participants adopted a standing position with minimal clothing and barefoot, body mass assessments were performed on the scale. The participant then grasped the handles with each hand for the impedance measurements. Total body water (L), fat mass (% and kg), muscle mass (kg), and dominant lower-limb fat (kg) were measured.

Isokinetic strength

Concentric and eccentric peak torque and mean torque (average of 5 repetitions) of the knee extensors and knee flexors were measured using an isokinetic dynamometer (Biodex Medical Systems Inc., Shirley, NY, USA). The isokinetic dynamometer is widely considered the gold standard of muscle strength testing (Dvir & Müller, 2020) and possesses high validity and reliability (Drouin et al., 2004). Dynamometer calibration was performed as per manufacturer guidelines. A 5-min warm-up was performed, which involved participants pedaling between 50 and 60 rpm using a cycle ergometer (814E Monark, Varberg, Sweden) with a resistance corresponding to 2% body mass (Brown, 2000). Participants were seated and straps were applied across the trunk, pelvis, and thigh to reduce excessive movement artefact. The crank axis of rotation was aligned to the lateral femoral epicondyle of the knee and the cuff on the padded lever arm was placed 5-cm proximal to the malleoli. Before isokinetic assessments, the tested limb remained passive and was weighed at 30° to correct for the effects of gravity (Osternig, 1986). The repetitions were performed through a range of 5 − 90° (5° close to full extension). A familiarization session was initially undertaken to minimize learning effects (three repetitions). Five repetitions were performed for each movement at angular velocities of 60 and 180° s^{-1}. Outputs were analyzed with the Acknowledge software version 4.1 (Biopac Systems, Inc., Goleta, CA, USA). Each curve was inspected to consider true isokinetic torques within 95% confidence limits (Duarte, Valente-dos-Santos, Coelho-e-Silva, Couto, et al., 2018).

Countermovement Jump (CMJ) and Squat Jump (SJ)

Countermovement jump (CMJ) and squat jump (SJ) height were measured using a portable optical measurement system (Optojump, Microgate, Bolzano, Italy). The intraclass correlation coefficients (ICC) for this measurement protocol has demonstrated good reliability (ICC = 0.997-0.998). Test-retest reliability of the Optojump system has demonstrated excellent ICCs (0.982 to 0.989), low coefficients of variation (2.7% and 3.98%) and low random error (0.8 and 2.81 cm) (Attia et al., 2017; Glatthorn et al., 2011). For CMJ, players were instructed to stand with their feet shoulder width apart and maintain hand-to-hip contract to negate the influence of arm swing on jump height. When prompted, participants descended rapidly into a ~60° squat position and immediately jumped vertically with maximum effort landing in the same position as takeoff. The SJ consisted of jumping from a fixed semi-squat position with the hands also placed on the hips. Whilst adopting a standing position, the participants were instructed to flex at the knees to ~90° and jump maximally. The participants had to avoid as much as possible any countermovement, and they were instructed to stop for 2 seconds at each phase. Three maximal efforts were performed for both jumps with 30 seconds passive recovery between jumps; the best score was retained for analyses.

Linear sprint performance (time) 10, 20 m and 30 m shuttle

Linear sprint performance (time) was recorded for 10, 20, and 30 m sprint tests. Sprint times were recorded with three pairs of photocells (SpeedTrap II, Brower Timing Systems, Utah, USA). The photocells were placed at the start and finish (10, 20 and 30 m mark). The tests were undertaken on natural turf and conditions were standardised between repeated measures. Each sprint was performed from a standing start position and was separated by 25 seconds of active recovery. The best sprints times taken at each distance were used for analyses.

Statistical analysis

Descriptive statistics (mean, standard error of the mean [SEM], 95% confidence interval [CI], and standard deviation [SD]) were carried out, and normality checked with the Shapiro-Wilk test. Two variables displayed non-normal distributions, and subsequently, these data were logarithmically transformed to counter the effects of non-normality. Therefore, for the first stage of data analysis, a two-tailed Pearson's correlation (r) was used, with 1000 bootstrap samples. For correlations, the following criteria, whether positive or negative, were used to interpret the magnitude of r: <0.1, trivial; 0.1-0.3, small; 0.3-0.5, moderate; 0.5-0.7, large; 0.7-0.9, and very large; 0.9-1.0, almost perfect (Bonilla et al., 2020). All predictors that indicated a moderate (i.e., r = ≥0.3) and significant correlation were kept for further analyses, while all other variables were omitted. Multiple hierarchical linear regressions were used as appropriate with the remaining predictor variables and their dependant variable correlates. Significance and relative contribution of predictors were determined using a combination of standardized Beta values, t-statistics (i.e., the predictor makes a significant contribution to the model), and 95% confidence intervals. Statements were made regarding the magnitude of change in the dependant variables resulting from a 1 SD change (increase or decrease) in the predictor variable. All analyses were performed using the Statistical Package for the Social Sciences version 26.0 (SPSS Inc., IBM Company, Armonk, NY, USA).

2.3.4 Results

Table 1 presents the participants' morphological characteristics. Descriptive statistics for sprints, jump variations and isokinetic strength are presented in Table 2.

Moderate and significant correlations are outlined in Table 3 for four predictor variables (SJ, CMJ height, KEcon and KFcon). The multiple regression model combining KE and KF at 180º/s was found to be significant for predicting 10 m ($F(2, 8) = 5.886$: $p < 0.05$; $R^2 = 0.595$), 20 m ($F(3, 7) = 2.475$: $p = 0.146$; $R^2 = 0.515$) and 30 m sprint times ($F(3, 7) = 5.282$: $p < 0.05$; $R^2 = 0.562$) (Table 4).

Table 2.3.4.1. Descriptive statistics and normality test considering age, experience, anthropometry, and body composition for the total sample (n=33)

variables	units	mean			SD	Shapiro-Wilk	
		value	SEM	95% CI		value	*p*
Chronological age	years	26.4	0.8	(24.7 to 28.1)	4.8	0.957	0.224
Training experience	years	17.7	1.0	(15.7 to 19.7)	5.5	0.938	0.059
Stature	cm	180.9	1.1	(178.6 to 183.2)	1.1	0.972	0.565
Body mass	kg	77.4	1.5	(74.4 to 80.4)	1.5	0.954	0.189
Total body water	L	48.4	0.8	(46.6 to 50.1)	4.9	0.985	0.925
Fat mass	%	14.2	0.5	(13.2 to 15.3)	3.0	0.978	0.751
Fat mass	kg	11.1	0.5	(10.0 to 12.2)	3.0	0.962	0.318
Muscle mass	kg	37.8	0.7	(36.4 to 39.2)	3.9	0.980	0.803
Inbody dominant lower-limb fat	kg	1.66	0.1	(1.52 to 1.81)	0.4	0.945	0.098

Abbreviations: SEM (standard error of the mean); CI (confidence interval); SD (standard deviation).

Table 2.3.4.2. Descriptive statistics and normality test considering acceleration, speed/velocity, strength and jumping performance for the total sample (n=33)

variables	units	mean			SD	Shapiro-Wilk	
		value	SEM	95% CI		value	*p*
Sprint 10 m	s	1.57	0.02	(1.52 to 1.61)	0.13	0.952	0.163
Sprint 20 m	s	2.99	0.03	(2.92 to 3.05)	0.03	0.937	0.063
Sprint 30 m	s	4.55	0.04	(4.46 to 4.63)	0.24	0.973	0.589
Squat jump (SJ)	cm	36.0	0.8	(34.4 to 37.6)	4.4	0.975	0.660
Countermovement jump (CMJ)	cm	37.2	1.0	(35.2 to 39.1)	5.5	0.969	0.483
KE isokinetic concentric muscular action 60°/s	Nm	254.1	7.4	(238.9 to 269.2)	42.7	0.963	0.321
KF isokinetic concentric muscular action 60°/s	Nm	146.0	4.0	(137.8 to 154.2)	23.1	0.964	0.352
KE isokinetic eccentric muscular action 60°/s	Nm	317.0	13.4	(289.8 to 344.2)	76.7	0.983	0.887
KF isokinetic concentric muscular action 60°/s	Nm	197.4	6.5	(184.1 to 210.8)	37.6	0.957	0.224
KE isokinetic concentric muscular action 180°/s	Nm	170.5	6.6	(155.6 to 185.3)	22.1	0.967	0.853
KF isokinetic concentric muscular action 180°/s	Nm	110.1	4.0	(101.1 to 119.1)	13.4	0.920	0.315
KE isokinetic eccentric muscular action 180°/s	Nm	285.9	15.2	(257.5 to 312.9)	45.6	0.921	0.404
KF isokinetic concentric muscular action 180°/s	Nm	170.5	7.6	(154.9 to 185.0)	22.7	0.972	0.915

Abbreviations: SEM (standard error of the mean); CI (confidence interval); SD (standard deviation).

Table 2.3.4.3. Bivariate correlations between strength and sprint performance

Variable	units	Linear sprinting (s)					
		10 m		20 m		30 m	
		p	r	*p*	r	*p*	r
Squat jump (SJ) height	cm	0.198	−0.230	0.018	−0.417*	0.014	−0.430*
Countermovement jump (CMJ) height	cm	0.347	−0.169	0.015	−0.425*	0.022	−0.405*
KE isokinetic concentric muscular action 60°/s	Nm	0.895	0.024	0.089	−0.306	0.273	−0.200
KF isokinetic concentric muscular action 60°/s	Nm	0.230	0.215	0.203	−0.231	0.836	−0.038
KE isokinetic eccentric muscular action 60°/s	Nm	0.927	−0.017	0.388	−0.158	0.698	−0.071
KF isokinetic eccentric muscular action 60°/s	Nm	0.735	−0.061	0.472	−0.132	0.682	−0.075
KE isokinetic concentric muscular action 180°/s	Nm	0.011	−0.726*	0.028	−0.657*	0.002	−0.823**
KF isokinetic concentric muscular action 180°/s	Nm	0.014	−0.712*	0.387	−0.290	0.080	−0.549
KE isokinetic eccentric muscular action 180°/s	Nm	0.551	−0.230	0.186	−0.485	0.188	−0.483
KF isokinetic eccentric muscular action 180°/s	Nm	0.109	0.570	0.705	0.148	0.653	−0.175

Abbreviations: BD (bilateral difference); PT (peak torque); T (torque); KE (knee extension); KF (knee flexion).

*p<0.05

**p<0.001

Table 2.3.4.4. Unstandardized and standardized Beta values for each regression models

Assessment	Variable	*B*	SE	***ß***
10 m sprint	Constant	2.476	0.261	
	KE isokinetic concentric muscular action 180°/s	–0.003	0.002	**–0.440**
	KF isokinetic concentric muscular action 180°/s	–0.004	0.003	**–0.388**
20 m sprint	Constant	4.106	0.521	
	Squat jump (SJ) height	0.019	0.033	**0.411**
	Countermovement jump (CMJ) height	–0.030	0.032	**–0.710**
	KE isokinetic concentric muscular action 180°/s	–0.004	0.003	**–0.428**
30 m sprint	Constant	6.633	0.566	
	Squat jump (SJ) height	–0.021	0.036	**–0.330**
	Countermovement jump (CMJ) height	0.018	0.035	**0.312**
	KE isokinetic concentric muscular action 180°/s	–0.011	0.003	**–0.858***

* Standardized beta values are significant at the $P<0.05$ level.

2.3.5 Discussion

Based on the notion that linear sprint time is key for success in professional football (Faude et al., 2012), the main objective of this study was to determine the relationship between linear sprint time and other physical performance predictors in elite football players. Large and very large relationships were found between 10 m sprint time and KEcon and KFcon at 180 ° s^{-1}, 20 m sprint time and SJ, CMJ and KEcon at 180 ° s^{-1}, and 30 m sprint time and SJ, CMJ and KEcon at 180 ° s^{-1}. Multiple regression analysis evaluates the strength of the relationship between the dependent variable and several predictor variables to facilitate robust conclusions. Such data can be utilised by strength and physical conditioning practitioners to adapt training protocols and optomize linear sprint performance in professional football players.

The current findings that knee extensor strength at higher velocities was correlated with sprint speed are consistent with data derived from similar research (Hlavonova et al., 2017). This investigation demonstrated that there was a significant relationship between knee extensor peak torque at 240° · s^{-1} and 30 m sprint performance. Knee extensor peak torque is thought to be a key determinant for performing rapid knee extension during the swing phase while sprinting (Hori et al., 2021). Sprint performance has also shown to better correlated with knee extensor peak torque at 240° · s^{-1} than the knee flexors (Newman, Tarpenning, & Marino, 2004). Furthermore, a separate investigation reported stronger correlations with isokinetic knee extension strength with faster velocities (150 and 240° · s^{-1}) versus slower speeds of 60° · s^{-1} (Dowson, Nevill, Lakomy, Nevill, & Hazeldine, 1998). Therefore, it seems that the ability to produce greater knee extensor peak torque at high velocities is a positive factor for sprint performance. As such, knee extensor strength may need to be developed at higher speeds in order for sprint ability to be improved. Future research should assess whether training interventions targeting high velocity knee extensor peak torque translates to improvements in sprint performance.

The SJ and CMJ jump tests showed a moderate inverse correlation with 20 m and 30 m sprint performance, but no associations with 10 m sprint performance were identified. These findings are similar to those published in previous studies, suggesting that relative peak power output during the bilateral CMJ is negatively associated with linear sprinting performance over 5, 10, and 20 m in English Premier League football players (Northeast et al., 2019). The findings are also somewhat analogous with another study evaluating 25 professional football players, with strong and negative correlations between CMJ and 30 m sprint performance, but no relationships with 10 m sprint performance (Boraczynski et al., 2020). Therefore, vertical jump height appears to be negatively correlated with sprint performance only at higher distances (i.e., 20 and 30 m). This notion may be related to how the transition from lower to higher speeds results in shorter stance phase duration, with a concomitant increase in maximum vertical force production (Loturco et al., 2015; Nilsson & Thorstensson, 1989). This in turn leads to an increase in flight time and stride length (Weyand, Sternlight, Bellizzi, & Wright, 2000), but these factors may not have chance to influence sprint time over such short distances (Nilsson & Thorstensson, 1989), perhaps explaining the lack of correlation for 10 m sprint performance. The ability to produce maximum force rapidly is a requirement for explosive jump performance — which is also a prerequisite for rapidly accelerating over short distances and reaching high speeds (Boraczynski et al., 2020). These actions are integral moments in match-play and occur during the decisive phases of play (Loturco, Bishop, Freitas, Pereira, & Jeffreys, 2020). Therefore, this information is important for practitioners with a training focus geared towards developing linear sprint and acceleration capacity.

The current study provides novel insights into the physical determinants of linear sprint performance in football although, the findings must be considered within the constraints of professional sports. Firstly, there are an absence of measures assessing horizontal jump performance, despite previous research demonstrating that horizontal ground reaction forces are more predominantly involved in top-speed acceleration (Robbins, 2012). Therefore, this must be considered a limitation since horizontal jumping and the associated force vectors may be better predictors of linear sprint performance than solely vertical jump performance and isokinetic strength. Additionally, football players rarely accelerate from a stationary position to maximum speed during matches (Amonette et al., 2014), but are more likely to increase speeds from low-velocity movements. Therefore, the ecological validity of the sprinting mechanics with reference to their translational application in football may be questionable. Further studies should assess the predictive ability of horizontal ground forces across different positional roles in football.

2.3.6 Conclusions

The results in the present study suggest that strength and power variables at faster speeds are associated with linear sprint performance. Professional football players with greater torque at 180 ° s^{-1} had faster sprint times at 10, 20 and 30 m. It is recommended that staff responsible for implementing training regimes should design training protocols that develop knee extensor strength at a higher rate to optimize running performance in professional football players. Another key finding demonstrated that SJ and CMJ are negatively correlated with 20 and 30 m sprint performance. Such relationships between vertical force generation and sprint times indicate that training protocols aimed at increasing lower extremity explosive strength should be incorporated into weekly football microcycles to maximize sprint performance. Future research avenues should explore the predictive capacity of reactive strength markers and horizontal jump indices in football players of different playing levels.

Funding

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Institutional Review Board Statement

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of University of Coimbra (code: CE/FCDEFUC/0069202).

Informed Consent Statement

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

Conflicts of interest

The authors declare no conflict of interest.

Chapter II

Study 4

2.4 Study 4

Contemporary Practices of Physical Trainers in Professional Soccer – A Qualitative Study

Reference: *Barrera-Díaz, J., Figueiredo, A. J., Field, A, Ferreira, B., Querido, S., Silva J. R., Ribeiro, J., Pinto, I., Cornejo, P., Torres, H., Saffa, A., & Sarmento, H. (20XX). Contemporary practices of physical trainers in professional soccer – a qualitative study.* ***Accepted for publication*** *- Frontiers in Psychology, section Movement Science and Sport Psychology.* Submitted on 18/11/2022.

2.4.1 Abstract

Physical trainers (PTs) are integral for managing load, reducing injury and optimizing performance in professional soccer. However, little is known about how this practitioners operate in the applied setting and how some of the nuances experienced influence practice. This study explored the contemporary practices of PTs in professional soccer. Semi-structured interviews were undertaken with eight PTs from different professional teams in European and South American leagues. Interview questions were designed to extract information on the evaluation of physical abilities, monitoring and control of training and injury prevention. Subsequently, the interviews were video-recorded, transcribed, verbatim and analyzed using a content analysis approach. The results suggest that the evaluation of physical capacities is carried out by PTs at the beginning of the preseason. It also appears that it is attempted that this process of regular testing is applied during the competitive period, with most participants conducting partial physiological and physical evaluations at different stages throughout the competitive season. In relation to the monitoring and control of training, subjective feedback scales are used to estimate the internal load, and the use of GPS devices is common to quantify external loads. Injury prevention programmes were implemented by all participants and were generally in a multi-component format focused on preventing or optimizing physical capabilities. These insights can be used as a scientific reference point to inform applied practice in professional soccer, especially for practitioners that are inexperienced and aspiring to enhance how they operate in the field. Future investigations should explore the practices of PTs in detail and across a wider network in order to gain deeper and comprehensive insights into the applied soccer environment.

Keywords: physical abilities, evaluation, monitoring and control, injury prevention, optimization, professional football.

2.4.2 Introduction

Soccer is characterized as a high-intensity, intermittent team sport with many games across a competitive season (Konefal et al., 2018; Turner & Stewart, 2014). Professional soccer PTs must use their understanding and experience of sports science and training to optimize physical and athletic performance, while reducing injury-risk, (Weldon et al., 2021). Such expert sport science support ensures professional soccer players continue to develop and maintain a high level of conditioning during the season (Turner & Stewart, 2014). It is key that this process is optimized to enhance performance (Bangsbo, 2014; Ribeiro et al., 2021; Slimani & Nikolaidis, 2017; Turner & Stewart, 2014); however, there is little research to facilitate the understanding of how PTs operate within the applied environment. Contemporary research has surveyed strength and conditioning practitioners (Weldon et al., 2021), however, this research mainly included European practitioners and used survey methods with critics arguing that insights lack key details that might be captured during interviews (Bailer, 2014). Therefore, it appears warranted to obtain a deeper understanding of applied practice across several continents to design and implement periodized training plans (Bompa & Buzzichelli, 2019).

The role of the PTs is complex and multifaceted, with the role including the development and maintenance of strength and endurance capabilities for optimal performance (Jones, Howatson, Russell, & French, 2013). The planning involved across an entire season involves optimizing both performance and recovery (Gaudino et al., 2015a; Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004; Moalla et al., 2016), in addition to ensuring an ideal workload to minimize injuries (Jaspers, Brink, Probst, Frencken, & Helsen, 2017). In order to achieve this balance, adaptations to the volume and intensity of training must be made around matches, facilitating harmony between adaptations and recovery (Springham, Walker, Strudwick, & Turner, 2018), It may also be necessary to individualize training loads due to the differences in individual training history, physical condition, body composition, strength asymmetries and injury history (Bahr & Krosshaug, 2005), since a specific external load can generate a different internal load for each player within a team, moreover, it is necessary to adjust the loads based on time and performance in competition to further examine their relationship with physical fitness, injuries and the diseases (Jaspers et al., 2017). To this end, different internal and external load monitoring tools are commonly used both in training and in competition (Newton, Owen, & Baker, 2019). To estimate the internal load, tools such as the subjective perception of effort are currently used (Gabbett & Whiteley, 2017), and objective measures of exercise intensity, such as, autonomic heart rate regulation indices (exercise heart rate) (Ali & Farrally, 1991) or biochemical markers (creatine kinase: CK) (Lazarim et al., 2009b; Ribeiro et al., 2022) are currently use. For external load, the most used tool are tracking system (global positioning systems: GPS) (Weldon et al., 2021b), these parameters provide information on work performed by each individual player. This information allows the PTs in professional soccer to make informed decisions regarding the timing of training sessions (Newton et al., 2019). However, it is unclear precisely how these methods are adopted to inform periodization, and strength and conditioning programmes.

Injury prevalence is high in professional soccer (Pérez-Gómez et al., 2020) and has a detrimental economic impact, particularly since player inactivity results in additional costs for medical treatment and influences team selection and player availability (Ekstrand, 2016b). This in turn reduces team success both in the league and in international competitions (Hägglund, Waldén, Magnusson, et al., 2013). As such, the implementation of prevention programmes aim to reduce the negative implications of injury and consequently increasing sporting success (Hägglund, Waldén, Magnusson, et al., 2013). Due the importance of PTs in enhancing performance and minimizing injury, the objective of this study is to investigate the contemporary practices of PTs professional soccer across two continents. This will help identify the methodologies used in the assessment of physical capabilities, monitoring and control of training and injury prevention which will support in the development of applied research and practice. Additionally, the knowledge gained can provide a source of information for trainee PTs, with the data also able to be used for current PTs for their practices.

2.4.3 Methods

The participants were asked to describe their practices and opinions, with the aim of providing an understanding of their knowledge and practices in professional soccer. The semi-structured interview script was submitted for review by five sports science experts. All reviewers were contacted via e-mail, and included the following; three reviewers with PhDs in sports science (two with experience in qualitative research design) and two reviewers presently operating as PTs. A pilot interview was also carried out with a PT. Minor modifications to the wording and organization of the survey were made to the interview questions following review and pilot testing to avoid conceptual ambiguities and ensure validity. Finally, the pilot test was incorporated within the analyses. The interview consisted of three sections: (1) evaluation of physical capacities; (2) training monitoring and control; and (3) injury prevention. The interview answers were all open and the PTs were able to share experiences and opinions on each of the questions. The study was carried out in accordance with the ethical standards of the Declaration of Helsinki and was approved by the scientific council and the ethics committee of the University of Coimbra (CE/FCDEF-UC/00692021).

Initially, ten professional men's soccer PTs (Europe and South America) were contacted via email or telephone during the recruitment process, these two continents were considered for their relevance in world soccer. From those ten, eight responded positively and agreed to participate in this research. Before conducting the interviews, all participants signed an informed consent agreeing to participate in the research and their interview was video recorded. All interviews were conducted during the month of January 2022 (middle of the season for the European teams and the beginning of the season for the South American teams). All interviews were conducted by the same researcher (JB). The PTs had a mean age of (37.5 ± 5.8 years) with vast experience of working in professional soccer (14.8 ± 6.4 years of experience). The participants had degrees in Physical Education (n = 7) and physiology (n = 1), all had a master's degree or equivalent (n = 8), with some also possessing a doctorate (n = 3).

To be able to participate in this study, the PTs had to be working in a professional club at the time of data collection (first or second division and/or national team). Once eligibility and consent were obtained, participants engaged in a one-on-one semi-structured interview. Only entire interviews that were conducted from start-to-finish were used for analyses. The interview began with an explanation of the purpose, topics, estimated duration and the anonymity of the information and its use (questionnaire in supplementary material). Each participant partook in an interview conducted via Zoom, which lasted between 60 and 90 minutes, (some interviews were prolonged since a few PTs provided lengthier responses to the questions). The structure remained similar for all interviews.

To process the results, the qualitative content analysis technique was used to understand how the theory is applied in professional practice. All interviews were transcribed into a Word 2019 document (Microsoft Corporation, Redmond, WA) and coded using a deductive-inductive approach. The transcripts were read repeatedly to promote data familiarization and immersion in the underlying content (Creswell, 2007). The coding was based on a tree of nodes that was built to reflect the working models (figure 1) (Côté, Ericsson, & Law, 2005; Davids, Gullich, Shuttleworth, & Araújo, 2017; Fraser-Thomas, Côté, & Deakin, 2008; Henriksen, Stambulova, & Roessler, 2010; Kristoffer Henriksen, Stambulova, & Roessler, 2011) and mainly involves higher order issues. Similar to methodologies used previously, inductive coding expanded the node tree when new categories or ideas emerged; such categories and ideas primarily involved low-order topics and the content of topics (2010). The interviews and notes were then subjected to meaning condensation, in which participant's' statements were condensed into precise formulations and a summary was written for each node. QSR NVivo 12 software was used to code the interview transcripts.

Figure 2.4.3.1. Elements of interest in the study.

In this study, different techniques were used to establish reliability. The principal investigator received training in qualitative research methods described by several academic sources (Côté, Salmela, Baria, & Russel, 1993; Creswell, 2007; Lincon, 1995; Smith & Caddick, 2012). Member checks (i.e., the data were returned to participants to check for accuracy and resonance with their experiences) were undertaken to establish data credibility (Lincon, 1995). These checks occurred twice in the present study. The first took place during the information session that occurred at the end of each interview. At this point, participants were allowed to change any of their responses. The complete verbatim transcript of each interview was also sent to the participants for their final approval. At this point, the participants had another chance to clarify, add to, or delete any comments they had made during the interview. In addition, the intrapersonal reliability of the data was ensured by a panel of three experts in qualitative methodology who analyzed all units of meaning, themes and categories.

2.4.4 Results

The eight participants worked for a club that competed in professional leagues on one of two continents: Europe (*n* = 4) and South America (*n* = 4). The main themes resulting from the qualitative content analysis are presented below.

2.4.4.1 Evaluation of physical abilities (figure 2.4.4.1.1)

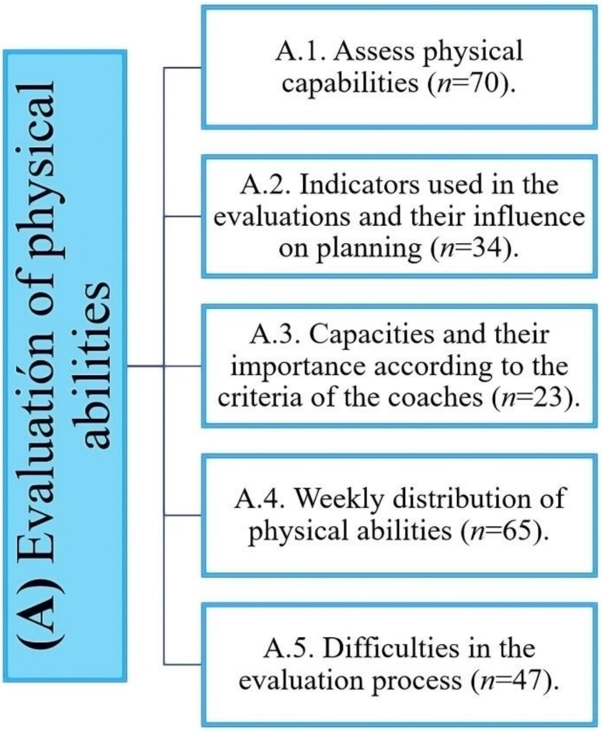

Figure 2.4.4.1.1. Distribution of the evidence obtained in the evaluation of physical abilities.

Relevance of carrying out evaluations for physical capacities

Regarding the "Relevance of carrying out evaluations for physical capacities", we verified that it is a frequent process applied by PTs, who subjectively based on their beliefs and methodological preferences, perform different evaluations, that allow them to objectively measure and prescribe optimal training loads for their players.

> Yes, always use tests to evaluate (...) with the objective above all to be able to prescribe training with more rigor, that was always the concern.
>
> PT 6

As for the "time of evaluations", PTs attempt to carry out evaluations at different times; the first at the beginning of the season (during the first or second week so as not to expose the players to maximum efforts), then again in the middle of the season (holidays) and lastly, at the end of the season. that in some cases may be conditioned by the decisions of the head coach's or the continuity of the players in the squad (contract termination and team changes).

> (…) I do these diagnostic evaluations in the second week after a fitting so as not to subject the players to maximum effort after the holidays.
>
> PT 2

On the other hand, some PTs use partial evaluation strategies with sub-maximal evaluations or tests that do not generate great physical stress on the players. The aim of such work is to gradually adjust the prescription of training loads, limit the additional burden to training sessions and thus not retracting from the time the head coach must implement their tactical strategy for the next match.

> Another thing that I find interesting are the sub-maximal tests that I have already used many times, which are very easy to apply and are not so subject to this calendar variability, because they can be done in the initial part of the warm-up.
>
> PT 7

Finally, "the physical tests that are used by PTs to determine the physical condition of the players" and that were considered a priori at the time of construction were anthropometry, agility, speed, aerobic capacity, anaerobic capacity, strength and flexibility. The answers provided blood tests as an option a posteriori. The tests for anthropometry consist of the assessment of body mass, height and the sum of six skinfolds. For agility participants used the Illinois agility test and T tests. The speed tests are linear and vary between 5, 10, 20 and 30 m. Aerobic capacity is estimated through evaluations of direct consumption, carried out in the laboratory with a maximum progressive test and in the field using the 30-15, the Yo-Yo test (both level 1 and 2 variations) or the 1200 m test. Anaerobic capacity is determined by the 35-m Running-based Anaerobic Sprint Test (RAST), but there are others who do not consider it a necessary evaluation and do not perform it. Flexibility or range of motion is determined by the Functional Movement Screen (FMS). Force is determined using isokinetic tests to determine peak concentric and eccentric torque, as well as the

Isometric Mid-Thigh Pull (IMTP). In addition, the neuromuscular performance of the lower limbs is determined through different jump evaluations such as the Squat jump (SJ), and Countermovement jump (CMJ). Finally, for the upper limbs, only one trainer indicated evaluating the maximum repetition test (RM) using the bench press.

> (…) we performed some muscle function and neuromuscular performance tests such as the SJ and CMJ, isokinetic, then some dynamometry tests in an isometric regimen more related to hip abduction and abduction, and then a more general test that is related to very well with the performance that is the Isometric Mid-Thigh Pull (IMTP).
>
> PT 8

In this same context, but using other reference indicators such as blood markers, PTs use these evaluations to determine muscle damage or stress level of the players before the start of the season or during periods of high match congestion, among other factors.

> (...) I ask a laboratory to carry out a blood test to see how the players are when they arrive, to see if they are overstimulated, overtrained, stressed or not, based on being able to have this week of recognition from the players (...) I measure creatinine, ammonium, which are the stress hormones that tell you, look, this player is overtrained, you have to give him a break or, on the other hand, this player has not been stimulated for several weeks or a month.
>
> PT 4

Indicators used in the evaluations and their influence on planning

The use of data was diverse across participants and often depended on the preferences of each PTs. In some cases, the use of information for planning ahead was to determine reference values at the beginning of the preseason process to inform subsequent training processes. This also included who should remain in the squad from the previous year or to obtain a baseline for the new players. These data enabled comparisons later in the season to assess progress and highlight potential injury-risk. Despite the intention of the PTs in the current study attempting to conduct end of season testing, there seems to be a consensus this it is challenging given the high turnover of players and accumulation of changes at the club.

> (...) this helps us to have a diagnosis to know how they arrived, how the reinforcements are located, how they are located in the group.
>
> PT 2
>
> (...) the great objective is to try to determine if there is any type of muscular deficit in relation to one member to another.
>
> PT 5

The information collected and analyzed allows decisions to be made that help to set goals or adjust training loads, mainly individually or by position, understanding that the demands in each positional role is different. Therefore, Complementary work can be designed for the main training session, which are carried out according to their complexity before or after training, trying not to interfere with the work of the head coach, nor with the physical performance of the player.

> Those who are above the average usually do maintenance work and those who are below average do complementary work logically associated with the metrics.
>
> PT 6

Capacities and their importance according to the criteria of the PT

Determining the importance of each physical component of the players is highly complex. If it were necessary to separate and analyze each one of the abilities according to their importance in the players' performance, two preferences were presented for the PTs: (1) strength is considered the most important capacity and it is the one that allows to achieve greater sports performance. Additionally, strength is a facilitating capacity for others such as speed and resistance; (2) the importance of aerobic capacity is also highlighted due to the benefits it provides for rapid recovery after maximum effort, increased ability to repeat and tolerate these demands, delay the onset of fatigue and, in addition, its importance as a protective element to avoid injury.

> Yes, strength (...) as a basic physical capacity, when we develop it, we know that we have greater contractile capacity, therefore, we are going to improve speed

levels, we also have greater mitochondrial capacity, which is also going to help us with resistance.

PT 4

Another element that was considered relevant at this point is the mental capacity or cognitive and emotional well-being of the athletes. Specifically, it was deemed crucial to support the athletes emotional well-being as this is the foundation for enhancing all other elements of performance.

> (...) I have an opinion regarding how the athlete should be in an emotional sense and my way of working is aimed first at having the athlete emotionally well, which for me is the basis of everything.

PT 2

Difficulties in the evaluation process

The PTs refer to the challenges experienced across different phases of their professional development. Four key barriers to carrying out evaluations were highlighted, with the first being player culture (i.e., buy-in and adherence). To overcome this challenge, the PTs conduct educational sessions on the importance of evaluating performance for the athletic development to influence perceptions and subsequent engagement.

> (...) the daily conversation, in the moments together of conversation when a trust begins to be produced and you begin to explain to him... he is going to be something in which you must have him at the maximum of the maxims of his will to carry them out , because if he did not have the will, it is preferable not to do anything because the data would not be valid.

PT 7

Another element pointed out as a factor that hinders the application of the evaluations is the club's own culture and standards. This can relate to the lack of economical allocation of resources allocated for assessing physical performance. Most PTs reported not having adequate equipment to conduct their role and often the PTs themselves have to source equipment or facilities to implement evaluations.

> (...) the resource, we did not have it in the club and I had to go out and look for it in clinics, sports centers that had a isokinetic device, but once it was achieved, when they gave me the values to evaluate each of the athletes, this It was escaping from the reality and possibilities of the club and from that point of view what I had to do was manage publicity to put in the stadium and lower the costs of the evaluation.
>
> PT 4

Finally, there are also some problems at the operational level of different origins such as the structure of local and international competitions that can affect the planning, the fatigue of the players at a general level (physical and mental), and the change of opinion of the head coaches without prior notice and environmental factors.

> (...) then there are other elements such as environmental ones, there must be optimal conditions to carry out the test, it is temperature, humidity, because they are things that influence the result.
>
> PT 7

Weekly distribution of physical abilities

PTs consider that the structure of each microcycle should aim to improve all elements of performance, including, technical, tactical, mental, emotional and physical as part of a holistic model. PTs modify the structures of the drills that undertaken by players by changing pitch/drill dimensions, number of players, durations, and goals depending on days within the weekly schedule (e.g., competition, +1, +2, -4, -3, -2, -1 and competition). Day +1 tends to be targeted towards promoting recovery (one day of active recovery and another of passive recovery). For day's -4 to -1 are days of optimization of elements of performance. In a microycle with a mid-week match, more recovery days may be implemented within the schedule and less days allocated to performance optimization. Day +1 or +2 can be used for passive recovery or active recovery, PTs preferring active recovery on +1 to speed up and facilitate the recovery process and on +2 allocated to passive recovery or rest. However, some head coaches prefer to carry out passive recovery at +1 to promote psychological recovery after the competition and leave active recovery at +2 being a training with recurrent stops that allow players to recover before the following effort, which causes training with some discontinuity. Additionally, the active recovery day can be used to balance the loads of the players who did not play or who played fewer minutes during the competition. At certain times, this can also be done after the competition on the field itself in a 'cool down' format.

> (...) the second day (+2) is of active recovery and a differentiation is made between the players who played the entire game and those who played less than 45 minutes and did not play, must have a higher load.
>
> PT 1

On day -4, trainers focus on physical conditioning training with reduced number of players (e.g., 1 vs 1 or 2 vs 2), which involves accelerations, decelerations, duels for the ball, jumps and changes of direction, interspersed with periods of reduced effort. The PTs declared that given that some players may not be 100% physically or emotionally recovered and it may be necessary to control and manipulate the intensity for certain players. This can involve different strategies, such as reducing the number of drills a player performs or providing the player with lighter duties within the session.

> Strength work on day -4, there is a focus for tasks focused on accelerations and decelerations that cause explosive actions of short duration.
>
> PT 8

Day -3, being the furthest day from the previous and subsequent competition, tends to involve larger structures and more players. This allows the main behaviors in the different phases to be developed more collectively (offensive and defensive transition) and moments of the game (offensive and defensive organization). It is intended that the players cover similar distances and reach maximum speeds consistent with those reached in competition. Data analysis can be carried out post training session to determine those that have not reached the established parameters. It is necessary to point out that for this type of control it is necessary to have Global Positioning Systems (GPS) devices that provide feedback in real time.

> We call it the day of resistance, but at the base it is to create more specific contexts of everything that we want to work on in the game, therefore, resistance is not only aerobic resistance, it is a specific resistance, which later moments of the game will require us for the different positions (...) we try to achieve what is known as speed running that we achieve during the competition.
>
> PT 5

Day -2 is oriented to higher speed actions, which can be achieved in a specific way, but with low complexity in decision making.
Finishing exercises with pursuit or more analytical linear running exercises of 30 m or more, with long recovery periods and reduced execution periods, are usually used.

> On a more speed basis, not only in analytical-type actions, but also with more specific finishing actions, arrivals to the area and faster actions with a short duration (time) but with enough recovery time between the different actions.
>
> PT 5

Day -1 is oriented to active recovery or match activation. This day together with the speed day is also recognized as tapering, and less of a physical impetus. The day before competition is also focused on completing match preparation, with tasks focused on reaction speed and covering more detailed elements of the competition from a on psychological, technical and tactical preparation.

> The last day, which is a little more focused on the socio-affective part, the work of some tactical concepts of stopped ball and in the activation, we make games that are more oriented in the union of the group and the creation of bonds between the players, to be able to go all united to compete with the rival on duty.
>
> PT 2

During two match micro cycles, recovery becomes much more of a focus when compared with one game weeks. The main emphasis of the week is to optimize performance, but it was also a key priority to managing physical elements that help maintain performance such as reducing fatigue, overreaching and injuries. For this, PTs use different strategies that range from reducing the duration of exercises and training sessions, combining days off with different stimuli such as strength with resistance or speed with activation, or strategies focused on the methodology of the head coach.

> (...) at certain times you intend to recover, but it may be more important to adjust certain situations or certain technical-tactical behaviors than to have the players 100% recovered (...) the challenge for the head coach is planning and creating training, in order to obtain the greatest possible fruit, with the lowest cost.
>
> PT7

2.4.4.2 Monitoring and control of training and competition (figure 2.4.4.2.1)

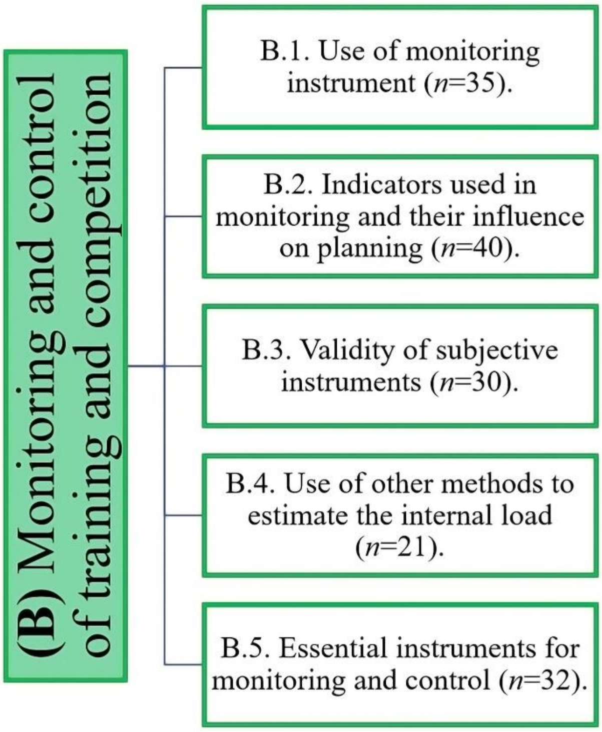

Figure 2.4.4.2.1. Distribution of the evidence obtained on the monitoring and control of training and competition.

Use of monitoring instruments

The monitoring and control of training has become a fundamental factor in soccer for maintaining high performance in matches and managing player's workload. There was a revelation that the practitioners used monitoring methods which focused on primarily on three factors, including, subjectively assessing player wellbeing prior to each training session, monitoring GPS activity throughout the session for objectivity and analyzing data post session.

Before the session, "the use of well-being questionnaires" is implemented to minimize fatigue, injury risk and maximize a player's physical and emotional well-being.

> (...) we use the Wellness questionnaire, which allows us to know what conditions the athlete is in to carry out the training session.
>
> PT 1

During the session, "external load control" can be monitored in real time or after the training session on the premise that the club possesses 'live' feedback systems. A consensus existed in the current study that practitioners used GPS devices, with the training session controlled by the quantification of specific parameters (i.e., total distance, accelerations, decelerations, maximum speed and distances at high and very high intensity).

> GPS for external load, (...) I chose to take only some indicators (...) first the total distance, then (...) ranges of higher speeds that would be maximum and sub-maximum and then (...) accelerations and great accelerations and also finally the maximum speed reached.
>
> PT 7

"Internal load control" was determined by the subjective perception of effort (CR10 scale). For this process the PTs recommend individualized protocols, which were applied 30 minutes after training so as not to reduce the influence of scoring associated with collecting data immediately post session. Players were educated and familiarized with scales in advance of use to ensure accurate interpretations and valid data. The value of using heart rate as an important objective monitoring tool was recognized among the practitioners, but this metric is often omitted given the discomfort associated with wearing these devices on the front. Some PTs used blood markers such as CK to determine muscle damage, but it is generally used at times when more than one match per microcycle is completed. Blood lactate was not used for monitoring due to the complex application and the information deemed not necessary for the planning process.

(...) post-training we applied the subjective effort perception scale, and there we had important data on how the player felt the training load.

PT 2

Indicators used in monitoring and their influence on planning

The information collected from the training session is used to estimate load and determine weekly load is within optimal parameters to promote adaptation and reduce overreaching. At a statistical level, the information is used to make comparisons between players, microcycles or between sessions and competitions and from there estimate metrics such as the Z-score to assess where the player is in relation to the team average and specific positional roles.

(...) the metrics are organized according to the competition, (...) this allows us to evaluate more from the performance point of view.

PT 6

At a collective level, monitoring allows a more general view of the total load of the session, competition or microcycle, but the major adjustments are made to individuals. This may be attributed to the understanding that the specificity of playing positions requires stimuli and demands that vary. In this sense, the information is analyzed to adjust the loads when the expected values are not reached or exceeded.

(...) the individual data allowed us to know which athlete we had to raise or lower the load.

PT 2

Validity of subjective instruments

Subjective evaluation instruments are recognized, used and validated by all PTs on a daily basis, however, they make some recommendations in their application. For instance, the application of the questionnaire must be applied in a certain degree of privacy so as to reduce bias. The RPE should be taken and recorded approximately 30 minutes after the end of the session or competition. The subjective monitoring questionnaires should also be shortened where possible to increase engagement. The results that appear substantially different from the group average, are questioned and addressed with the player in an effort to understand the nature of the response, given the complexity of collecting subjective data.

> The evaluation of the effort perception scale or any other tool that gives me the proximity to what is happening to the athlete is going to be crucial for me not to make a mistake and give the head coach a tired athlete at the time of the competition.
>
> PT 4

Use of other internal load indicators

In general, the trainers value and used heart rate monitors. However, all the trainers made the same comment related to the lack of comfort of the monitors/bands, interfering with player buy-in. CK was the most used blood markers to determine muscle damage, but it is generally used when there is more than one competition per week to try to help in the recovery process without creating overloads in the players and to reduce the invasion of drawing blood weekly.

> Yes, we already use the cardio frequency meter and we stopped using it because of the discomfort expressed by the players.
>
> PT 5

> We use the CK indicator as an indirect measure of muscle damage.
>
> PT 8

Other tools that PTs have used to monitor players and determine the degree of recovery range from sleep analysis with an electroencephalogram (EEG), hydration levels with a refractometer, and estimated neuromuscular capacity with a jumping platform.

> (...) strength is also a good indicator to determine fatigue and that is why we use jump ability as a method to evaluate 48 hours after the game.
>
> PT 3

In this same sense, an indicator that is not used and to which PTs do not give importance is the measurement of lactate, which in their opinion is not practical to be applied in the normal training process.

> Lactate for me is not useful and impractical and I don't use it.
>
> PT 7

Fundamental elements for monitoring

The PTs highlighted that GPS devices are crucial to obtain this information ideally in real time to make decisions that allow them to quickly adjust loads.

> (...) the GPS would be to control the external load and have this possibility of controlling them at the moment.
>
> PT 2

At the internal load level, the use of the different subjective perception questionnaires is valued and validated and was applied before and after training sessions.

> (...) the Borg Scale, Wellness Questionnaire are simple things that I am already familiar with and use and have worked for me, because I believe that sometimes less is more.
>
> PT 2

In this same sense, heart rate appears as a valid and objective indicator of effort at the internal level, for which its value is recognized and its use is recommended, as well as CK analysis to determine muscle damage.

> (...) heart rate, because it is an objective measure and is more valid, can be influenced by various factors, but during training, it is logically a valid indicator.
>
> PT 7

Other elements that PTs consider important for this process is the creation of multidisciplinary departments that allow players to be monitored in a more comprehensive way. They revealed that this should include, nutritionists, physiologists, doctors and coaching staff to thoroughly analyze the preparation strategies, training processes and recovery regimes.

> (...) first a good monitoring center, (...) with a physiologist, physical trainer, a monitoring manager generating a competitive department... internal, debatable where all the variables are analyzed very thoroughly.
>
> PT 3

2.4.4.3 Injury prevention (figure 2.4.4.3.1)

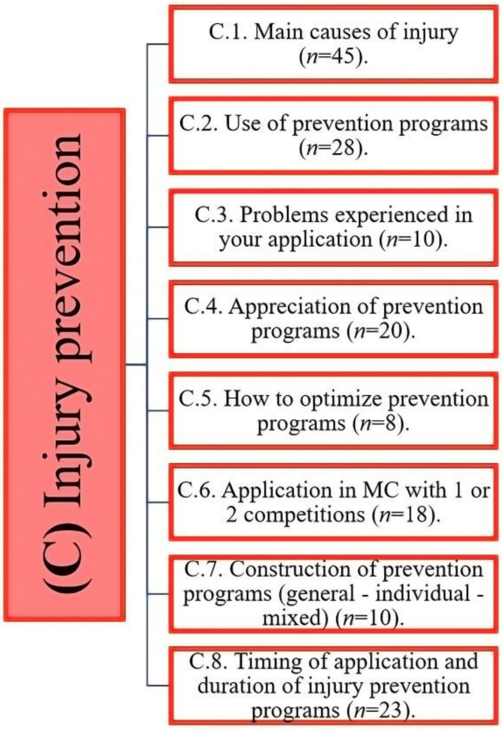

Figure 2.4.4.3.1. Distribution of the evidence obtained on injury prevention programs.

Main causes of injury

The PTs highlighted three main elements that are considered most important to minimize injury-risk, including, previous injury, age and fatigue. Other less commonly highlighted factors were poor recovery, match congestion, contextual variables and psychological factors.

> If an athlete has already had an injury, the probability of suffering another injury is very high, therefore, the care with that player must be doubled.
>
> PT 6

PTs also consider other elements as risk factors for injury, such as low levels of oxygen consumption, high levels of body fat and low levels of muscle mass, returning to competition prematurely, methodological elements (absence of preventive work), dangerous training processes, poor diet and rest habits, muscle deficits, overload, and underload.

> Players with a low level of oxygen consumption are more likely to suffer an injury than a player with a good oxygen consumption.
>
> PT 1

> (...) deficits at the muscular level, it also seems to me something very relevant or something to which we give a lot of relevance... if a player has a lot of difference or significant differences between the lower limbs, it can be a sign that he will suffer an injury in a period next.
>
> PT 5

Use of prevention programs

Injury prevention programs used by PTs focus on programs considered multicomponent, since they consider different elements, such as central strengthening (CORE), eccentric exercises, proprioceptive exercises, running technique work, speed, Total-body Resistance Exercise (TRX) and FMS. However, some coaches prefer not to refer to these programs as preventive, but rather optimization programs. This appears to be linked to their focus on improving the ability of the players, which will secondarily allow them to be better conditioned to the demands of the game.

> (...) we have multicomponent injury prevention programs, that is, that use those exercises that are described in the literature, such as the Nordic exercises, Copenhagen abduction, balance exercises, some FIFA 11+ exercises (...), using those exercises that have already been validated and that have some efficacy in preventing injuries and we do it that way.
>
> PT 8

The PTs refer to other elements that they consider fundamental within the prevention process that are due to the training methodology used. The alternation of loads is completed from the day of active recovery (+2 or +1) and up to the activation session (-1).

> When training in a contextualized way, the muscle creates adaptations in specificity, that is, the muscle fiber adapts to the effort or stimulus that is required. This is essential.
>
> PT 1

Problems experienced by the physical trainer in the application of preventive programs

The participation of the players in a professional context does not seem to be subject to great difficulties since, due to contractual elements, the players must carry out the activities indicated by the technical staff that leads the sports project. For this reason, participation in prevention programs is high and absences are relatively low and motivated by specific reasons.

On the other hand, they highlight the importance of accurately instructing players during their training process (e. g., young player) on the importance of these preventive works, so that it becomes a self-care habit that lasts throughout their career.

> I haven't had any problems, I think that the different teams have been working well for a long time and the players, despite changing clubs, understand that before training they have to do some exercises that are important for their health.
>
> PT 2

However, the problems that some PTs have experienced are punctual, such as: (1) assignment of the players in different work groups (headlines - reserves) which generates poor status in some reserves; (2) some young players who did not have good professional training related to injury prevention issues and therefore are not used to it; (3) minimal human resources to control and guide tasks; (4) refusal of some specific exercises; and the sports context (team or selection).

> (...) there are specific exercises with which we later have more difficulties, specifically the Nordic hamstring exercises.
>
> PT 8

Appreciation of prevention programs

The assessment and acceptance of injury prevention programs by head coaches and the medical staff according to PTs is quite high. In the case of the head coach, having all the players available and in optimal conditions is essential to achieve the sporting objectives. However, PTs recognize that depending on the professional training and the head coach's own experience as a player, sometimes they generate some difficulty, so it is essential to justify and explain the relevance of this process. On the other hand, the medical departments are key in this process, since their contribution, experience and knowledge of the players who have been with the club for a longer time, help to better optimize the process. In this sense, there is agreement that the implementation of prevention programs should be designed by a multidisciplinary team considering the maximum amount of information from athletes for greater optimization and effectiveness.

> (...) with the medical team this is done in direct collaboration and many times we adjust the training programs because they are carried out on a daily basis (...) we adjust in relation to the complaints or problems that there are from the players in the medical department, to clinical level… for this reason there is a 100% interaction with the medical department.
>
> PT 8

How to optimize prevention programs

There is agreement that injury prevention programs can be optimized to obtain the maximum benefit from their application, whether from a prevention-oriented perspective or the improvement of the athlete's physical capacity. PTs use various strategies such as; i) ensuring the work is soccer-specific and simulates the movement patterns performed during a match; ii) design programs that are carefully implemented to determine a balance with workload, fatigue, rest and nutrition; iii) consider all risk factors, both internal and external; iv) create harmonious, dynamic and engaging programs that facilitate their application; v) elements of the medical department such as kinesiologists or physiotherapists should be incorporated to have a more proactive role in injury prevention; vi) train and educate academy players on the importance of prevention programs to adhere to such protocols as they progress to the professional level, and; vii) individualize the prevention programs for each player, attending to their needs and abilities.

> (...) Preventive work must be related to the main tasks (specific field work), since preventive tasks are complementary to the main tasks and must have a certain link with the type of muscle contraction that is applied.
>
> PT 1

Application in microcycle with 1 or 2 competitions

The application of prevention programs is mainly based on whether teams compete in a one or two game microcycle, with which PTs adjusting loads accordingly. Thus, a maintenance injury prevention program is carried out on one match microcycles, but not on a two game weekly schedule to avoid negatively influencing player wellbeing.

> By having a standard microcycle with competition from Sunday to Sunday, the application of prevention programs is normal, considering the different elements that were mentioned above depending on the day of the week.
>
> PT 1

To reduce load, alterations are made to compensate for the additional game in a competitive microcycle with two matches per week. These measures are used in order to promote physical recovery for the next competitive encounter, allowing the player to focus on the more technical and tactical aspects of the next game.

> There is a substantial reduction in the volume of the load of these prevention programs in the gym. Many times they stop carrying out these programs in congested periods of the sports or competitive calendar... this manifests itself with a reduction or a complete absence on certain days of these programs.
>
> PT 8

Construction of injury prevention programs

PTs consider two major aspects for the construction of prevention programs. The first relates to elements of the PTs own learning and their scientific knowledge on this subject, which is used in a broader and more general context. The second adds individual factors to these elements, such as injury history, and anthropometric or physical evaluation results to determine imbalances that may affect the player's health. Consequently, the trainers, when considering both elements, consider that the construction of their prevention programs is of a mixed nature, since they articulate both elements when constructing these programs.

> We did general days in which the work for the entire team related to strength and they also had individual work guidelines for each one, based on the body composition evaluations, the FMS evaluation, the injury questionnaire and your previous injuries, to strengthen your irrigation areas.
>
> PT 2

Timing of application and duration of injury prevention programs

The moment of application of the prevention programs is mainly oriented to be carried out prior to the main training session, mainly when the work is oriented towards the lower limbs to activate and prepare the neuromuscular system for an intense session. Another factor is related to the willingness of players to work before the field session and not after. However, there is also the possibility that these programs are carried out after the main training session when double shifts are carried out or when the muscles need to be worked to correspond to the upper limbs.

> (...) the player in general prefers to arrive earlier and do this work before, instead of doing more work after the training session.
>
> PT 5

The estimated duration of the prevention work can fluctuate between 10 and 35 minutes, depending on the day of the week in which it is being carried out. Another factor that influences the duration of the prevention program relates to the player who is carrying out the session, and the context involved with whether the player required greater work or whether recovery is a higher priority.

> It depends on the type of work it is, it can last 10, 15 or 20 minutes depending on the work that is done.
>
> PT 6

2.4.5 Discussion

The aim of this study was to investigate the contemporary practices of professional soccer physical trainers across two continents. This study provides an understanding of the contemporary practices of PTs from two continents and different leagues. The PTs presented an extensive period of experience at a professional level, and were educated to a high academic level. This provides an understanding of how these PTs carry implement the theory acquired in their training process into practice and how they adjust according to their experience in the professional context in three areas (figure 5).

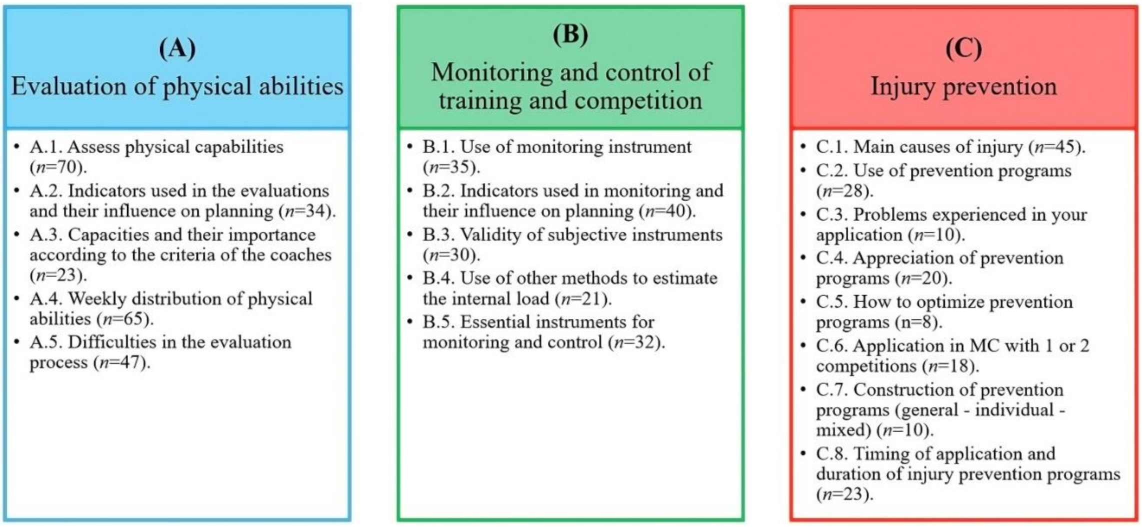

Figure 2.4.5.1. Summary of the findings found in the three areas studied

Anthropometric evaluation

The anthropometric and body composition assessments are considered an important indicator of fitness for PTs. This was considered an important aspect of physical fitness for soccer by the current participants, since the superfluous adipose tissue can act as dead weight in activities in which body mass is repeatedly raised against gravity when running or jumping during play (Reilly, 1994). Additionally, possessing favorable body composition (high muscle mass and low fat indices) has been considered as an important selective factor to achieving success in sport (Rienzi et al., 2000). However, caution is advised when interpreting such claims as each successful athlete may possess different physical characteristics (Rienzi et al., 2000). Therefore, each PT allocated less importance to this this matter, assuming that other physical performance parameters were adequate. Practitioners used skinfold assessments for assessing body composition. Skinfolds, although less reputable than other more sophisticated methods (e.g., DEXA), have been advocated for their simplicity and day-to-day consistency (Kasper et al., 2021). Little information was provided as to how the practitioners might use the data obtained to determine subsequent nutritional and training protocols. Therefore, more work appears warranted to determine how skinfold data are used to inform practice and delve into the specific role of the PT in relation to skinfold practices to enhance understanding of this key undertaking within the applied setting.

Physical evaluation

To cope with the physical demands of soccer, players must be able to adapt to the unpredictable changes and unorthodox movement patterns (Drust et al., 2007), which increase energy expenditure over anticipated locomotion patterns (Reilly & Bowen, 1984). Such movements can include acceleration and braking, forwards, backwards or sideways actions, and cutting and side-stepping maneuvers to evade the opponent's defensive marking (Drust et al., 2007). The use of physical fitness tests helps to examine the abilities of soccer players (strength, power, speed, agility, aerobic and anaerobic capacity) and training programs to be better targeted. This is even more crucial given the complex nature of soccer (Svensson & Drust, 2005). The evaluations can be applied both in the laboratory context, which is usually more expensive and sensitive, and in the field, which are carried out by the trainers themselves and at a lower cost (Drust et al., 2007). The evaluations of the physical capacities of the players were highly supported and used by the PTs to provide a more comprehensive depiction of player fatigue and whether recovery should be prioritized akin with previous research (Viru & Viru, 2001). This careful monitoring allows practitioners to demonstrate the evolution of the training process and information make more accurate decisions for training prescription (Svensson & Drust, 2005). Such evaluations provide a logical framework for the use of performance tests that better understand the physiological demands of soccer (Drust et al., 2007). The PTs interviews revealed that there is also a classification by positions for a more accurate and specific analyses of the demands of competition, as suggested within the literature (Barrera, Sarmento, et al., 2021; Rienzi et al., 2000). In this sense, and despite the difficulties that the participants may experience during the evaluation process (instrument, logistics, cultural, among others), they continue to be used to try to understand the player's performance capabilities. The practitioners tended to favor field-based tests that are more sport-specific, given their acyclic nature that is not amenable to time series analysis and is incompatible with traditional exercise study models in laboratory conditions (Svensson & Drust, 2005).

A key laboratory test that was commonly used among practitioners — provided that the necessary resources are available for this purpose — was isokinetic dynamometry evaluations of the lower limbs to determine peak torque and muscle imbalances (strength), specifically around the main knee extensor and flexors muscles (quadriceps and hamstrings) (Duarte, Valente-dos-Santos, Coelho-e-Silva, Couto, et al., 2018; Duarte, Valente-dos-Santos, Coelho-e-Silva, Malina, et al., 2018; Rosa et al., 2022). Evaluation of adductors and abductors with a dynamometer (Smart Groin Trainer) to identify imbalances or muscle weakness, monitor the progression of optimization and rehabilitations (Rosa et al., 2022) and neuromuscular capacity assessments via countermovement jumps (CMJ) and squat jumps (SJ) were also performed (Boraczynski et al., 2020; Jovanovic, Sporis, Omrcen, & Fiorentini, 2011; Loturco et al., 2018; Rosa et al., 2022). The field-based tests carried out focused on speed over numerous distances (5, 10, 20 or 30 m), agility (Illinois T) and aerobic capacity (Yo-Yo test), which have been widely used in the scientific literature (Jovanovic et al., 2011; Kaplan, Erkmen, & Taskin, 2009; Little & Williams, 2005; Mirkov, Nedeljkovic, Kukolj, Ugarkovic, & Jaric, 2008). This shows consistency between the practices employed and the scientific evidence-base. When asked about the importance of specific physical abilities over others, the vast majority highlighted strength as the key fitness component, since matches incorporate explosive efforts such as sprints, jumps, tackles, kicks, changes of pace and duels for ball possession (Cometti et al., 2001) to ensure successful performance in competition (Papaevangelou, Metaxas, Riganas, Mandroukas, & Vamvakoudis, 2012). Therefore, the ability to generate explosive muscular force in as short a time frame as possible is an important determinant of performance (Thorlund, Aagaard, & Madsen, 2009). However, some PTs also highlighted the relevance of aerobic capacity as an important element to ensure players can tolerate fatigue and recover quicker (López-Revelo &

Cuaspa-Burgos, 2018), as well as its benefits as a moderating factor of injuries (Malone, Owen, et al., 2017b; Windt, Zumbo, Sporer, MacDonald, & Gabbett, 2017). These revelations are plausible, as both abilities are considered important determinants of soccer performance, as they are key characteristics of physical ability and the main regulators of important soccer-specific tasks (Hoff & Helgerud, 2004). The PTs interviewed revealed the importance of evaluating physical abilities from both a performance and injury prevention and rehabilitation perspective to support decision making in the return to competition. It is recommended that the optimization process focuses on strength and aerobic capacities that, for the PTs, appears to be more predominantly targeted towards achieving sporting success.

Monitoring and control of training and competition

In the world of sport, the main objective of athletes and coaches is to achieve success in competition. However, by increasing the frequency, duration or intensity of training, they risk creating excessive fatigue that can lead to functional impairment, described as 'overtraining syndrome', 'staleness' or 'burnout' (Hooper, Mackinnon, Howard, Gordon, & Bachmann, 1995). Therefore, it is essential that PT permanently monitor and control the training process, since this process helps establish a balance between performance and recovery (Gaudino et al., 2015b; Moalla et al., 2016). This methods also allows control over weekly workloads, which enhances physical conditioning and prevents injuries or illnesses (Jaspers et al., 2017). However, achieving these goals requires careful planning and manipulation of the training load over the course of a competition schedule (Gabbett, 2016a).

All PTs noted that GPS devices are key to the monitoring process, consistent with the literature and reported use in Europe, the United States, and Australia (Akenhead & Nassis, 2016). Reasons given for use of such units were tool the attainment of valid data (Reinhardt et al., 2019), data are reliable and relevant to track external load in professional soccer, both collectively and individually (Rave et al., 2020), and the device allows the measurement of positions, speeds and movement patterns of the players (Cummins et al., 2013), A differentiation of the specific loads is recommended according to the individual demands of the game or position (Barrera, Sarmento, et al., 2021); evidence that is supported and shared by PTs.

It was also highlighted that the practitioners use subjective tools, which allows them to understand how the player is reacting to certain external loads and also obtain information on the training performance that can be expected from individual players during a training session (Malone, Owen, Newton, et al., 2018), during different days, weeks and also at different times of the season (Nobari, Fani, et al., 2021). For this process, the PTs mainly use two subjective perception questionnaires. The first is the wellness questionnaire that provides information about the athlete before the training session and competition, and the level of fatigue experienced (Cullen, McCarren, & Malone, 2021). It is important to note that the PTs recommend adapting or eliminating some questions according to their personal criteria (subjectively), so as lessen the time burden with irrelevant questions. Second, the Subjective Perception Scale (session-RPE) proposed by Foster et al. (Foster, 1998; Foster, Daines, Hector, Snyder, & Welsh, 1996; Foster et al., 2001; Foster et al., 1995) which is used post-training and competition, to quantify the load of the session at an acute level. This is considered a good indicator of the global internal load of soccer training (Casamichana, Castellano, Calleja-Gonzalez, San Román, & Castagna, 2013; Fanchini et al., 2017; Impellizzeri et al., 2004), using the category proportion scale (CR10 scale) (Borg, Hassmén, & Lagerström, 1987) for its duration. It was also revealed that educating players about the importance of this information for the process of planning and executing training is key to ensuring engagement. For this to occur, the PTs indicated that this information is not used to determine starting, substitutions or non-squad players in the subsequent match, but instead the veracity of the information is important for an adequate optimization and care process.

The PTs stated that they do not use the acute-chronic load relationship for training control. A practice that we believe should be incorporated, since it has been shown that high chronic workloads can be useful as a control parameter for injury prevention when adequately achieved in professional athletes of all sports, such as rugby players (Hulin, Gabbett, Lawson, Caputi, & Sampson, 2016), Gaelic footballers (Malone, Roe, Doran, Gabbett, & Collins, 2017) and soccer players (Malone, Owen, et al., 2017b), which can be a fundamental tool to incorporate into practice. The PTs also considered the use of heart rate important to estimate the internal load in a more precise and objective way and to plan training sessions, in addition to being an individual indicator of the assimilation of accumulated workloads (Naranjo, De la Cruz, Sarabia, De Hoyo, & Domínguez-Cobo, 2015). However, it was reported that the players feel discomfort when using the elastic bands on the chest, since it is necessary to adjust them constantly, in turn making their application difficult throughout the season. This perhaps offers an avenue for future research with technology companies adjusting the products to ensure player comfort.

Some PTs that possessed the resources used CK as an indirect blood marker of muscle damage and overload in soccer players (Lazarim et al., 2009a; Thorpe & Sunderland, 2012), in conjunction with other measure (e. g., CR10 and Wellness). This marker was typically used within two game microcycles. However, contrary to anecdotal belief, PTs indicate that they do not use blood lactate due to the perception that this marker is impractical, and the information provided is not considered relevant for daily training planning and prescription. Coutts et al. (2009) pointed out that lactate alone cannot accurately explain the overall intensity of soccer exercises, but that the subjective perception of the players' effort, which is a simple, cheap and easy-to-use tool should be used as a more accurate indication. Finally, it should be mentioned that all this information is considered in the training planning process, both individually and collectively. It was also shown that well-being values far from the mean, as well as workload peaks, will force modifications within the training process individually or collectively, since players respond differently to the same training stimuli (Mäestu, Jürimäe, & Jürimäe, 2005).

In general, it must be understood that the use of technological tools for the estimation of the internal and external load have become essential in high performance. However, in the absence of economic resources, other options such as subjective questionnaires can be used to replace the indicators of internal load or recovery. On the other hand, if the resources exist and it is intended to provide greater comfort to the athlete, there may be other options for monitoring the external load (i.e., camera-based systems). It is important that monitoring and control must be present in the training process, since it directly impacts the planning of each session, micro cycle or mesocycle, if the intention is to reach the maximum sporting level with the lowest possible risk of injury to players.

Injury prevention

Injury etiology models have evolved over the last few decades, highlighting a number of factors that contribute to the causal mechanisms of sports injuries (Windt & Gabbett, 2017). Three factors are highlighted: (1) internal modifiable and nonmodifiable risk factors (e.g., age, neuromuscular control); (2) exposure to external risk factors (e.g. playing surface, equipment) and; (3) inciting events, in which biomechanical breakdown and injury occur (Meeuwisse, 1994; Meeuwisse, Tyreman, Hagel, & Emery, 2007). In this context, the PTs indicated as intrinsic risk factors the history of injuries and the age of the players and as extrinsic risk factors the fatigue caused by training and the high congestion of matches (Dvorak et al., 2016). However, it should be noted that the PTs highlighted the complexity of the injuries and their unpredictability, which makes them a complex problem to predict and address.

As a product of the high complexity of injuries and how important it is to maintain low injury rates for sporting success, as well as for the economic sustainability of the club (Ekstrand, 2016b), the PTs pointed out that they use multicomponent programs, which incorporate different exercises for different types of injuries that a player can suffer. It was also stated that these programs build on the basis of scientific evidence focusing on two topics: (1) main injuries that occur in soccer (e.g. groin injuries, joint injuries, muscle injuries) (Chomiak, Junge, Peterson, & Dvorak, 2016) and; (2) greater prevention benefits in these injuries, such as the Copenhagen Adduction exercise programs (Harøy et al., 2019), Nordic hamstring exercise (Al Attar, Soomro, Sinclair, et al., 2017), reverse Nordic hamstring exercises (Alonso-Fernandez, Fernandez-Rodriguez, & Abalo-Núñez, 2018) knee-specific training modules (Krutsch et al., 2020), as well as the training methodology focused mainly on meeting the specific needs of the sport (e.g., accelerations, decelerations, distance covered at high intensity and sprints performed, among others). The PTs indicated that the participation of the players in these programs is high with, which eliminates the problems or difficulties that may arise due to low adherence (Engebretsen et al., 2008). These programs are carried out mainly before the training session, despite the fact that evidence has shown greater benefits against new injuries when applying prevention programs before and after the training session (Al Attar, Soomro, Pappas, et al., 2017) and have a duration between 15 to 30 minutes. However, the duration times according to the literature do not influence the positive results of application in preventative programs for injuries suffered in the lower limbs, the type, severity or mechanism of the injury (Rahlf & Zech, 2020). The configuration of injury prevention programs can vary depending on the day of their application within a normal microcycle (one competition), as well as in a microcycle with two competitions per week. Programs can often be overlooked during the fixture congested periods of matches depending on the physical trainer, and these variations have shown to affect the effectiveness of programs (Van Beijsterveldt et al., 2013). These programs are designed in a specific way depending on the needs of each player and the demands of the different structures (Alcalá et al., 2020), which has shown favorable results against muscle injuries and days of absence without recurrence (Melegati et al., 2013). Therefore, it is essential to consider the flexibility of the planning and delivery of these programs in order to achieve the benefits of these injury prevention programs.

The PTs believed that both head coaches and members of the medical team value the work done when using these prevention programs and highlight the importance of having a more interdisciplinary approach that involves different members in the optimizing process to reduce the risks related to the sports discipline given its high complexity, as suggested by the scientific evidence (Dvorak et al., 2016). Finally, the interviewed PTs believe that prevention programs can address the more specific demands of soccer, as proposed by Moras (Moras, 2000; Seirul-lo, 2017) with the degrees of approximation of the tasks in the auxiliary work.

Finally, PTs generally support the use of prevention programs, basing their decision on the available scientific evidence. However, they believe that improvements can still be made in these processes, which contribute to the prevention of injuries.

2.4.6 Conclusions

This study explored the contemporary practices of PTs in professional soccer across two continents. The data suggest that the evaluation of physical capacities is based on scientific evidence and different methodologies depending on the stage of the season (pre-season, competitive period or end of the season). It became apparent that for some stages of the season, emphasis was placed on the development and optimization of physical qualities, while optimizing recovery and fatigue management was prioritized in other stages of a season. On the other hand, the PTs monitored and managed training load, and supported the use of technological tools (such as GPS devices) and considered this aspect a fundamental part of the role. However, they also supported the use of subjective questionnaires, since some players deviated from the team average, and as such required bespoke intervention. Finally, the PTs recognize the use of injury prevention programs, which are multi-faceted in nature, and require the support of several disciplines working in sync. However, there was a revelation that since contextual factors can influence the adherence to strictly working within the scientific guidelines, practice must change to encourage player engagement. Therefore, although the scientific guidelines are closely followed, some flexibility is shown within the role to accommodate a multitude of contextual factors. This will allow current and future PTs who want to enter this sport discipline as a reference of what is done in high performance and the nuances that can appear in different situations during a season.

Limits of the study and possible future studies

The main limitations of this research arise when considering a small number of participants. On the other hand, it is possible that future investigations of this type consider it opportune to replicate this interview in other contexts, compare, deepen or adapt certain criteria that increase knowledge of the practices of PTs in soccer or other sports disciplines.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions

JB, HS and AJF directed the project, established the protocol, wrote and revised the original manuscript. AF translated and revised the original manuscript. BF, SQ, JRS, JR, IP, PC, HT and AS provided the evidence for this study by sharing their professional experience as interviewees. All authors have read, comment and accepted the published version of the manuscript.

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Chapter III

General discussion and Conclusions

Chapter III

General discussion and conclusions

3.0 General discussion and conclusions

3.1 Soccer injuries

By aiming for an increase in the physical capabilities and maximum performance of players in competition, it is likely that every day they are getting closer to the possibility of suffering an injury. In this sense, it is fundamental to understand that, an injury is considered a physical discomfort suffered by a player as a result of a soccer match or soccer training, regardless of the need for medical attention or time loss from soccer activities (Fuller et al., 2006). At the same time, its severity is determined by the days of absence (Fuller et al., 2006), being a 1 to 7 days injury considered mild, 8 to 21 days moderate and more than 21 days severe (Arnason et al., 2004b).

In soccer, injuries have become a critical issue to achieve sporting success. For this reason, injury prevention programs have been gaining popularity among coaches and experts involved in soccer, who see these programs with great interest because they see in them an opportunity that allows their players to face the demanding competitive schedules that entail both maximum performance and fitness of the player for as long as possible without an injury. That is, from the beginning of the season, so as not to lose ground (points) with other teams and until the end of the season, which is when it is generally determined whether the objectives proposed by the coach and the club are achieved (Ekstrand, 2008).

This need for performance is constant and, despite the increase in the literature related to injury prevention, the results of our third study determined that the systematic reviews related to injury prevention had a low methodological quality (Barrera, Figueiredo, Clemente, et al., 2022). Due to this, we believe it is important to look at what the literature proposes in relation to injury prevention in more detail, because on average, a team of 25 players can expect 40 to 50 injuries per season, half of which cause absences of less than one week, but six players cause absences of more than one month (Ekstrand, 2008).

Sport itself carries the risk of injury and each sport has its own particular injury profile (Kirkendall, Junge, & Dvorak, 2010). The incidence of injury in high-level soccer is six to nine injuries per 1000 h of total exposure, which are divided into three to five injuries per 1000 h of training and 24 to 30 injuries per 1000 h of match play (Ekstrand, 2008). This shows that there is concord in the literature, as the time when the greatest number of injuries occur is during competition and not over training (Ekstrand et al., 2011a; Wong & Hong, 2005); as well as showing an increase in the number of muscle injuries as playing time progresses (Ekstrand et al., 2011a). These injuries can be differentiated according to the action that precedes the injury, which can be with or without contact. Hawkins and Fuller (1999) reported that injuries caused by non-body contact were more frequent (59%) than those caused by body contact (41%). In addition, running, shooting, turning, and jumping caused 39% of all injuries, which were classified as non-body contact. Later findings by Hawkins et al. (2001) who studied professional soccer clubs over two seasons found that the percentage of non-body contact injuries (58%) was higher than body contact injuries (38%). Thus, running (19%), twisting and turning (8%), shooting (4%) and landing (4%) were the most common injury mechanisms and were classified as non-contact injuries. Recently, a study published by Chomiak et al. (2016) with players from the Czech Republic recorded that 46% of injuries were caused by contact and 54% by non-contact; in agreement with the trend of previous studies, despite a decrease in non-contact injuries and an increase in contact injuries, which may be subject to the increased competitiveness and intensity presented by current competitions. For this reason, and given the importance of injuries in sports performance at the European level (domestic and international competitions) (Hägglund, Waldén, Magnusson, et al., 2013), in our fourth study, coaches indicated that they perform strengthening works, which can have different objectives and be of different types: preventive, structural, specific, and restoration or recovery (Gómez, Roqueta, Tarragó, Seirul·lo, & Cos, 2019). They also mentioned that the goal is not to not get injured, but instead to achieve the best performance of the player and the team in general, but that, at the same time, it is quite clear that different elements are taken into consideration at the time of the construction of the programs, such as fatigue, injury history, rest and the last and next competition among other elements.

The anatomical region where injuries occur in soccer generally corresponds to the lower limbs, which are divided into the following regions: hip, groin, upper leg, knee, lower leg, ankle and foot (Wong & Hong, 2005), with serious injuries being caused mainly by trauma (81.5%) and overuse (18. 5%). There is a predomination of joint sprains (30%), followed by fractures (16%), muscle strains (15%), ligament tears

(12%), meniscal tears and contusions (8%), and other injuries, being knee injuries the most prevalent ones (29%), followed by ankle injuries (19%) spine (9%) and hand and groin with (8%) (Chomiak et al., 2016). In this sense, the coaches in our fourth study stated that, despite not being able to avoid these types of contact injuries because they are circumstantial, they can improve the physical structure of the players to try to better withstand these impacts that are part of the dynamics of the game and suffer less damage from these events, which generate sporting and economic losses for the club.

Additionally, a player can suffer 0.6 muscle injuries per season and a team of 25 players can expect about 15 muscle injuries per season, constituting 31% of all injuries and 27% of injury-related absences (Ekstrand et al., 2011a). Ninety-two percent of all muscle injuries affected the 4 major muscle groups of the lower limbs: hamstrings (37%), adductors (23%), quadriceps (19%), and calf muscles (13%) (Ekstrand et al., 2011a). These four diagnoses accounted for 81% of all muscle injuries and 88% of all days of absence due to muscle injuries (Hallén & Ekstrand, 2014). Ekstrand et al. (2011a) demonstrated that injuries caused by overuse with a gradual onset were more common among hip/joint injuries than, among injuries to the hamstrings, quadriceps, and calf muscles (42% vs. 30%, 26%, and 28%, respectively). Almost all muscle injuries (95%) occurred in non-contact situations (adductors, 92%; quadriceps and hamstrings, 96%; and calf muscles, 95%), and only 5% occurred during a dirty game.

It is evident that science has provided great evidence on the origin and causes of injuries, as well as on the effectiveness of prevention programs; however, there is a need for progress at the methodological level, greater rigor, longer interventions and the incorporation of control groups in the studies, so that the findings can be used with greater certainty. At a practical level, coaches can use this information to create multicomponent prevention plans that are specific to each player, and that consider among other key elements for prevention: age, injury history, fatigue and competition; in order to improve these complementary works and, in turn, allow the player to achieve optimal fitness.

3.2 Evaluation of performance in competition

Performance in competition and obtaining three points is what really matters in professional soccer. Nowadays, it is clear that there is a lot of scientific evidence on this matter, but in relation to professional Portuguese soccer players the evidence is scarce. In this sense, GNSS devices are a valid, reliable and relevant tool for monitoring external training load in professional soccer and previous recommendations have highlighted the importance of monitoring external training load to reduce the risk of injury and optimize the physical performance of players (Ravé, Granacher, Boullosa, Hackney, & Zouhal, 2020). Moreover, the use of these devices has allowed us to observe variations against different contextual variables, such as match location, opponent level, and match half (Minano-Espin et al., 2017; Rampinini et al., 2007); in the case of our findings, these variables did not imply significant differences (Barrera, Sarmento, et al., 2021).

Currently, there is already a consensus on the performance profile in terms of the soccer players total distance run by position, regardless of the competitive level and competition, where the results vary between 10 and 12 km in the different positions (Al Haddad et al., 2018; Barnes et al., 2014; Mohr et al., 2003; Rampinini et al., 2007), following the guidelines of the literature, the results obtained in our study reflected the same trends (Barrera, Sarmento, et al., 2021). However, differences have been observed in other variables such as high intensity or very high intensity running between different competitions (Dellal et al., 2011). A study comparing the Spanish League with the Premier League showed that Premier League players had a higher performance in sprint distance (Dellal et al., 2011), a difference that was also reflected when comparing our findings of distance covered in sprint by all positions (Barrera, Sarmento, et al., 2021), with Premier League players (Barnes et al., 2014). These discrepancies may be due to the difference that exists between first and second league competitions, as well as the country to which these leagues belong, reflecting cultural differences between the leagues in each country, either in the working conditions in each of them or in the competition itself, as well as the training methodologies used.

However, these results should be observed and analyzed with caution, when compared to some studies that have been conducted to analyze performance in competition in the same country or in the same league. For example, Di Salvo et al.

(2013) compared the match performance of the two main leagues in England (Premier League (1st) and Championship (2nd)) over four seasons (2006 - 2010), demonstrating that Championship players record a (slightly) higher performance than Premier League players in all travel intensities, making it clear that this may potentially be related to superior decision making, technical skills and greater efficiency in players from the top league (Di Salvo et al., 2013). Additionally, a study conducted in the (1st) Spanish League, which analyzed the competitive performance of Real Madrid (RM) during six seasons (2001 - 2007), showed that RM players covered shorter distances in high-speed running and sprinting and executed fewer sprints than players of the opposing team. This also demonstrates that the level of the opponent did not condition their performance and that they were able to impose and maintain their pattern of play despite the alteration of variables throughout the match (Minano-Espin et al., 2017). At the same time, this could be associated with cultural diversity, which has shown to be an important factor since more heterogeneous teams perform better than more homogeneous teams. This factor is also associated with the ability of clubs with greater economic resources to purchase players from different origins and regions of the world (Ingersoll, Malesky, & Saiegh, 2017). In turn, coaches who are inserted in teams with great cultural diversity have a possibility that facilitates the learning and adaptation of their players to their training methods and game ideas, which in consequence improves their performance (Sarmento et al., 2013).

These results allow us to reach certain preliminary conclusions regarding the classification of performance in competition, considering only quantitative parameters. In the first place, it can be seen that the most important characteristics for playing in the maximum division are based on quality and not on quantity and, secondly, the former is correct as long as the physical performance values are within the parameters established for each competitive level, since a player with great quality but without physical capacity would not be able to perform at the highest level of competition. Thus, it is essential that coaches know the different performance indicators of the maximum competition of each country (both in competition and tests), to use them as a reference and indicative of where the performance of players in each of the positions should be directed to.

To achieve these objectives, coaches must plan according to what is expected to be achieved and monitoring the process in order to evaluate, adjust or modify the planning in relation to the feedback obtained. In addition, coaches must create specific contexts related to physical, technical-tactical and psychological demands (decision making), for each position and with the highest degree of specificity, in order to help the player to optimize his performance in competition in a holistic way and not segmented.

3.3 Evaluation of physical abilities in soccer

According to the above, it seems evident that understanding performance in competition is not an easy task and that different elements that seem to affect the performance of players must be considered. For this reason, the evaluation of physical capacities in professional soccer became something usual, that tried to understand sports performance from the point of view of physical performance in capacities that seem to be key for competition. Following these ideas, the results expressed in this matter by the physical trainers in our fourth study make sense; results that are focused on strength as the most important physical capacity and that are followed by aerobic capacity. In correspondence with strength, our third study aimed to detect which elements best predicted 10, 20 and 30 m linear sprint performance, concluding that both isokinetic strength at an angular velocity of 180° knee extension could predict the 10, 20 m throwing and 30 m linear sprint performance; while knee flexion only correlated with 10 m velocity, whereas countermovement jump (CMJ) correlated with the longer distances of 20 m throwing and 30 m. Yet isokinetic evaluation at a lower angular velocity (60°) did not correlate with any sprint distance (Barrera, Figueiredo, Duarte, et al., 2022). These results are interesting, because soccer matches involve activity of different speeds, with high intensity efforts and between 10-20 sprints (high intensity running) performed approximately every 70 seconds, representing about 10% of the total running in a match (Stølen et al., 2005). However, in the decisive moments when a goal is scored in a match, 83% of these moments largely require a powerful action from the assisting player (46% direct sprint) or the scorer (45% direct sprint) (Faude et al., 2012), highlighting the importance of high or very high intensity movements during competition.

This leads us to think, what the best training strategies to improve performance in straight sprint are nowadays as well as power actions to achieve sporting success. Given the results expressed in our study on linear sprint prediction (Barrera, Figueiredo, Duarte, et al., 2022), we believe that velocity-based training (VBT) can induce the improvements that are much needed to achieve sporting success in modern soccer. In this sense, it has been shown that VBT with moderate to high external loads (50-75% RM) is an important tool to use in professional soccer players and it has shown that it can lead to improvements in absolute and relative power in concentric phases of half squat (Ramírez et al., 2015). Also, it has been shown that performing VBT for a period of 7 to 8 weeks can lead to clear improvements in maximal strength, strength endurance, jumping and lower extremity sprint performance (Zhang, Feng, Peng, & Li, 2022). On the other hand, applying 10-20% velocity losses can help induce neuromuscular adaptations and reduce neuromuscular fatigue, which is associated with maintaining better/improved work quality (Włodarczyk, Adamus, Zieliński, & Kantanista, 2021). As for recommendations for resistance training, training loads eliciting a movement velocity of ≈1.00 m-s-1 are the most appropriate loads to improve average propulsive power, with a velocity loss between 15 and 10% for the lower limbs and between 5 and 10% for the upper limbs (Guerriero, Varalda, & Piacentini, 2018). Additionally, the combination of resistance training with maximal movement speed (≥1.00 m-s-1) and plyometric exercises is recommended as an effective method to better transfer strength gains to sprint performance and also in explosive sport elements such as jumping and accelerations (Guerriero et al., 2018; Rodríguez-Rosell, Torres-Torrelo, Franco-Márquez, González-Suárez, & González-Badillo, 2017), which should be performed before specific technical-tactical training sessions, with a duration time that does not exceed 35 minutes, in order to produce low levels of fatigue (Rodríguez-Rosell, Torres-Torrelo, et al., 2017).

On the other hand, physical trainers indicated that a high aerobic capacity was important for their players mainly because of two elements: (1) the shorter recovery time required after a high intensity effort, and; (2) the prophylactic effect against injuries, which has been documented by the literature (Jones et al., 2013; Malone, Owen, Mendes, et al., 2018; Windt & Gabbett, 2017; Windt et al., 2017). For this reason and on a scientific level, various methods aimed at improving this capacity are suggested, ranging from: specific training targeting aerobic components (Jones et al., 2013), with reduced sets (Sarmento et al., 2018), resistance and speed training sessions (Castillo, Raya-González, Sarmento, Clemente, & Yanci, 2021; Clemente & Sarmento, 2021) and repeated 40-m sprint (Tønnessen, Shalfawi, Haugen, & Enoksen, 2011), among others.

All the evidence above shows that as science advances and its impact on the training process is proved, the way forward is also revealed. Thus, with each passing day, the training process requires the incorporation of new technological tools that allow individualizing and optimizing the training process, so as not to create problems in the search for maximum performance (injuries, low performance, fatigue, etc.) which, as mentioned above, creates financial and sporting difficulties that make it impossible to achieve sporting success.

3.4. Quantification and training control.

In relation to the above, at the scientific level there is a need that increases every day in terms of the quantification and control of training loads. This quantification and control of training loads as well as their proper balance between volume and intensity to control fatigue and optimize player performance is a constant challenge for all physical trainers (Owen et al., 2015). Workload monitoring provides valuable information to ensure that players recover effectively and also helps to understand how a player adapts and reacts to training (Nobari, Vahabidelshad, Pérez-Gómez, & Ardigò, 2021); for this, regular and continuous monitoring of workloads is necessary, which helps coaches to analyze daily changes in the athlete's fitness during training and competitions (Gabbett, 2020; Nobari et al., 2020). However, for this to happen, individualized control of workloads needs to be obtained, which, is rarely seen in soccer, as training prescriptions are generally group-based (Weston, 2018). This leads us to the need of changing the prescription forms and control of players, with the aim of optimizing individual performance and hoping that these improvements are transferred to the team, for which there are already different tools of different complexity, but equally valid.

In this sense, various research have discovered certain relevant elements that every coach should know, control and monitor in order to optimize the performance of their players. Firstly, it has been shown that excessive workload peaks can increase injury occurrence (Gabbett, 2020; Nobari, Vahabidelshad, et al., 2021), which indicates the attention that should be taken when prescribing workouts that exceed 10% of the weekly load, since, as this increases, so do the chances of getting injured (Gabbett & Whiteley, 2017). Additionally, some elements such as fatigue (Benjaminse, Webster, Kimp, Meijer, & Gokeler, 2019) as well as acute match fatigue have been shown to increase the risk of injury at the end of each period, primarily (Ekstrand et al., 2011b). On the other hand, recent evidence shows that, when properly achieved, relatively high and appropriate chronic training loads are associated with lower injury risk and improved performance (Gabbett & Whiteley, 2017), this is essential, since achieving high levels of endurance, strength, speed, agility and optimal levels of body composition are considered key to achieving sporting success (Cabell et al., 2019; Haycraft et al., 2017; Johnston et al., 2018). For this reason, understanding the correct relationship between acute load and chronic load is critical to achieve the best levels of athletic performance along with a low injury rate. To achieve this, it is useful to know the method proposed by Banister et al. (1975), who seeks the balance between fitness (chronic load - moving load from 3 to 6 weeks or a mesocycle) and fatigue (acute load - one week or a microcycle), since it is considered a benchmark to examine the injury rate in training.

In this sense, two estimations are currently used for training load which are, internal load (physical, mental and psychological response of the individual) and external load (e.g., global positioning system, location position system, inertial measurement unit) (Charlot, Zongo, Leicht, Hue, & Galy, 2016); for both of these, different control methods are used. In this context, elements such as the Rating Perception of Exertion Scale (RPE) appear, which is undoubtedly the simplest load metric to apply in collective sports such as soccer (Gabbett & Whiteley, 2017), and which has proven to be an accurate and valuable monitoring tool, that also has a high correlation with heart rate (Clarke, Farthing, Norris, Arnold, & Lanovaz, 2013).

Gabbett (2016b), proposes different zones of relationship between acute load and chronic load. Regarding the lowest injury risk, the point of relationship between these variables is located between values 0.8 and 1.3 referred to as the "sweet spot". Oppositely, the "danger zone" is established at values >1.3 and also at values <0.8.

However, afterwards, Malone et al. (2017a) further specified these values with professional soccer players in relation to the sweet spot and determined that, if the ratio between acute and chronic workload during the season was somewhere between >1.00 and <1.25 (OR = 0.68, p=0.006), they had a significantly lower risk of injury compared to the reference group (≤0.85). This highlights the importance of recording and controlling the relationship between these variables to decrease the risk of injury in professional players.

Thus, the current evidence shows the importance of quantifying and controlling training loads, due to the implication it may have on injury prevention, which directly affects the team's performance and the coach's work.

3.5 Conclusions

This thesis increased the knowledge of the work performed by physical trainers in order to optimize players performance in the professional context, addressing critical issues of their daily work. In addition, it increased the information referred to professional soccer players in Portugal, highlighting their performance in official competitions and physical capacities related to performance. Unfortunately, other elements incorporated in this work, which should have been done with information related to the referred context, could not be done for external reasons that did not depend on the researcher's will. For this reason, it was necessary to make some adjustments that led to the realization of a general review of systematic reviews related to prevention programs in male soccer players, allowing to synthesize the large amount of evidence that exists in this regard. The main conclusions and practical applications drawn from this thesis were as follows:

i. The overall review provided a comprehensive synthesis of evidence of injury prevention programs in men's soccer, including several beneficial practices for players, teams, and clubs. Highlighting the fact that programs aimed at improving muscle strength and proprioception reduce the incidence and severity of injuries, particularly hamstring strains and ankle sprains. In addition, warm-ups that include dynamic activity before soccer matches decrease the incidence of injuries, while the impact of static stretching as a preventive strategy seems ambiguous.
ii. A low methodological quality was detected in the systematic reviews included in the overall review, suggesting that new research needs to be conducted in

accordance with current criteria in order to provide quality evidence and applicability.

iii. A lack of consistency was evident among studies reporting on prevention programs in male soccer players. More homogeneous research is required to elucidate the efficacy of injury prevention protocols to inform practice in the applied environment in the applied setting.

iv. The physical demands in competition are specific to each playing position, so that preparation for competition should be performed in a position-specific manner.

v. It was shown that some contextual variables can affect running performance; e.g. the location of the match (playing at home or playing away); achieving a favorable result (i.e. winning or drawing) led players to cover greater distances; And the first and second part of the competition.

vi. Players with higher torque at an angular velocity at 180 $\cdot$ s^{-1} had lower sprint times (i.e., were faster) at 10, 20, and 30 m, while torque at an angular velocity of 60° $\cdot$ s^{-1} was not related to sprint performance. This suggests that assessments performed to predict sprint performance need to be associated with higher angular velocities at the expense of slower ones. Whereas SJ and CMJ jump tests were negatively associated with 20 and 30 m sprinting (higher jump height, lower sprint times).

vii. It is recommended that training protocol design should be aimed at increasing lower extremity explosive strength and that they develop on a weekly manner in order to maximize sprint performance.

viii. Contemporary coaching practices are increasingly based on the use of scientific elements to evaluate, monitor, optimize and prevent injuries of players at different times of the season.

ix. Despite having a link with science, physical trainers recommend having some flexibility in the application of different elements of evaluation, monitoring, optimization and prevention due to the demands of coaches and the particularities of the players.

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Appendix A

Curriculum Vitae

Curriculum Vitae - cienciavitae

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