ABSTRACT

The physiological demands of soccer challenge the entire spectrum of the response capacity of the biological systems and fitness requirements of the players. In this review we examined variations and evolutionary trends in body composition, neuromuscular and endurance-related parameters, as well as in game-related physical parameters of professional players. Further, we explore aspects relevant for training monitoring and we reference how different training stimulus and situational variables (e.g., competition exposure) affect the physiological and performance parameters of players. Generally, improvements of small magnitude in non- (non-CMJ) and countermovement-based jumps (CMJ\textsubscript{Based}) and in the sprint acceleration (ACC\textsubscript{Phase}) and maximal velocity phase (MV\textsubscript{Phase}) are observed from start of preparation phase (PPS) to beginning of competition phase (BCP). A greater magnitude of increases is observed in physiological and endurance performance measures within this period; moderate magnitude in sub-maximal intensity exercise (velocity at fixed blood lactate concentrations; $V_{\text{2-4mmol/l}}$) and large magnitude in VO\textsubscript{2max}, maximal aerobic speed (MAS) and intense intermittent exercise performance (IE). In the middle of competition phase (MCP), small (CMJ\textsubscript{Based} and ACC\textsubscript{Phase}), moderate (non-CMJ; MV\textsubscript{Phase}, VO\textsubscript{2max}; sub-maximal exercise) and large (MAS and IE) improvements were observed compared to PPS. In the end of competition period (ECP), CMJ\textsubscript{Based} and MV\textsubscript{Phase} improve to a small extent with non-CMJ, and ACC\textsubscript{Phase}, VO\textsubscript{2max}, MAS, sub-maximal intensity exercise and IE revealing moderate increments compared to PPS. Although less investigated, there are generally observed alterations of trivial magnitude in neuromuscular and endurance-related parameters between in-season assessments; only substantial alterations are examined for IE and sub-maximal exercise performance (decrease and increase of small magnitude, respectively) from BCP to MCP and in VO\textsubscript{2max} and IE (decrements of small magnitude) from MCP to ECP. Match performance may vary during the season. Although, the variability between studies is clear for TD, VHSR and sprint, all the studies observed substantial increments in HSR between MCP and ECP. Finally, studies examining evolutionary trends by means of exercise and competition performance measures suggests of a heightened importance of neuromuscular factors. In conclusion, during the preseason players “recover” body composition profile and neuromuscular and endurance competitive capacity. Within in-season, and more robustly towards ECP, alterations in neuromuscular performance seem to be force-velocity dependent, and in some cases, physiological determinants and endurance performance may be compromised when considering other in-season moments. Importantly, there is a substantial variability in team responses that can be observed during in-season. Consequently,
this informs on the need to both provide a regular training stimulus and adequate monitoring throughout the season.

**Subjects** Anatomy and Physiology, Kinesiology, Biomechanics, Sports Medicine

**Keywords** Training and testing, Football, Power, Neuromuscular training, Endurance training, Body composition, Match activity, Time-motion analysis, Training monitoring, Soccer physiology

**INTRODUCTION**

In soccer, during both training practices and matches, players perform a wide range of activities (e.g., sprints) that demand players be able to sustain and produce forceful contractions (Stolen et al., 2005). Moreover, there is evidence (e.g., global positioning systems) suggesting that the mechanical and metabolic loads imposed during training and games is even higher that previously suspected (Barnes et al., 2014; Bush et al., 2014; Konefal et al., 2019b; Osgnach et al., 2010; Varley & Aughey, 2013). The repeated bouts of intermittent soccer-specific activities of an aerobic and/or anaerobic nature impose acute and chronic strains on various physiological systems (e.g., musculoskeletal, nervous, and metabolic) that may lead to declines and impairments in performance (e.g., reductions in strength/power-based parameters), biological functions (e.g., hormonal milieu, biochemical responses) and perceptual responses (e.g., muscle soreness) in different players (Bangsbo, Mohr & Krustrup, 2006; Kraemer et al., 2004; Reilly, Drust & Clarke, 2008; Reinke et al., 2009; Silva et al., 2013a; Silva et al., 2014; Smith et al., 2018).

Notwithstanding the evidence that there are physiological characteristics that favor the capacity of playing a specific field position in soccer (Altmann et al., 2020; Carling & Orhant, 2010; Konefal et al., 2019b), the game demands sufficient skills such that substantial deviations from this profile remain compatible with a high standard of performance (Shephard, 1999). Nevertheless, a positive body composition (e.g., low adiposity) and proficient neuromuscular (e.g., strength and power) and endurance-related (e.g., high-intensity intermittent exercise) qualities provide a competitive advantage, as they are associated with improved fatigue resistance during the game (Bangsbo, Iaia & Krustrup, 2008; Silva et al., 2018) faster post-match recovery (Hader et al., 2019; Owen et al., 2015; Tofari, Kemp & Cormack, 2017) and injury prevention (Al Attar et al., 2017; Malone et al., 2019; Malone et al., 2016; Zouita et al., 2016). As so, players perform intense training programs to potentiate these fitness determinants to cope with the acute and chronic demands of a high-level soccer season cycle (Brocherie et al., 2014; Chmura et al., 2019; Eliakim et al., 2018; Malone et al., 2018; Silva et al., 2014). Therefore, to prevent performance decline and to ensure that training programs are effective, elite clubs should have as a required organizational practice the implementation of a training monitoring system (e.g., performance tests, records of daily exercise intensity) and effective strategies to aid in player recovery (Silva & Rebelo, 2019).

**Rationale for the review**

Player’s physical performance is one of the relevant performance domains and so, understanding the dynamic nature of adaptations throughout the season is of relevance for
the population of soccer players. However, despite that there are important reviews concerning physiological characteristics of soccer players (Shephard, 1999; Stolen et al., 2005; Svensson & Drust, 2005), soccer biomechanics (Lees et al., 2010; Lees & Nolan, 1998), determinants of players’ performance (Bangsbo, Iaia & Krustup, 2007; Bangsbo, Mohr & Krustup, 2006; Reilly, Drust & Clarke, 2008), specific training-induced effects (Hill-Haas et al., 2011; Hoff, 2005; Hoff & Helgerud, 2004; Iaia, Rampinini & Bangsbo, 2009; Silva, Nassi & Rebelo, 2015), and development of soccer fatigue and kinetics of recovery (Hader et al., 2019; Mohr, Krustup & Bangsbo, 2005; Nedelec et al., 2012; Nedelec et al., 2013; Reilly, Drust & Clarke, 2008; Reilly & Ekblom, 2005; Silva et al., 2018), an understanding of seasonal adaptations and evolutionary trends on players’ physical fitness is still required.

Intended audience and organization
Understanding the different variables that affect the dynamic nature of adaptations during the season may allow coaches, medical departments, and researchers to improve training periodization and monitoring. We target this review for students (e.g., exercise physiology and strength and conditioning), researchers, and all practitioners (coaches and medical department related staff) to whom the knowledge about the physiological and functional characteristics of the players is a matter of undeniable interest and understanding the different variables that affect the dynamic nature of adaptations occurring within the training season may allow informed decisions on training periodization and monitoring.

In this review we examined adaptations in body composition (body mass, body fat and lean body mass) and different neuromuscular qualities of professional soccer players (force production, jump, sprint and change of direction abilities). Subsequently, we analyzed seasonal alterations in endurance-related physiological and performance parameters as well as in competition measures of professional soccer players. Moreover, we will reference how different training stimulus and situational variables (e.g., competition exposure) affect the physiological and performance parameters of highly trained players. Further, we will explore aspects relevant for training monitoring of professional players.

SURVEY METHODOLOGY
Literature search strategy
For the search for relevant scientific literature, a review was performed using the PubMed and SportDiscus databases multiple times until June 2022. Additionally, Google Scholar and bibliographic searches of relevant articles were also completed. The description of seasonal trends comprises papers from January 2000 to April 2022 (Tables 1 and 2).

The search strategy included the following search terms and Boolean operators using the term “soccer” AND “seasonal alterations”, OR “performance analysis”, OR “competition”, OR “physiology”, OR “body composition”, OR “strength training”, OR “neuromuscular performance”, OR “fatigue”, OR “field tests”, OR “intermittent endurance”, OR “muscular power”, OR “jump ability”, OR “sprint ability”, OR “agility”, OR “change of direction”, OR “training period”, OR “detraining”, OR “off season”, OR “in season”, OR “preseason” OR “competition period”.

Silva (2022), PeerJ, DOI 10.7717/peerj.14082
| Study | Sample | N (Age) | Time points | Study | Sample | N (Age) | Time points |
|-------|--------|---------|-------------|-------|--------|---------|-------------|
| (Aziz, Tan & Teh, 2005) | Elite Singapore | 41 (25.7) | X | X | X | X | (Krustrup et al., 2006) | 1st & 2nd League Denmark | 15–20 (adult) | X | X | X |
| (Bonuccelli et al., 2012) | Elite Italy | 10 (26.7) | X | X | X | X | (Lago-Beñas et al., 2013) | Professional Spain | 42 (25) | X | X | X |
| (Boullosa et al., 2013) | Elite Spain | 12 (24) | X | X | X | (Link & de Lorenzo, 2016) | Professional Germany | 428 (adult) | X | X |
| (Bradley et al., 2011) | Elite Denmark | 10 (adult) | X | X | X | X | (Los Arcos et al., 2015) | Professional Spain | 14 (20.6) | X | X |
| (Bunc, Hráský & Skalská, 2015) | Elite Czech Republic | 45 (21.9) | X | X | X | (Manzi et al., 2013) | Elite Italy | 18 (28.4) | X | X |
| (Campos-Vazquez et al., 2016) | Professional Spain | 12 (27.7) | X | X | X | (Medel et al., 2018) | Professional Israel | 18 (22–32) | X | X | X |
| (Casajus, 2001) | Elite Spain | 15 (25.8) | X | X | (Metaxas et al., 2006) | Elite Greece | 10–12 (18.1–18.2) | X | X | X | X |
| (Castagna et al., 2011) | Elite Italy | 14 (25) | X | X | (Michalczewski et al., 2008) | Professional Poland | 19 (26.1) | X | X |
| (Castagna et al., 2013) | Elite Italy | 18 (28.6) | X | X | (Mohr, Krustrup & Bangsbo, 2003) | Professional Denmark | 10 (26.4) | X | X | X |
| (Clark et al., 2008) | Elite England | 10–22 (25) | X | X | X | (Mohr, Krustrup & Bangsbo, 2002) | Elite Denmark | 11 (24.0) | X | X | X |
| (Clemente et al., 2021) | Professional Portugal | 25 (28.1) | X | X | (Morgans et al., 2014) | Professional England | 6 (25.7) | X | X | X |
| (D’Ascenzo et al., 2013) | Professional Italy | 23 (26.6) | X | X | X | (Ostojic, 2003) | Elite Serbia | 30 (23.5) | X | X | X |
| (Devlin et al., 2017) | Elite Australia | 18 (25.5) | X | X | X | (Ostojic et al., 2009) | Elite Serbia | 12 (25.8) | X | X |
| (Dunbar, 2002) | Professional England | 11 (NS-adults) | X | X | X | (Owen et al., 2018) | Elite European | 22 (24) | X | X |
| (Edwards, Macfadyen & Clark, 2008) | Professional England | 12 (36.2) | X | X | (Padron-Cabo et al., 2018) | Professional Spain | 519 (adult) | X | X | X |
| (Ensieler et al., 2012) | Professional Israel | 31 (NS-adults) | X | X | (Papadakis, Postris & Georgiou, 2015) | Professional Greece | 10 (23.6) | X | X | X |
| (Fessi et al., 2016) | Elite Turkey | 14 (25.8) | X | X | (Rampini et al., 2007) | Professional Italy | 20 (26.4) | X | X | X |
| (Fessi et al., 2016) | Professional Qatar | 17 (23.7) | X | X | X | (Remke et al., 2009) | Professional Germany | 10 (20–36) | X | X | X |
| (Hantoudis et al., 2004) | Elite Greece | 12 (25) | X | X | X | (Rezmini et al., 2017) | Professional Spain | 19 (26.2) | X | X | X |
| (Jau et al., 2009) | Professional Denmark | 12 (22.4) | X | X | X | (Silva et al., 2013b) | Professional Portugal | 13 (25.7) | X | X | X |
| (Iuga et al., 2014) | Professional England | 35 (20.4) | X | X | X | (Silva et al., 2011) | Professional Portugal | 18 (25.7) | X | X | X |
| (Kalapotharakos, Ziegas & Tokmakidis, 2011) | Elite Greece | 12 (25) | X | X | (Suda et al., 2012) | Professional Japan | 21 (24.7) | X | X | X |
| (Koundourakis et al., 2014) | Professional Greece | 22–23 (23.8–25.5) | X | X | X | (Zoppi et al., 2006) | Professional Brazil | 10 (18.2) | X | X |
| (Krustrup et al., 2003) | Elite Denmark | 10 (adult) | X | X | X | (Krustrup et al., 2000) | Elite Denmark | 11 (24.0) | X | X | X |

Note: N, sample size; PPS, prior pre-season; BCP, beginning competition phase; MCP, middle competition phase; ECP, end competition phase.
| Study                                                                 | Body Composition | Strength | Jump ability | Sprint ability | Endurance | GPP |
|----------------------------------------------------------------------|------------------|----------|--------------|---------------|-----------|-----|
| (Aziz, Tan & Teh, 2005)                                             | BM; BF           | S\text{WAS} | 5–20-m       | E             |           |
| (Bonuccelli et al., 2012)                                            | BF; LBM          | CMJ\text{Based} | ACC\text{Phase} | MV\text{Phase} | COD | VO_{2}\text{max} | MAS | SM | IE |
| (Boullosa et al., 2013)                                              |                  |           |              |               |           |     |               |     |     |    |
| (Bradley et al., 2011)                                               |                  |           |              |               |           |     |               |     |     |    |
| (Bunc, Hraský & Slabká, 2015)                                       |                  | D        |               |               |           |     |               |     |     |    |
| (Casajus, 2001)                                                     |                  | Vpeak   |               |               |           |     |               |     |     |    |
| (Castagna et al., 2011)                                             |                  | D        |               |               |           |     |               |     |     |    |
| (Clark et al., 2008)                                                |                  | AT%VO_{2}\text{max} |               |               |           |     |               |     |     |    |
| (Clemente et al., 2021)                                             |                  | D        |               |               |           |     |               |     |     |    |
| (D'Ascenzi et al., 2013)                                            |                  | D        |               |               |           |     |               |     |     |    |
| (Deslin et al., 2017)                                               |                  | D        |               |               |           |     |               |     |     |    |
| (Dunbar, 2002)                                                      |                  | D        |               |               |           |     |               |     |     |    |
| (Edwards, Macfadyen & Clark, 2003)                                  |                  | D        |               |               |           |     |               |     |     |    |
| (Eniseler et al., 2012)                                             |                  | D        |               |               |           |     |               |     |     |    |
| (Fessi et al., 2016)                                                |                  | D        |               |               |           |     |               |     |     |    |
| (Haritodinis et al., 2004)                                          |                  | D        |               |               |           |     |               |     |     |    |
| (Iaia et al., 2009b)                                                |                  | D        |               |               |           |     |               |     |     |    |
| (Iga et al., 2014)                                                  |                  | D        |               |               |           |     |               |     |     |    |
| (Kalapotharakos, Ziogas & Tokmakidis, 2011)                          |                  | D        |               |               |           |     |               |     |     |    |
| (Koundounakis et al., 2014)                                         |                  | D        |               |               |           |     |               |     |     |    |
| (Krustrup et al., 2008)                                             |                  | D        |               |               |           |     |               |     |     |    |
| (Krustrup et al., 2006)                                             |                  | D        |               |               |           |     |               |     |     |    |
| (Lago-Peñas et al., 2013)                                           |                  | D        |               |               |           |     |               |     |     |    |
| (Link & de Lorenzo, 2016)                                           |                  | D        |               |               |           |     |               |     |     |    |
| (Los Arcos et al., 2015)                                            |                  | D        |               |               |           |     |               |     |     |    |

(Continued)
| Study                              | Body Composition | Strength Jump ability | Sprint ability | Endurance | GPP |
|-----------------------------------|------------------|-----------------------|---------------|-----------|-----|
|                                   |                  |                       |               |           |     |
| (Malliou et al., 2003)            | KE               | SJ                    | CMJ           | D         | V<sub>max</sub>@4mmol/l, VT, VO<sub>2</sub> | YYIR1 |
| (Manzi et al., 2013)              | BM; BF; LBM      | CMJ                   |               | D         | VT, Speed |
| (Manzi et al., 2013)              | BM; BF; LBM      | CMJ                   |               | D         | TD, HSR |
| (Malliou et al., 2003)            | BM; BF; LBM      | CMJ                   |               | TD; HSR; | V<sub>H</sub> | Sprint |
| (Ostojic, 2003)                   | BM; BF; LBM      | CMJ                   | 50-m          | D         | TD; HSR; | Sprint |
| (Ostojic et al., 2009)            | BM; BF           | CMJ                   |               | V<sub>max</sub>@2-4mmol/l |
| (Owen et al., 2018)               | BM; BF           | CMJ                   |               | V<sub>max</sub>@2-4mmol/l |
| (Padron-Cabo et al., 2018)        | BM; BF           | CMJ                   |               | V<sub>max</sub>@2-4mmol/l |
| (Rampinini et al., 2007b)         | BM; BF; LBM      | CMJ                   | 15-m          | Vam-Eval  |
| (Requena et al., 2017)            | BM; BF           | CMJ                   |               | V<sub>max</sub>@2-4mmol/l |
| (Silva et al., 2013b)             | BM; BF           | CMJ                   | 5-m 30-m T-test | YYIE2 |
| (Silva et al., 2011)              | BM; BF; LBM      | CMJ                   |               | TD; HSR; | Sprint |
| (Zoppi et al., 2006)              | BM; BF           | CMJ                   |               | TD; HSR; | Sprint |

**Note:**

N, sample size; BM, body mass; BF, body fat; LBM, lean body mass; KE, knee extensors in isokinetic mode; KF, knee flexors in isokinetic mode; Non-CMJ, non-countermovement jump; CMJ<sub>based</sub>, jumps involving a countermovement jump; ACC<sub>Phase</sub>, sprint acceleration phase; MV<sub>Phase</sub>, maximal velocity phase; COD, change of direction ability; VO<sub>2max</sub>, maximal oxygen consumption; MAS, maximal aerobic speed; SM, submaximal intensity exercise; IE, intense intermittent exercise; GPP, game physical parameters; CMJ, countermovement jump; CMJ<sub>WAS</sub>, countermovement jump with arm swing; SJ, squat jump; SJ<sub>WAS</sub>, squat jump with arm swing; E, estimated; D, direct measurement; YYIR1, yo-yo intermittent recovery test level 1; YYIR2, yo-yo intermittent recovery test level 2; YYIE2, yo-yo endurance intermittent test level 2; TD, total distance; HSR, high speed running distance; VHSR, very-high speed running distance; GT, Gancon Test; VT, Speed/HR/VO<sub>2</sub>; Speed/Heart rate/oxygen consumption at ventilatory threshold; V<sub>max</sub>@2-4mmol/l, Speed at a blood lactate concentration of 2, 3 and 4 mmol/l; LT, Speed, speed at lactate threshold; LT<sub>VO2</sub>, oxygen consumption at lactate threshold; HR<sub>10-14-18 km/h</sub>, heart rate at speed of 10 14 and 18 km/h; %VO<sub>2max</sub>@4mmol, Percentage of VO<sub>2max</sub> at a blood lactate concentration of 4 mmol/l; AT<sub>%VO2max</sub>, percentage of VO2max at the anaerobic threshold.
Analysis and interpretation of the results

Studies were included if they: (i) investigated adults (>19 years) soccer players described as professional or elite player (ii) measured at least two season time points; specifically, the preparation period (PPS), beginning of the competitive period (BCP), middle (MCP) or end of competition period (ECP).

The mean and standard deviation for each measurement was extracted. In the case the necessary statistics were represented in figures and graphs their value was extrapolated using a specific software for the purpose (webPlotDigitizer; https://automeris.io/WebPlotDigitizer/). To evaluate the magnitude of the effects, percent change was calculated for each dependent variable for each study using the procedures defined elsewhere (Silva et al., 2018). Using the procedures defined in Schmitz et al. (2018) we compute a global mean (by time-point and variation between moments) based on the reported means of the individual studies for each outcome. We apply this procedure assuming that the players from each research within the same group belong to the same population and that their test results were extract from the same normal distribution (Schmitz et al., 2018). Each global mean was computed as weighted mean of the individual reported mean, with weights built by the number of subjects per investigation (Schmitz et al., 2018). Effect size (ES) were computed to present standardized values on the outcome variables (Cohen, 1998). The different ES within individual studies were calculated with Cohen’s d, by dividing the raw ES (difference in means) by the pooled standard deviations, as proposed (Cohen, 1998). To account for possible overestimation of the true population ESs were corrected accounting for the magnitude of the sample size of each study (Lakens, 2013). Therefore, a correction factor was calculated as proposed by Hedges & Olkin (1985). Threshold values for g were defined as trivial (<0.2), small (0.2–0.6), moderate (0.6–1.2), large (1.2–2.0) and very large (>2.0) (Cohen, 1998).

ANTHROPOMETRIC AND NEUROMUSCULAR ADAPTATIONS: WHY THE RELEVANCE?

Players body composition analysis is becoming increasingly widespread in professional football and is considered important for help players reach optimal performance potential (Mills, De Ste Croix & Cooper, 2017). As example, excessive BF may act as “dead weight” placing an unnecessary “load” and stress on players every time they “compete” against gravity and opponents for conquer a positional advantage during the game. Additionally, improved/increases in “lean body mass” (muscle mass) may favor the execution of the high impulsive actions (e.g., sprint) that are essential from a performance and recovery standpoint (e.g., greater fatigue resistance and decrease muscle damage) (Malone et al., 2016; Owen et al., 2015; Silva, 2019; Silva & Rebelo, 2019).

The analysis of the players’ activity during games and trainings, along with the physiological, neuromuscular, and perceptual responses to training and competition demands, highlights the important role of neuromuscular function for successful soccer performance (Nedelec et al., 2012; Silva et al., 2018). The high-impulsive efforts, such as sprints, jumps, acceleration/deceleration, and duels require maximal neuromuscular efforts (Cometti et al., 2001). These efforts have the goal of maximize the impulse produced
(Winter et al., 2016) as this determines the decisive decision-making situations in professional soccer (e.g., speed) (Faude, Koch & Meyer, 2012; Martinez-Hernandez, Quinn & Jones, 2022). Consequently, the impulse produced during these muscle actions of both concentric, isometric, and eccentric nature, with more relevance to the latter impose significant stress on the neuromuscular and physiological systems (Dellal et al., 2010; Gaudino et al., 2013; Hader et al., 2014; Hader et al., 2019). In effect, a massive mechanical and metabolic load is imposed on players not only during the maximal intensities' phases of the game but also every time acceleration occurs, even when speeds are low (Osgnach et al., 2010). These speed and direction of movement changes performed during games place stress on the involved musculature from a metabolic viewpoint, thereby affecting energy usage and resulting in a higher physiologic impact than habitual forward movements (Buchheit et al., 2010; Dellal et al., 2010). From a mechanical standpoint, an increased eccentric load is associated with exercise-induced muscle damage (Byrne, Twist & Eston, 2004), contributing to more rapid development of fatigue (e.g., transient, and residual fatigue; peripheral or central) and consequently increasing the odds of injury.

Other evidence of the relevance of neuromuscular function for actual soccer has been suggested by reports that VO$_{2\text{max}}$ values among professional players are not improving over time (Tonnessen et al., 2013), and contrasting findings concerning sprinting velocity have been observed, e.g., small but positive inter-seasonal development (Haugen, Tonnessen & Seiler, 2013). These facts lead to the suggestion that neuromuscular and anaerobic-related parameters (e.g., sprinting ability) are assuming a greater preponderance in modern soccer than other, more typical endurance parameters (e.g., VO$_{2\text{max}}$). Interestingly, there are also indications for greater dominance of neuromuscular factors during game (Barnes et al., 2014; Pons et al., 2021).

Although not universally confirmed (Metaxas et al., 2009), some reports suggest that superior neuromuscular function can be observed in soccer players of a higher standard, which includes greater strength (Cometti et al., 2001; Dauty & Potiron Josse, 2004), short distance sprint speed (Cometti et al., 2001; Dauty & Potiron Josse, 2004; Haugen, Tonnessen & Seiler, 2013), agility or COD (Mujika et al., 2008; Power, Dunbar & Treasure, 2005; Reilly et al., 2000) and anaerobic endurance (Power, Dunbar & Treasure, 2005). In addition, these greater neuromuscular capabilities are not only suggested by the higher ability to perform powerful contractions during isokinetic force production tasks but also during and throughout repetitive stretch-shortening cycle activities (SSC) (Impellizzeri et al., 2008; Mujika et al., 2008; Rampinini et al., 2009b). Given these factors, the recent observation that power and speed abilities are determinants in defining result outcomes is not surprising (Faude, Koch & Meyer, 2012; Martinez-Hernandez, Quinn & Jones, 2022) and should be considered when monitoring training plans. Moreover, neuromuscular and anaerobic-related qualities of professional players (e.g., sprint capacity, power production) have been associated with higher and improved soccer-specific running capacity and are reflected by the following: (i) the ability to perform high-intensity intermittent endurance exercise tests (Ingebrigtsen et al., 2013a; Wells et al., 2014); (ii) maximal speed and time to exhaustion of the players during a maximal anaerobic running test being strongly associated with YYIR2 performance (Wells et al., 2014); (iii) increments in the former
neuromuscular and anaerobic qualities being associated with improvements in YYIR2 (Wells et al., 2014); (iv) high performance in certain game-related physical parameters (Altmann et al., 2018) as well as lower fatigue development during the match (Silva et al., 2013b) and during the post-match recovery period (Tofari, Kemp & Cormack, 2017, 2020); and (v) strength may acts as a moderator of injury occurrence (Al Attar et al., 2017; de Hoyo et al., 2015a). Along this line of reasoning, recent reports have revealed that professional players with higher chronic competition exposure may show higher performance in muscle power actions (Morgans, Di Michele & Drust, 2017; Silva et al., 2011; Sporis et al., 2011). These facts may also suggest that seasonal alterations in neuromuscular performance may be influenced by competition time – match exposure represents a considerable and important “training” stimulus for improving muscle-power-based actions (Morgans, Di Michele & Drust, 2017).

VARIATIONS IN PHYSIOLOGICAL DETERMINANTS AND NEUROMUSCULAR PERFORMANCE

Body composition

Studies investigating seasonal changes in anthropometric variables, such as body mass (BM, n = 507) (Aziz, Tan & Teh, 2005; Bunc, Hráský & Skalská, 2015; Casajus, 2001; Clemente et al., 2021; D’Ascenzi et al., 2013; Edwards, Macfadyen & Clark, 2003; Fessi et al., 2016; Kalapotharakos, Ziogas & Tokmakidis, 2011; Koundourakis et al., 2014; Lago-Peñas et al., 2013; Meckel et al., 2018; Metaxas et al., 2006; Michalczyk et al., 2008; Ostojic, 2003; Ostojic et al., 2009; Reinke et al., 2009; Silva et al., 2011; Suda et al., 2012), body fat (BF, n = 579) (Aziz, Tan & Teh, 2005; Bonuccelli et al., 2012; Bunc, Hráský & Skalská, 2015; Casajus, 2001; Clemente et al., 2021; D’Ascenzi et al., 2013; Devlin et al., 2017; Fessi et al., 2016; Iga et al., 2014; Kalapotharakos, Ziogas & Tokmakidis, 2011; Koundourakis et al., 2014; Lago-Peñas et al., 2013; Los Arcos et al., 2015; Meckel et al., 2018; Metaxas et al., 2006; Ostojic, 2003; Ostojic et al., 2009; Owen et al., 2018; Papadakis, Patras & Georgouli, 2015; Reinke et al., 2009; Silva et al., 2011; Suda et al., 2012) and lean body mass (LBM, n = 226) (Bonuccelli et al., 2012; Bunc, Hráský & Skalská, 2015; Casajus, 2001; D’Ascenzi et al., 2013; Devlin et al., 2017; Metaxas et al., 2006; Ostojic, 2003; Owen et al., 2018; Reinke et al., 2009; Suda et al., 2012) are presented in Tables 1 and 2 and Figs. 1–3.

The overall analysis of a reasonable number of investigations seems to suggest that players’ BM (Fig. 1) is stable during the season; trivial effects from PPS to BCP (Δ = −0.79%, ES = −0.07), MCP (Δ = −0.85%, ES = −0.04) and ECP (Δ = −1.33%, ES = −0.12) are examined by average.

Generally, both the absolute and relative BF decreases during the season (Figs. 1 and 2). From the observed studies, we might conclude that alterations of small magnitude are examined from PPS to BCP (Δ = −9.6%, ES = −0.54), MCP (Δ = −8.2%, ES = −0.57) and ECP (Δ = −8.7%, ES = −0.39) in absolute BF. In this line of study, relative BF may decrease by a small magnitude in BCP (Δ = 8.9%, ES = 0.45), MCP (Δ = 9.9%, ES = 0.43) and ECP (Δ = 12%, ES = 0.53). Interestingly, at BCP 88% (16 in 18), at 94% (MCP 17 in 18) and at ECP 100% (12 in 12) of the ES reported are negative and so pointing on a decrease in
absolute BF. Moreover, there are reports of decrements by moderate magnitude at BCP (Clemente et al., 2021; D’Ascenzi et al., 2013; Devlin et al., 2017; Meckel et al., 2018; Ostojic, 2003), MCP (D’Ascenzi et al., 2013; Devlin et al., 2017; Kalapotharakos, Ziogas & Tokmakidis, 2011; Meckel et al., 2018) and ECP (D’Ascenzi et al., 2013; Koundourakis et al., 2014; Ostojic, 2003; Papadakis, Patras & Georgouli, 2015). Although on average trivial changes in BF (absolute and relative) may occur during in-season (BCP vs MCP and MCP vs ECP, $\Delta = -2.4\%$ and $-1.8\%$, ES = $-0.06$ and $-0.07$, respectively), within the 16 studies that monitored in-season changes, both substantial decrements (Casajus, 2001; D’Ascenzi et al., 2013; Fessi et al., 2016; Kalapotharakos, Ziogas & Tokmakidis, 2011; Koundourakis...
et al., 2014; Ostojic, 2003; Papadakis, Patras & Georgouli, 2015; Suda et al., 2012) and
increments (Devlin et al., 2017; Papadakis, Patras & Georgouli, 2015; Suda et al., 2012) are
reported.

In this line of evidence towards a more positive body composition profile during season,
the overall analysis of the studies suggest that players may substantially increase LBM
during in-season. Our analyses reveal increases of small magnitude at BCP ($\Delta = 1.3\%$, ES = 0.23), MCP ($\Delta = 1.8\%$, ES = 0.33) and ECP ($\Delta = 3.1\%$, ES = 0.37) concerning PPS. Importantly, there are no reports of substantial decreases in LBM within the in-season assessments (BCP vs MCP and MCP vs ECP). On average increments of trivial magnitude are observed from BCP to MCP ($\Delta = 0.67\%$, ES = 0.15) and MCP to ECP ($\Delta = 1.2\%$, ES = 0.12). Curiously, variations in body composition seems to not be associated with the players’ participation time (combined training and match exposure time) and did not differ across seasons (Carling & Orhant, 2010) and are independent of players position (Milanese et al., 2015). In summary, the general picture (Fig. 1) may suggest that professional players may maintain their BM after starting the training period through decreases in BF and increases in LBM. Although off-season detraining seems to reverse these anthropometric adaptations, with alterations of small magnitude in BM ($\Delta = 1.9\%$, ES = 0.2), BF ($\Delta = 1.6\%$, ES = 0.5) and decrements of moderate magnitude in LBM ($\Delta = 5\%$, ES = 0.9) (Silva et al., 2016) they may return to “optimal” initial values for competition after the preparation period. Factors related to training (e.g., the type of strength training), competition fixtures (e.g., extent of the pre-season and/or in-season period, mid-season breaks) and diet (e.g., a Mediterranean diet) (Ostojic, 2003) may, among other factors, may explain part of the observed variability throughout the season (e.g., BF). Nevertheless, the computed values for the different BM, BF and LBM were
derived from diverse assessment methods that have different measurements and precision errors associated (Mills, De Ste Croix & Cooper, 2017). Moreover, only a general picture has been provided and so, not capable to characterize the different body regions and associated seasonal variations.

**Force production**

Longitudinal studies examining changes in the force production capacity of specific muscle groups in professional players mainly relied on isokinetic assessments, despite the discrepancy in the angular velocities analyzed (Table 2) (Eniseler et al., 2012; Malliou et al., 2003; Silva et al., 2011). Seasonal alterations in force production capabilities of specific muscles groups at angular velocities of 60°/s⁻¹ (Eniseler et al., 2012; Malliou et al., 2003), 90°/s⁻¹ (Silva et al., 2011), 180°/s⁻¹ (Malliou et al., 2003), 300°/s⁻¹ and 500°/s⁻¹ (Eniseler et al., 2012) have been analyzed. Off-season induces alterations of small magnitude in knee extensors force production capacity at moderate (180°/s⁻¹) angular velocities (KE, Δ = 3.9%, ES = 0.37); no substantial alterations were observed at low angular velocities (60°/s⁻¹, Δ = −0.8%, ES = −0.07) (Malliou et al., 2003). During preseason, trivial effects are by average observed in KE at angular velocities of 60°/s (ranging from 227–272 and 222–229 N·m, respectively at PPS and BCP) (Malliou et al., 2003), 90°/s⁻¹ (ranging from 239–242 and 241 N·m, respectively at PPS and BCP) (Silva et al., 2011) and 180°/s (ranging from 150–155 and 157–158 N·m, respectively at PPS and BCP) (Malliou et al., 2003). The same was observed for KF at 90°/s⁻¹ (ranging from 129–131 and 129–132 N·m, respectively at PPS and BCP) (Silva et al., 2011). In this line of evidence, effects of trivial magnitude are by average observed from PPS to MCP for KE and KF, respectively when evaluated at 90°/s (KE, ranging from 241 N·m and KF ranging from 133–135 N·m at MCP) (Silva et al., 2011). Interestingly, when profiling adaptation in the force-velocity continuum perspective from PPS to ECP, small decrements at low (ranging from 272–273 and 251–253 N·m, respectively) (Eniseler et al., 2012), changes of trivial magnitude at moderate (ranging from 239–242 and 244 N·m, respectively) (Silva et al., 2011) and very large alterations at high angular velocities (ranging from 74–80 and 136–150 N·m, respectively) (Eniseler et al., 2012) for KE strength have been reported. Interestingly, a consistent substantial increment is KF force production from PPS to ECP seems to take place independently of the angular velocity evaluated. Specifically, from small magnitudes at low (<60°/s⁻¹, ranging from 148–150 and 159–178 N·m, respectively), moderate at moderate angular velocities (90°/s⁻¹, ranging from 129–131 and 134–138 N·m, respectively) and moderate and at high (300°/s⁻¹, ranging from 97–107 N·m, respectively) and very large at very high angular velocities (500°/s⁻¹, ranging from 148–150 and 159–178 N·m, respectively), respectively (Eniseler et al., 2012; Silva et al., 2011). This is particularly interesting, since is well documented that soccer-related injuries likely occur under rapid movement perturbations or actions requiring rapid force development and are more prevalent in hamstring muscles group (Hagglund, Walden & Ekstrand, 2005; Walden et al., 2015).
Jump ability

Seasonal changes in jump ability (15 studies, 390 players, Tables 1 and 2, Figs. 4–6) have frequently investigated the performance on single non-countermovement jump (Non-CMJ, SJ and SJWAS, Fig. 7) (Aziz, Tan & Teh, 2005; Casajus, 2001; Koundourakis et al., 2014; Lago-Peñas et al., 2013; Malliou et al., 2003) and single (CMJBased, CMJ and CMJWAS; Fig. 8) (Casajus, 2001; Clark et al., 2008; Eliakim et al., 2018; Fessi et al., 2016; Koundourakis et al., 2014; Lago-Peñas et al., 2013; Los Arcos et al., 2015; Malliou et al., 2003; Meckel et al., 2018; Ostojic et al., 2009; Papadakis, Patras & Georgouli, 2015; Requena et al., 2017; Silva et al., 2011), and repeated countermovement jumps (Casajus, 2001; Clark et al., 2008).

Non-countermovement jump

The Non-CMJ (Fig. 5) improves with a small magnitude during preseason training (Δ = 3.1%, ES = 0.27) but greater magnitudes can be observed by average from PPS to MCP (Δ = 7.8%, ES = 0.83) and ECP (Δ = 10%, ES = 1.04), respectively. Interestingly, at BCP 66% (one trivial (Malliou et al., 2003), small (Lago-Peñas et al., 2013) and moderate effect (Aziz, Tan & Teh, 2005)), at MCP (one small (Lago-Peñas et al., 2013) and large (Aziz, Tan & Teh, 2005) and three moderate effects (Koundourakis et al., 2014)) and at ECP (two moderate (Koundourakis et al., 2014) and two large (Aziz, Tan & Teh, 2005; Koundourakis et al., 2014)) 100% of the ESs calculated are substantial and so suggestive of an increase in non-CMJ ability. Although more scarcely investigated, trivial effects are by average computed between in-season assessments (BCP vs MCP and MCP vs ECP).

Countermovement jump

Generally, CMJBased (Fig. 6) improves by average with a small magnitude from PPS to BCP (Δ = 1.8%, ES = 0.26), MCP (Δ = 4.0%, ES = 0.47) and ECP (Δ = 3.3%, ES = 0.43). Interestingly, at BCP, 58% (seven in 12, six of small (Los Arcos et al., 2015; Meckel et al., 2018; Ostojic et al., 2009; Papadakis, Patras & Georgouli, 2015; Requena et al., 2017; Silva et al., 2011), and repeated countermovement jumps (Casajus, 2001; Clark et al., 2008).
Figure 5  Seasonal variations in non-countermovement jumps within the different studies (weighted effect sizes). PPS, prior preseason phase; BCP, beginning competition phase; MCP, middle competition phase; ECP, end of competition phase; gray filled circles (squat jump with arm swing); white filled circles, squat jump without arm swing; dashed line represents average values.

Figure 6  Seasonal variations in countermovement-based jumps (weighted effect sizes). PPS, prior preseason phase; BCP, beginning competition phase; MCP, middle competition phase; ECP, end of competition phase; gray filled circles (countermovement-jump with arm swing); white filled circles, countermovement-jump without arm swing; dashed line represents average values.
2018; Papadakis, Patras & Georgouli, 2015; Silva et al., 2011) and one of moderate magnitude (Fessi et al., 2016), at MCP 61% (height in 13, two of small (Koundourakis et al., 2014; Meckel et al., 2018) and six of moderate magnitude (Clark et al., 2008; Fessi et al., 2016; Koundourakis et al., 2014; Papadakis, Patras & Georgouli, 2015)) and at ECP
78% (seven in nine, four of small (Clark et al., 2008; Koundourakis et al., 2014; Papadakis, Patras & Georgouli, 2015) and three of moderate magnitude (Koundourakis et al., 2014; Papadakis, Patras & Georgouli, 2015)) of the ES computed are indicative of a substantial increase in CMJ\textsubscript{Based} performance. Although more scarcely investigated, trivial effects are by average computed between in-season assessments (BCP vs MCP and MCP vs ECP).

Moreover, it seems that the maximal mechanical power and ability to sustain fatigue during the repeated performance of CMJ\textsubscript{Based} (average height during 20-s or mean power during a 15-s CMJ test) may improve with moderate and small magnitudes from PPS to MCP (Δ = 6.7%, ES = 0.74) and ECP (Δ = 2.2%, ES = 0.24), respectively (Casajus, 2001; Clark et al., 2008).

The improvements in jump ability after players return to normal training routines are somewhat expected as detraining or training cessation during off-season results in small to moderate decrements in jump ability (Δ = 4% to 5.3%, ES = 0.4 to 0.8) (Silva et al., 2016). Importantly, we would like to call the reader attention for the variability in responses that can be observed during in-season. With this intention we select the performance of CMJ to expound on this problematic. Although CMJ return to “competition” values after players restart normal training routines, there are quite inconsistent responses during in-season. In fact, the overall trivial effects from BCP (ranging from 37.5–55.8-cm) to MCP (ranging from 39.4–52.7-cm) are the result of three decrements (Casajus, 2001; Fessi et al., 2016; Silva et al., 2011) and increments of small magnitude (Meckel et al., 2018; Papadakis, Patras & Georgouli, 2015) and one trivial effect (Lago-Peñas et al., 2013). From MCP to ECP (ranging from 40.9–51.5-cm), the trivial changes are a product of the four decrements (Clark et al., 2008; Papadakis, Patras & Georgouli, 2015), one improvement of small magnitude (Koundourakis et al., 2014) and the four trivial effects examined (Koundourakis et al., 2014; Requena et al., 2017; Silva et al., 2011). All these investigations inform on the substantial variability in team responses that can be observed, and consequently, advise the practitioner on the need to provide players a consistent neuromuscular stimulus throughout the season. Although not universally confirmed, jump abilities may improve during the pre-season and can be further improved in-season when some mode of strength/power intervention is applied to the normal training routines of highly trained soccer players (Allen et al., 2021; Silva, 2019; Silva, Nassis & Rebelo, 2015). Given the large inter-individual variability of responses to training programs and match stimulus, efforts are being developed to optimize training programs at individual level (Haugen, 2018; Jimenez-Reyes et al., 2022; Loturco et al., 2015a; Morin & Samozino, 2016).

**Sprint ability**

**Linear speed**

Seasonal changes in the sprint (Tables 1 and 2, Fig. 4, n = 230 players) acceleration phase (ACC\textsubscript{Phase}, 5 to 20-m distances, Fig. 7) (Aziz, Tan & Teh, 2005; Fessi et al., 2016; Koundourakis et al., 2014; Los Arcos et al., 2015; Requena et al., 2017; Silva et al., 2011) and maximal velocity phase (MV\textsubscript{Phase}, 30 to 50-m, Fig. 8) (Fessi et al., 2016; Ostojic, 2003; Silva et al., 2011; Zoppi et al., 2006) has been analyzed. Traditionally, improvements in
sprint ability after players return to normal training routines are fairly expected as offseason results in moderate decrements (ES = 0.8 to 1.0) in ACC\textsubscript{Phase} (~2.5%) and MV\textsubscript{Phase} (~7%) (Silva et al., 2016). Specifically, when ACC\textsubscript{Phase} and MV\textsubscript{Phase} are distinctly examined, the later, although more sparsely investigated, tends generally to result in greater improvements and somewhat more substantial effects, as observed between:

- PPS (ranging from 0.97–1.04, 1.78–1.8, 1.83–2.29, 3.04–3.07, 4.16–4.9-s for 5, 10 15, 20 and 30-m sprint time) to BCP (Δ = 1.2% vs 3%; ES = 0.36 vs 0.65, respectively for ACC\textsubscript{Phase} and MV\textsubscript{Phase} (ranging from 0.95–1.06-s, 1.70-s, 2.27-s, 3.01-s, 4.22 to 4.7-s for 5, 10, 15-, 20- and 30-m sprint time)).
- PPS to MCP (Δ = 1.9% vs 3.1%; ES = 0.49 vs 0.85, respectively for ACC\textsubscript{Phase} and MV\textsubscript{Phase} (ranging from 1.02, 1.70–1.76, 3.01–3.05, 4.14–4.7-s for 5, 10, 20 and 30-m sprint time)).
- PPS to ECP (Δ = 2.3% vs 3.3%; ES = 0.58 vs 0.35, respectively for ACC\textsubscript{Phase} and MV\textsubscript{Phase} (ranging from 1.0–1.03, 1.73–1.76, 2.95–3.04 and 4.16-s for 5, 10, 20 and 30-m sprint time)).

Curiously, within the season the variations and magnitudes are almost identical; BCP to MCP (Δ = 1% ES = 0.23) and MCP to ECP (Δ = 0.7% and ES = 0.04 vs 0.14, respectively for ACC\textsubscript{Phase} and MV\textsubscript{Phase}). However, the phase analysis results in the inclusion of a reduced number of studies within each stage (more robustly in the MV\textsubscript{Phase}) with obvious consequences in the interpretation of the results. Importantly, we would like to call the reader attention for the variability in the observed responses during in season. Moreover, recently examination of the force-velocity profiling during sprint reported that sprint mechanical properties are subjected to change during the season (Haugen, 2018; Jimenez-Reyes et al., 2022). Particularly, the theoretical maximal horizontal force production seems to be more compromised than maximal velocity towards the end of the season. Accordingly, the authors suggest that specific training stimuli should be consistently applied to increase maximal speed and acceleration (Haugen, 2018; Jimenez-Reyes et al., 2022).

**Change of direction speed**

COD seems to be negatively affected during the offseason (Δ = 1.6%, ES = 0.6) (Silva et al., 2016). During preseason training players may restore their COD when evaluated by the time to perform a 4 × 10 m task (Δ = 2.5%, ES = 1.0) (Meckel et al., 2018). However, this was not observed when evaluated by the T-test (Δ = 0.5%, ES = 0.12) (Silva et al., 2011). Contradictory findings were also reported from PPS to MCP with trivial (Δ = 0.0%, ES = 0.0) (Meckel et al., 2018) and moderate (Δ = 3.5%, ES = 0.95) (Silva et al., 2011) improvements being reported simultaneously. However, they may stay consistent until ECP (Δ = 2.4%, ES= 0.67) when compared to PPS. Whithin the season both moderate performance decrements (Δ = 2.5%, ES = 0.78) (Meckel et al., 2018) and increments (Δ = 3.9%, ES = 1.0) (Silva et al., 2011) were recorded from BCP to MCP and a performance decrement of small magnitude from MCP to ECP was reported (Δ = 1.1%, ES = 0.32) (Silva et al., 2011).
Insights from training

Preseason

Pooled results from different experimental studies with professionals’ players of different standards suggests that by average soccer players may experience a large ($ES = \sim 1.25$) increase in maximum dynamic strength performance during multi-joint exercises ($\sim 25\%$ of $1RM_{Squat}$) throughout preseason training ($Silva, 2019; Silva, Nassis & Rebelo, 2015$). In fact, studies examining the effects of pre-season high-intensity strength training in force production, revealed that professional players improved maximum dynamic strength performance ($1RM$) in half-squat exercise (ranging from $11\%$–$26\%$) ($Bogdanis et al., 2009; Ronnestad et al., 2008$). The same evidence was observed following pre-season concurrent high-intensity aerobic and high-intensity strength training ($\sim 52\%$) ($Helgerud et al., 2011$). Moreover, improvements in relative force production ($6\%–16\%; LLV; 1RM/LLV$) ($Bogdanis et al., 2009$) after high-intensity strength training and after concurrent high-intensity aerobic and high-intensity strength pre-season training are also reported ($47\%$) ($Helgerud et al., 2011$).

Studies examining pre-season strength training programs reveal substantial improvements in, jump ability ($5\%–10\%$) ($Bogdanis et al., 2009; Loturco et al., 2012$), acceleration ($Bogdanis et al., 2009; Loturco et al., 2012$), maximal speed phases (ranging from $1\%$ to $2\%$) ($Bogdanis et al., 2009; Ronnestad, Nymark & Raastad, 2011$) and COD performance of professional players ($Bogdanis et al., 2009$). More specifically, a $~23\%$ and $~18\%$ increase in IRM during Squat exercise may on average result in a $~7\%$ and $~1.8\%$ improvement in jump (CMJ and SJ) and sprint time (10 and 40 m) ($Silva, Nassis & Rebelo, 2015$). Nevertheless, improvements in jump ability and in maximal speed during preparation phase may be possibly associated with the type of strength training performed by players (weight training plus plyometric training vs weight training only) ($Ronnestad et al., 2008$). On the other hand, $Helgerud et al. (2011)$ reported substantial improvements in CMJ ($5\%$), and acceleration phase ($1.6\%–3.3\%$) performance after pre-season concurrent high-intensity aerobic and strength training. Although already developed in the last millennium ($Tesch, Fernandez-Gonzalo & Lundberg, 2017$) and with “proof-of-concept” in soccer almost 20 years ago ($Askling, Karlsson & Thorstensson, 2003$), the systematic study of the training induced effects of isoinertial eccentric overload has been more recently implemented in soccer ($de Hoyo et al., 2015a; de Hoyo et al., 2015b; de Hoyo et al., 2016; Suarez-Arrones et al., 2018; Tous-Fajardo et al., 2016$). These previous studies reveal that this exercise model as shown to enhance common soccer tasks to at least a similar magnitude to those typical reported during the implementation of more traditional approaches during pre-season and in-season phases ($Allen et al., 2021; Silva, Nassis & Rebelo, 2015$).

In-season

Regarding in-season alterations in strength parameters, $Ronnestad, Nymark & Raastad (2011)$ observed that one high-intensity strength training session per week during the first 12-weeks of the in-season period was enough to maintain pre-season (2 week sessions throughout 10-weeks) gains in the strength performance of professional players. However,
a lower weekly in-season volume (one session every second week) only avoided the loss of training adaptations in jump performance; i.e., strength and sprint performances decreased (Rønnestad, Nymark & Raastad, 2011). There are also reports of substantial improvements in 10-m (1.1%) fastest times during an RSA test of professional players after a periodized 4-week in-season specific high-intensity aerobic training intervention (Owen et al., 2012). These findings lead to the interesting hypothesis that strength-based actions present in SSG performance, e.g., accelerations and decelerations, may stress the neuromuscular system to a point that allows in-season performance improvements in acceleration capacity (Thomas, French & Hayes, 2009). In fact, a high mechanical and metabolic load (acceleration/deceleration) seems to be imposed during soccer-specific scenarios (Hodgson, Akenhead & Thomas, 2014; Osgnach et al., 2010). As early mentioned, the different seasonal results during the performance of muscle-power-based efforts may be explained, at least in part, by the different neuromuscular stresses that are placed in players during the distinct periodization’s applied by teams. Indeed, an extended longitudinal report (Koundourakis et al., 2014) tracking three professional teams suggest that squads who periodized training programs involving higher neuromuscular training loads during the season might show subsequent performance improvements throughout the seasonal continuum in both sprinting and jumping actions; differences in strength/power training stress between the analyzed teams were mainly due to the higher employed volume of both soccer-specific strength and sprint sessions performed by the different teams and not by the general resistance training contents. In this regard, soccer player programs should target all the force-velocity potential/spectrum of the neuromuscular system for a great transfer of this strength to sport activities; increasing player’s ability to use strength and power effectively and consistently (Silva, Nassis & Rebelo, 2015). In fact, each player needs an individually optimized approach; one may need to prioritize the development of maximal force capabilities while others maximal velocity capabilities (Morin & Samozino, 2016). Moreover, adaptations at the neuromuscular level seem to not only be affected by training but also by the time of match exposure of the players (Morgans, Di Michele & Drust, 2017; Silva et al., 2011; Sporis et al., 2011). Despite the wide range of sprint distances evaluated, sprint ability may improve throughout the pre-season and further in-season and those improvements may be more marked during the acceleration phase (Silva, Nassis & Rebolo, 2015). The latest evidence is even more curious taking into consideration that analysis of games performed by young elite players (Mendez-Villanueva et al., 2011) reveals that athletes may rarely reached their maximal sprint speed during the game. Nevertheless, these was not observed in adult semi-professional players (Massard, Eggers & Lovell, 2017) and from our knowledge as not yet been investigated in high-level adult players.

In conclusion, the implementation of strength training routines as shown to result in increases of moderate magnitude in jump, linear speed (acceleration and maximal speed phases) and COD (Silva, 2019; Silva, Nassis & Rebelo, 2015). Moreover, the magnitude of adaptation and the training efficiency (% improvement by session) may be influenced by the chronic biomechanical and physiological context of the training program (Loturco et al., 2015b; Silva, Nassis & Rebelo, 2015). In fact, programs with greater biomechanical
specificity (e.g., force being applied in all the velocity continuum and planes of motion) seems to result in greater improvements in the performance of the analyzed tasks (Silva, Nassis & Rebelo, 2015). Moreover, the physiological demands of the overall session organization (e.g., degree of stress placed at the aerobic system) may affect the magnitude of adaptations (Loturco et al., 2015a; Silva, 2019). As example, research investigating the training induced effects of concurrent training programs observed that this training programs may produce increases of moderate magnitude in jump (~5.6%), sprint (3.2%) and COD (2.6%) (Silva, 2019). A systematic analysis suggest that greater magnitudes of adaptation and training efficiency scores can be detected when the physiological type of the session are more unidirectional (mechanical and metabolic sessions are performed alternatively) than multidirectional (strength and endurance in the same session) (Silva, 2019). In fact, the former organization seems to result in more substantial magnitudes of increases (moderate to large) in jump and sprint abilities that the later organization mode (small to moderate). When this is the case, adaptations may vary according to the session arrangement (endurance + strength and vice versa). Nevertheless, this systematic analysis included studies with professional and semi-professional players (Silva, 2019). According to Silva (2019) practitioners should adopt a holistic approach when defining the exercise timing of the strength-based component of the session. A couple of them are: (i) Is the player returning from injury or not? (ii) What is the training priority within this exact training period? (iii) Is the team in a congestive schedule period or not? (iv) What is the supposed metabolic/mechanical stress of the “overall” session? (iv) Does the player show enough technical competency to perform a complex strength exercise in fatigued state? (Silva, 2019). In summary, during the preparation phase players “recover” body composition and neuromuscular competitive capacity. Generally, improvements of small magnitude in non-CMJ and CMJ-based jumps and the acceleration (ACC\textsubscript{Phase}) and maximal velocity phase (MV\textsubscript{Phase}) of the sprint are observed from PPS to BCP. In the middle of competition phase, they are observed small (CMJ-based and ACC\textsubscript{Phase}), and moderate (non-CMJ and MV\textsubscript{Phase}) improvements compared to PPS. However, alterations towards end of competition phase seem to be force-velocity dependent; CMJ-based and MV\textsubscript{Phase} improve to a small extent with non-CMJ and sprint ACC\textsubscript{Phase} revealing moderate increments compared to PPS. Trivial alterations occur withing in-season in these parameters. However, these is the result of the variability observed between studies; more evident when monitoring the CMJ performance. Different resistance training methods or combination of methods may improve (pre-season) and assist in the maintenance or further improvement (in-season) of physiological determinants and neuromuscular performance during the season.

**ENDURANCE: WHY THE RELEVANCE?**

Activity pattern analysis of the players during the matches showed that elite soccer players cover 8 to 13-km during a competitive match (Bradley et al., 2009; Di Salvo et al., 2009; Rampinini et al., 2007b) at a mean intensity close to the anaerobic threshold (AT) (Stolen et al., 2005). Moreover, energy expenditure during a match play averages 70–75% of the maximal oxygen consumption (VO\textsubscript{2max}), which suggests that a high level of physical
performance in soccer may, in part, be determined by aerobic fitness (Bangsbo, Mohr & Krustrup, 2006; Reilly & Ekblom, 2005).

The determination of VO\textsubscript{2max} and AT are two of the most frequent parameters used when monitoring aerobic fitness in the laboratory settings. In addition, seasonal changes in the fitness of soccer players have also been examined by records of time to exhaustion (TE) and maximal aerobic speed (MAS) during maximal incremental tests performed in the laboratory or in field conditions. Although, the power of VO\textsubscript{2max} to discriminate higher and lower-level players have not been unanimously reported (Marcos, Koulla & Anthos, 2018; Rampinini et al., 2009a; Slimani et al., 2019; Tønnessen et al., 2013; Wells et al., 2012; Ziogas et al., 2011), higher values of VO\textsubscript{2max} have been positively associated with players in specific team position roles (midfielders) (Tønnessen et al., 2013). A better cardiovascular capacity, measures by means of VO\textsubscript{2max} and MAS seems related to a lower perception of exercise intensity during trainings and games (Azcarate et al., 2020). Moreover, players with poor aerobic fitness (Malone et al., 2018) or showing lower improvements during specific phases of the season (preseason) may have a greater risk of injury than players with better-developed aerobic fitness (Eliakim et al., 2018).

AT is defined as the highest exercise intensity, heart rate (HR) or VO\textsubscript{2}, in which the production and clearance of lactate is equal (Stolen et al., 2005). Several methods exist to determine AT, including blood lactate and ventilatory measurements. Lactate threshold (LT) and ventilatory threshold (VT) have been advocated as more sensible physiological parameters to detect changes in the fitness of soccer players, rather than VO\textsubscript{2max} (Clark et al., 2008; Edwards, Macfadyen & Clark, 2003; Helgerud et al., 2001); velocity at LT can better discriminate endurance characteristics of soccer teams of different level (Ziogas et al., 2011). Moreover, LT might change without changes to VO\textsubscript{2max}, and a higher LT means, theoretically, that a player can maintain a higher average intensity in an activity without the accumulation of lactate (Helgerud et al., 2001) and so, for the same external loads a lower internal homeostatic disturbance.

To increase the ecological validity of the measurements, maximal and sub-maximal soccer-specific field tests have been widely used to monitor the training status of professional soccer players. Recent evidence suggests that the intermittent endurance capacity of players is improving over time (Elferink-Gemser et al., 2012). Moreover, the level of competitiveness of the player is related to the performance in: (i) soccer-specific endurance tests, such as the 30-15 and the Yo-Yo tests (Casado Yebras et al., 2014; Ingebrigtsen et al., 2012; Mohr, Krustrup & Bangsbo, 2003; Rampinini et al., 2009a; Wells et al., 2012), (ii) repeated sprint ability tests with (RSSA) (Rampinini et al., 2009b; Wells et al., 2012) or without (RSA) (Aziz et al., 2008) changes of direction and (iii) to the intermittent exercise performance during games (Mohr, Krustrup & Bangsbo, 2003). Additionally, a positive relationship was observed between team success in the league and the Yo-Yo intermittent endurance test level 2 (YYIE2) (Randers, Rostgaard & Krustrup, 2007) and the Yo-Yo intermittent recovery test level 2 (YYIR2) (Ingebrigtsen et al., 2012). Several studies reported significant correlations between the performance on distinct intermittent endurance field tests and other physiological and performance measurements, such as VO\textsubscript{2max} (Castagna et al., 2006; Jones et al., 2013; Krustrup et al., 2006; Rampinini et al., 2009a; Wells et al., 2012).
et al., 2009a; Rampinini et al., 2009b; Stanković et al., 2021; Wells et al., 2014), VO$_2$ kinetics during high-speed running (HSR) (e.g., velocity at 80%ΔVO$_2$) (Wells et al., 2014), incremental treadmill test performance (ITT) (Krustrup et al., 2006), and TE during a maximal anaerobic running test (Wells et al., 2014). Moreover, improvements in the YYIR2 were associated with increases in power, TE and maximal speed during a maximal anaerobic running test (Wells et al., 2014). Importantly, YYIR1 (Krustrup et al., 2003), YYIE2 (Bradley et al., 2010) and in RS(S)A (Altmann et al., 2018; Rampinini et al., 2007b) performance have been shown to be associated with game-related physical activity (e.g., total distance, HSR and sprint) (Altmann et al., 2018; Bradley et al., 2010; Krustup et al., 2003; Krustup et al., 2005; Rampinini et al., 2007a). Additionally, correlations between changes in intermittent endurance field tests and changes in match activity (e.g., HSR) during the season, which were not evident for VO$_{2\text{max}}$ have been reported (Bradley et al., 2011). However, contradictory findings regarding measures of proficient match activity (HSR) have also been reported to correlate with laboratory fitness measures (ITT and VO$_{2\text{max}}$) (Impellizzeri et al., 2006; Krustup et al., 2003; Krustup et al., 2005). Nevertheless, it is important to note that most of the studies only detected moderate correlations and thus cannot be used to establish a direct cause-effect relationship (Rampinini et al., 2007a). Nevertheless, a greater discriminatory validity has been attributed to the field monitoring techniques and thus, at least in part, makes them more important (specific) in monitoring soccer players (Buchheit, 2010; Ingebrigtsen et al., 2012; Svensson & Drust, 2005; Wells et al., 2012). In addition, the examined reliability and sensitivity to training of field derived sub-maximal HR measures make these measures an important parameter for frequent, time-efficient, and non-exhaustive testing of intermittent exercise capacity of high-level soccer players (Altmann et al., 2021; Buchheit, 2014; Buchheit, Simpson & Lacome, 2020; Ingebrigtsen et al., 2013a; Rago et al., 2020). In fact, in addition to better physiological responses being observed in players of a higher standard (Ingebrigtsen et al., 2012), they also seem to be associated with acute (Rago et al., 2020) and chronic physical match performance (HSR) (Bradley et al., 2010). Notwithstanding the previous facts, it is important to highlight those maximal (e.g., VO$_{2\text{max}}$ and MAS) and sub-maximal aerobic fitness laboratory parameters (e.g., AT) cannot be neglected. In fact, others (Altmann et al., 2018; Vincenzo, Franco & Carlo, 2013) observed the ecological validity of these parameters via their association with match categories of an aerobic and anaerobic nature. As so, practitioners should always consider a cost/benefit approach (e.g., cost, ease of use, manpower and how it will impact the training program) (Buchheit & Simpson, 2017).

**VARIATIONS IN PHYSIOLOGICAL DETERMINANTS AND ENDURANCE PERFORMANCE**

**Maximal oxygen consumption**

Although with obvious limitations, e.g., just one study involves a longitudinal, inter-seasonal examination of soccer players (12 seasons, 1,545 players), it seems that among professional players, VO$_{2\text{max}}$ is not improving over time and perhaps has the
tendency to decrease (players tested from 2006–2012 showed 3.2% lower values than those tested from 2000–2006) (Tonnessen et al., 2013).

Seasonal alterations in VO2max have been extensively analyzed (Table 2, Figs. 9 and 10, n = 393) (Aziz, Tan & Teh, 2005; Bunc, Hráský & Skalská, 2015; Casajus, 2001; Castagna et al., 2013; Clark et al., 2008; Edwards, Macfadyen & Clark, 2003; Eliakim et al., 2018; Haritodinis et al., 2004; Kalapotharakos, Ziogas & Tokmakidis, 2011; Koundourakis et al., 2014; Lago-Peñas et al., 2013; Manzi et al., 2013; Meckel et al., 2018; Metaxas et al., 2009; Michalczyk et al., 2008; Mohr, Krstrup & Bangsbo, 2002). Generally, during the preseason, professional players appear to regain their oxygen capacity and maintain it throughout the season as off-season seems to induce a large impairment in this physiological parameter (Δ = 4.4%, ES = 1.4) (Silva et al., 2016). Studies with players from different backgrounds exposed a large magnitude of improvements in VO2max from the PPS (ranging from 52.2–62.7 ml min⁻¹ kg⁻¹) to BCP (Δ = 7.3%, ES = 1.3, ranging from 54.8–66.5 ml min⁻¹ kg⁻¹). Additionally, improvements of moderate magnitude were by average observed in the MCP (Δ = 6.4%, ES = 1.0, ranging from 55.5–66.8 ml min⁻¹ kg⁻¹) and ECP (Δ = 4.2%, ES = 0.8 ranging from 52.7–64.1 ml min⁻¹ kg⁻¹) compared with the PPS. Moreover, increases in VO2max (from PPS to BCP, MCP and ECP) seem to be independent of the position role (Metaxas et al., 2006). Interestingly, just one of the 14 ES did not confirm the substantial improvements at MCP and four on 13 at ECP compared to PPS assessments. Within the competitive phase they are observed by average trivial changes from BCP to MCP (Δ = 0.5%, ES = 0.1) and a small decrement from MCP to ECP (Δ = –2.3%, ES = –0.28).

**Anaerobic threshold**

Studies examining changes in physiological parameters at sub-maximal intensities are presented in Table 2 (13 studies, n = 249, Fig. 9) (Casajus, 2001; Castagna et al., 2011; Clark...
et al., 2008; Dunbar, 2002; Edwards, Macfadyen & Clark, 2003; Kalapotharakos, Ziogas & Tokmakidis, 2011; Los Arcos et al., 2015; Manzi et al., 2013; Meckel et al., 2018; Mohr, Krustrup & Bangsbo, 2002; Papadakis, Patras & Georgouli, 2015; Zoppi et al., 2006).

From the large variety of parameters examined, some were shown to be sensitive in one but not in other studies that used players of similar standards. Nevertheless, enhancements in the ability to cope with sub-maximal internal and external loads regarding PPS performances were by average detected by different parameters, as follows:

i) the percentage of VO\(_{2\text{max}}\) (76%VO\(_{2\text{max}}\)) and percentage of maximal heart rate (87% HR\(_{\text{max}}\)) at a lactate concentration of 4 mmol\(\text{L}^{-1}\) at BCP (ES = 0.62 and 0.71, 78% and 89%) and MCP (ES = 0.89 and 0.91, 78% and 89%), respectively (Kalapotharakos, Ziogas & Tokmakidis, 2011);

ii) oxygen consumption at the LT (ES = 0.5 at ECP, ranging from 51.4–53.5 ml\(\text{min}^{-1}\cdot\text{kg}^{-1}\)) (Edwards, Macfadyen & Clark, 2003) and VT (ES = 0.85 and 0.41 at BCP (ranging from 50.2–52.7 ml\(\text{min}^{-1}\cdot\text{kg}^{-1}\)) and ECP (52.9 ml\(\text{min}^{-1}\cdot\text{kg}^{-1}\)), respectively) (Casajus, 2001; Edwards, Macfadyen & Clark, 2003; Manzi et al., 2013);

iii) heart rate measures at speeds of 14-km/h (ES = 2.7), 16-km/h (ES = 2.6), and 18-km/h (ES = 2.0) at MCP (Mohr, Krustrup & Bangsbo, 2002);

iv) the speed at a fixed lactate concentration (Fig. 9) of: (a) 2 mmol\(\text{L}^{-1}\) (ES = 0.67, 0.66 and 0.68, at BCP (ranging from 11.4–14.5-km/h), MCP (ranging from 10.5–14.8-km/h), and ECP (ranging from 10.8–13.9-km/h) regarding PPS (ranging from 9.5–14.3-km/h) respectively) (Castagna et al., 2011; Castagna et al., 2013; Dunbar, 2002; Kalapotharakos, Ziogas & Tokmakidis, 2011; Manzi et al., 2013; Papadakis, Patras & Georgouli, 2015); (b) 3 mmol\(\text{L}^{-1}\) (ES = 0.52, 0.20 and −0.27 at BCP (ranging from
12.7–15.4-km/h), MCP (15.7 km/h), and ECP (15.0-km/h) regarding PPS (ranging from 12.2–15.4-km/h), respectively) (Dunbar, 2002; Los Arcos et al., 2015); (c) 4 mmol\(^{-1}\) (ES = 1.0, 1.41 and 1.27 at BCP (ranging from 13.6–14.9-km/h), MCP (ranging from 13.6–14.4-km/h) and ECP (ranging from 13.5–14.3-km/h), regarding PPS (ranging from 12.3–13.9-km/h), respectively) (Castagna et al., 2011; Castagna et al., 2013; Kalapotharakos, Ziogas & Tokmakidis, 2011; Manzi et al., 2013; Papadakis, Patras & Georgouli, 2015).

v) The speed at the LT (ES = 1.9 at BCP, ranging from 10.5–13.8-km/h, respectively) (Zoppi et al., 2006) and VT (ES = 0.57 and 1.1, at BCP (ranging from 11.6–12.2-km/h) and MCP (12.8-km/h), respectively) (Meckel et al., 2018).

Interesting, although a wide variety of submaximal parameters have been measured, substantial improvements between BCP and MCP are consistently reported within the analyzed studies in some form of physiological parameter (Casajus, 2001; Dunbar, 2002; Kalapotharakos, Ziogas & Tokmakidis, 2011; Meckel et al., 2018; Papadakis, Patras & Georgouli, 2015). Nevertheless, alterations of trivial magnitude have also been examined (Kalapotharakos, Ziogas & Tokmakidis, 2011; Papadakis, Patras & Georgouli, 2015). From the MCP to ECP distinct alterations have been observed with both reports of trivial (Papadakis, Patras & Georgouli, 2015), small improvements (Papadakis, Patras & Georgouli, 2015) and impairments (Dunbar, 2002).

Interestingly, although trivial alterations in VO\(_{2}\)\(_{\text{max}}\) are by average observed from BCP to MCP, an improvement of small magnitude (ES = 0.29) is observed between these time points, which suggest that further improvement in sub-maximal exercise performance (e.g., LT), but not in VO\(_{2}\)\(_{\text{max}}\) are likely related to a faster restoration or improvement of central factors (i.e., VO\(_{2}\)\(_{\text{max}}\)) than peripheral factors (i.e., muscle oxidative enzymes) (Impellizzeri et al., 2006). Furthermore, although adaptations in RE being dependent on multi-dimensional factors (e.g., mechanical, and neuromuscular skills) they may had occurred further in season, and so determinant for improving running performance (Foster & Lucia, 2007); RE can better discriminate soccer players of different standards with similar VO\(_{2}\)\(_{\text{max}}\) values (Ziogas et al., 2011).

In summary, these physiological determinants of endurance performance, improve during the first part of the season (4–8 weeks) and generally remain stable throughout the season. Generally, improvements in VO\(_{2}\)\(_{\text{max}}\) occurred after a relatively short period of time (e.g., pre-season training), while no significant further in-season increases are observed. Moreover, no increase was examined in the VO\(_{2}\)\(_{\text{max}}\) when players already possessed values of approximately 61–62 ml/kg/min. In fact, the increases in VO\(_{2}\)\(_{\text{max}}\) found in different standard of players during the in-season period (Caldwell & Peters, 2009; Jensen et al., 2009; Magal et al., 2009) occurred under this threshold and in players of a lower standard. Additionally, when professional players began the competitive season with values above this threshold (61–62 ml/kg/min), no improvements in the VO\(_{2}\)\(_{\text{max}}\) throughout the season were by average reported (Clark et al., 2008; Edwards, Macfadyen & Clark, 2003). This may be related with soccer training-specific constrains and/or demands, such as, the limited time for fitness training due to the high density of in-season match commitments.
Our analysis seems to corroborate the observations of others (Tonnessen et al., 2013), indicating that VO$_{2\text{max}}$ values of approximately 62–64 ml/min/kg may fulfill the general demands for aerobic capacity in male professional soccer players; nevertheless, characteristics related to the specific demands of different positional roles should be considered, as reported values reflect team averages and large inter-individual variations can be observed.

**Maximal aerobic speed**

MAS (Figs. 9 and 11) ($n = 143$) (Boullosa et al., 2013; Bunc, Hráský & Skalská, 2015; Fessi et al., 2016; Kalapotharakos, Ziogas & Tokmakidis, 2011; Lago-Peñas et al., 2013; Requena et al., 2017) reflects the maximum aerobic capacity and combines VO$_{2\text{max}}$ and RE into a single factor (Billat & Koralsztein, 1996). As such, MAS is a good indicator of aerobic performance (Billat & Koralsztein, 1996), and the determination of MAS gives a practical assessment of the aerobic demands during running performance (Kalapotharakos, Ziogas & Tokmakidis, 2011). Off-season break may induce a decrement of moderate magnitude in MAS ($\Delta = 4.6\%$, ES = 0.61) (Requena et al., 2017). Preseason training restores MAS ($\Delta = 5\%$, ES = 1.3, ranging from 18.1–19.7-km/h), with substantial improvements still evident at MCP ($\Delta = 4.3\%$, ES = 1.3, ranging from 17.4–19.6-km/h) and at ECP ($\Delta = 4.9\%$, ES = 1.05, ranging from 17.3–18.4-km/h) regarding the PPS values (ranging from 16.5–19.2-km/h). Although, by average no substantial improvements take place from BCP to MCP ($\Delta = -0.7\%$, ES = -0.11) and from MCP to ECP ($\Delta = 0.6\%$, ES = -0.09), there are contradictory observations between BCP and MCP, with both trivial ($\Delta = -0.4\%$, ES = -0.09) (Lago-Peñas et al., 2013), moderate impairments ($\Delta = -3.3\%$, ES = -0.82) (Fessi et al., 2016) and improvements of small magnitude ($\Delta = 1.7\%$, ES = 0.59)
(Kalapotharakos, Ziogas & Tokmakidis, 2011) reported. Interestingly, Boullosa et al. (2013) did not observe changes in the MAS (18.1 to 18.2-km/h) in professional players after pre-season. The different findings are, at least in part, associated with the dissimilar baseline MAS that were reported and the applied protocols (Dupont, Akakpo & Berthoin, 2004; Fessi et al., 2016; Kalapotharakos, Ziogas & Tokmakidis, 2011; Wong et al., 2010). We would like to highlight that in this narrative review we discussed the velocity at VO$_{2\text{max}}$ (vVO$_{2\text{max}}$) (Kalapotharakos, Ziogas & Tokmakidis, 2011), and final velocity reached (Vam-eval and Gacon test) as one parameter (Boullosa et al., 2013; Bunc, Hráský & Skalská, 2015; Fessi et al., 2016; Lago-Peñas et al., 2013; Requena et al., 2017). Although they are highly correlated, with the two terms being often used interchangeably, they refer to different physiological entities (Buchheit, 2010) with MAS maybe 10–15% greater than the vVO$_{2\text{max}}$ (Berthon & Fellmann, 2002).

In summary, despite the scarcity of research monitoring these performance parameters, MAS increase after pre-season training and remain stable throughout the season. The magnitude of alterations (MAS) may be associated with the baseline training status of players at the time of intervention (Boullosa et al., 2013).

**High-intensity intermittent exercise**

A summary of studies examining changes in high intensity intermittent exercise (IE) tests is presented in Tables 1 and 2 and Figs. 9 and 12 (Boullosa et al., 2013; Bradley et al., 2010; Campos-Vazquez et al., 2016; Castagna et al., 2013; Iaia et al., 2009b; Krustrup et al., 2003; Krustrup et al., 2006; Manzi et al., 2013; Silva et al., 2011). Off-season seems to result in decrements of moderate and very large magnitude in IE performance ($\Delta = 27.8\%$ and 10%, ES = 1.0 and 2.2 for YYIE2 and YYIR2, respectively). However, pre-season phase by average induces large improvements IE ($\Delta_{\text{overall}} = 32.4\%$, ES = 1.8). Specifically, improvements of 56%, 60%, 18% and 5%, and effect sizes of 4.1, 2.4, 1.1 and 1.25 for YYIR2 (ranging from 742–780-m and 1,033–1,160-m), YYIE2 (ranging from 1,120–2,171-m and 2,250–2,411-m), YYIR1 (ranging from 1,760–2,475-m and 2,211–2,600-m) and 30–15 (20.1 to 21.1 km/h), respectively. These performance improvements are extended to MCP ($\Delta_{\text{overall}} = 18.9\%$, ES = 1.5). Precisely, increases of 43.9%, and 17.9%, with magnitudes of 2.4 and 0.7 for YYIR2 (ranging from 742–780-m) and YYIE2 (ranging from 742–780-m). Interestingly, the magnitude of alterations is lower from PPS to ECP ($\Delta_{\text{overall}} = 22.5\%$, ES = 1.0). Specifically, increments of 11.9%, 29.7% and 19.5% with magnitudes of 0.51, 0.96 and 1.56, for YYIR2 (873-m), YYIE2 (ranging from 1,640–2,381-m), YYIR1 (2,103-m), are examined. Within the season, the ability to perform IE is by average impaired to a small extent from BCP to MCP ($\Delta_{\text{overall}} = -2.4\%$, ES = -0.23 ($\Delta = -7.2\%$ and 6.1%, ES = -0.47 and 0.24 for YYIR2 and YYIE2, respectively)) and from MCP to ECP ($\Delta_{\text{overall}} = -7\%$, ES = -0.3). We would like to highlight again, that within each team, a great inter-individual ability to perform repeated intense exercise can be observed throughout the season, with some players improving, others decreasing and/or maintaining their performance (Bangsbo, Iaia & Krustrup, 2008).

Interestingly, Boullosa et al. (2013) did not report substantial changes in YYIR1 from PPS to BCP. It should be observed that in this study, players started the season with a high
YYIR1 performance (2,475-m), which may be related to the performance of an off-season program (5 weeks/21 sessions). This previous evidence, at least in part, highly indicate the benefits of performing a structured training program during the off-season (Silva et al., 2016). Moreover, it should be noted that despite no significant improvements in YYIR1, the authors reported important changes in certain indices of cardiac autonomic adaptations (e.g., short heart-rate recovery) after this period of intensified training.

Repeated sprint ability

Impellizzeri et al. (2008) observed that elite players improved different parameters in RSSA test performance throughout the season. Namely, the mean time of the sprints (RSSA\textsubscript{mean}) improved to a moderate extent from PPS to BCP (Δ = 2.2%, ES = 1.14), MCP (Δ = 1.4%, ES = 0.74) and ECP (Δ = 1.6%, ES = 0.29). The fatigue index improved to a small magnitude from PPS to BCP (Δ = 20.4%, ES = 0.56), and in a moderate extent from PPS to MCP (Δ = 22.2%, ES = 0.62) and ECP (Δ = 25.9%, ES = 0.71). The lower fatigability during repeated sprints performed during MCP and ECP vs PPS as also been verified when monitoring U20 elite players using the Bangsbo sprint test (Jorge, Garrafoli & Cal Abad, 2020). Nevertheless, a small deterioration of the RSSA\textsubscript{mean} occurred from the BCP to MCP (Δ = 0.84%, ES = 0.41) with trivial changes been observed from MCP to ECP and for the fatigue index within these specific in-season moments.

We intended to characterize the general ability of performing repeated intense exercise and with this purpose we combined results of different specific IE tests that are widely used in professional settings. We acknowledge the differences between protocols of each

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**Figure 12** Seasonal variations in intense intermittent endurance performance (weighted effect sizes). PPS, prior preseason phase; BCP, beginning competition phase; MCP, middle competition phase; ECP, end of competition phase; white filled circles (YYIR1); blue filled circles (YYIR2); green filled circles (YYIE2); red filled circles (30–15 test); Dashed line represents average values.

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individual test and that they might evaluate slightly different physical capacities (Buchheit & Rabbani, 2014). As example, YYIR1 leads to a maximal activation of the aerobic system, whereas YYIR2 determines an individual’s ability to recover from repeated exercise with a high contribution from the anaerobic system (Bangsbo, Iaia & Krustrup, 2008). Nevertheless, their sensitivity to training is almost certainly similar (30-15 vs YYIR1 (Buchheit & Rabbani, 2014) and given the very large correlations between tests (YYIR1 vs YYIR2) practitioners have been advised to consider using only one of the Yo-Yo tests and a RSA test in a general soccer-specific field test protocol (Ingebrigtsen et al., 2012; Ingebrigtsen et al., 2013a).

Sub-maximal intermittent field exercise

It has been observed that soccer players %HR\textsubscript{max} at the 6-min point of the YYIR1 decreased from the PPS to the middle of the pre-season, BCP and ECP (Krustrup et al., 2003). Rago et al. (2020) when applying the same protocol during the in-season period (four assessment moments from MCP to ECP) observed a continuous moderate improvement in heart rate measurements towards ECP. Moreover, others observed that even though professional players may show a decline in VO\textsubscript{2max} from the preparation period to the end of the season, their heart rate responses during the sub-maximal version of the YYIE2 were not altered during five time-points of a soccer season (from 14 days pre-season to ECP) (Heisterberg et al., 2012).

Game-related physical parameters

Match analysis is a widely used instrument in professional soccer to study technical, tactical, and physical performances of players (Abt & Lovell, 2009). These instruments allow careful analysis of player match performance, dependent of a large number of factors (e.g., training status, field position, age) and allows for the investigation of seasonal changes in game-related physical performance (Helgerud et al., 2001; Impellizzeri et al., 2006; Morgans et al., 2014; Padron-Cabo et al., 2018; Rampinini et al., 2007b; Silva et al., 2013b) and study evolutionary trends over consecutive seasons (Akyildiz et al., 2022; Barnes et al., 2014; Bradley et al., 2016; Bush et al., 2014; Pons et al., 2021; Vigne et al., 2012).

Seasonal variations

Seasonal alterations in distance covered in different speed zones during the game is presented in Figs. 13–15 (Link & de Lorenzo, 2016; Morgans et al., 2014; Padron-Cabo et al., 2018; Rampinini et al., 2007b; Silva et al., 2013b). There are by average trivial changes in the TD (Fig. 14) from BCP to MCP (Δ = −1.09%, ES = 0.03, ranging from 9,150–10,513-m and 9,350–10,722-m, respectively) with a small increment between BCP and ECP (Δ = 1.63%, ES = 0.22, ranging from 9,600–10,921-m). A small increase in TD seems to occur from MCP to ECP (Δ = 1.5%, ES = 0.47). Interestingly, a clear variability exists, with both increments (Mohr, Krustrup & Bangsbo, 2003; Rampinini et al., 2007b; Silva et al., 2013b) and decrements (Link & de Lorenzo, 2016; Mohr, Krustrup & Bangsbo, 2003; Padron-Cabo et al., 2018) between these time-points. Importantly, within the season the variation ranged from −2.4% to 5.9% that are below for the reference value (10–15%)
Oliva-Lozano et al., 2021a) that can establish a practical significance considering the high match-to-match variability (Gregson et al., 2010; Oliva-Lozano et al., 2021a).

The distance covered in HSR (~>14.4–15 km/h; Figs. 13 and 15) during the match has been proposed to be of great importance for performance in elite soccer because clearly distinguishes players of different standards (Mohr, Krustrup & Bangsbo, 2003; Saeterbakken et al., 2019). However, these observations of HSR proficiency being associated with player standards have not been unanimously confirmed (Di Salvo et al., 2012). The amount of HSR by average decreases with a trivial magnitude from BCP to MCP (Δ = 2.1%, ES = −0.14, ranging from 1,350–2,450-m and 1,270–2,544-m, respectively) and increase to a moderate extent to ECP (Δ = 22.5%, ES = 0.75, ranging from 1,900–2,738-m) and from MCP to ECP (Δ = 25.9%, ES = 0.92). Interestingly all the studies, although reporting different magnitudes (small to large), observed substantial alterations between these two time-points (Mohr, Krustrup & Bangsbo, 2003; Rampinini et al., 2007b; Silva et al., 2013b). Moreover, the amount of HSR performed in the last fifteen-minute period of each half, indicative of the ability to maintain performance during the game (Krustrup et al., 2005), was reported to be higher towards the ECP (Silva et al., 2013b). Additionally, in the ECP, a greater distance in HSR was covered in the peak and in the lowest fifteen-minute periods of the match than in the corresponding fifteen-minute periods at other season time points (Silva et al., 2013b). Furthermore, Silva et al. (2013b) observed that professional players were more engaged in high-intensity activities and had higher peak 5-min periods of HSR during the matches towards the last quarter of the season (ECP).
Very-high speed running (>19.8–21 km/h; VHSR; Fig. 15) is stable from the BCP to MCP (Δ = 3.8%, ES = 0.10, ranging from 465–916-m and 485–829-m, respectively) and ECP (Δ = 4.5%, ES = 0.16, ranging from 481–977-m). Small increments in VHSR may take place from MCP to ECP (Δ = 0.74%, ES = 0.29). Importantly, within the different season moments the variation ranged from −18% to 20% that are below for the reference value of 60–64% informing that a real change take place (Gregson et al., 2010; Oliva-Lozano et al., 2021a).
The sprint distance performed during the match (>24–30 km/h; Fig. 15) (Morgans et al., 2014; Padron-Cabo et al., 2018; Silva et al., 2013a) is by average stable from BCP to MCP (Δ = 4.5%, ES = 0.19, ranging from 98–201-m and 111–225-m, respectively) and increase with moderate and small magnitude from BCP to ECP (Δ = 11%, ES = 0.69, ranging from 192–234-m) and MCP to ECP (Δ = 6.1%, ES = 0.55), respectively. However, within the three studies analyzed, two (Morgans et al., 2014; Padron-Cabo et al., 2018) consistently reported trivial changes between these time-points. It should be again highlighted, that a large match-to-match variability in game-physical parameters of elite players may occur, suggesting that only large sample sizes may allow the clarification of systematic changes and that the “training stimulus” provided by the match is largely variable (Gregson et al., 2010; Oliva-Lozano et al., 2021a).

**Evolutionary trends**

Evolutionary trends in match activity of professional players (Akyildiz et al., 2022; Barnes et al., 2014; Bradley et al., 2016; Bush et al., 2014; Pons et al., 2021; Vigne et al., 2012) has been analyzed in different contexts. Vigne et al. (2012) examined an Italian Serie-A team (2004–05 to 2006–07). The researchers observed significant progressive decreases in the distance covered per minute of play in low intensity running from the first to the second and third seasons. In addition, a significant decrease between the second and third seasons was also reported for moderate intensity running (Vigne et al., 2012); distance running and high intensity activities in Serie-A were similar in the three seasons. In spite no interaction between season and playing positions, and thus no signify alterations across all three seasons, were observed for the distinct field positions in the latter study (Vigne et al., 2012), others (Bush et al., 2014) performing a seven season longitudinal analysis (2006–07 to 2012–13) observed that the time dependent increase in physical demands (e.g., increase in HSR) in the English premier league was extended to all players positions; full backs demonstrating the most pronounced increases. Barnes et al. (2014) carrying out the same design of Bush et al. (2014) observed an evolution of physical parameters in the English Premier League e.g., across seven seasons high intensity running distance and actions increased by ~30% and ~50% and sprint distance and number increased by ~35% and ~85% respectively. Within this period (2006–13), Bradley et al. (2016) investigating the evolution of physical and technical performances in the same league with special reference to league ranking observed that physical and technical performances have evolved more in the 2nd Tier that included the teams from 5th–8th ranking than any other of the remaining three Tiers. According to the authors, this could indicate a narrowing of the performance gap between the top Tiers (Bradley et al., 2016).

Pons et al. (2021) examined evolutionary trends from 2015/2016 to 2018/2019 in the top two professional leagues of Spanish football. The authors observed a decrease in TD and an increase in the high-intensity distances and number of sprints performed, although a clearer trend was perceived in the top league. Additionally, VHSR and sprint distance increased during the second halves in both professional soccer leagues. Nevertheless, other authors did not observe an evolutionary trend in the Turkish league physical demands and independently of team’s final rankings (2015–2018) (Akyildiz et al., 2022). All these studies
that independently investigate seasonal alterations in match activity and evolutionary trends in physical match performance, point out that players need more, to be ready to sustain activities involving a high metabolic and neuromuscular “cost”. Interestingly an evolutionary trend in technical variables has been consistently reported (Akyildiz et al., 2022; Barnes et al., 2014), and that can be more evident in specific league tiers (Bradley et al., 2016).

Notwithstanding the intrinsic cultural characteristics associated with each league, differences between studies can be related, among other factors, to the (i) pre-defined thresholds of the different intensity categories of each analysis system (e.g., high-intensity categories), (ii) discrepancies between systems in the accuracy of the determination of the distance covered at HSR (Randers et al., 2010), (iii) accuracy of the intensity of the pre-defined thresholds with individualized thresholds of physiological stress of the players (Abt & Lovell, 2009), and (iv) different game and situational conditions (Paul, Bradley & Nassis, 2015). In this regard, we need to highlight that several influencing factors may affect team and player performances at a behavioral level. Some of them are: (i) match status (i.e., whether the team is winning, losing or drawing) (Andrzejewski et al., 2018; Augusto et al., 2021; Bradley & Noakes, 2013; Oliva-Lozano et al., 2021b), (ii) quality of opposition (Lago-Penas et al., 2011), (iii) match location (i.e., playing at home or away) (Augusto et al., 2021; Oliva-Lozano et al., 2021b), (iv) fixture congestion (Julian, Page & Harper, 2021; Lago-Penas et al., 2011; Oliva-Lozano et al., 2021b), (v) environmental conditions (heat) and altitude (Mohr et al., 2012; Nassis, 2013), (vi) playing formation (e.g., 1-4-2-3-1 vs 1-4-4-2) and style of play (e.g., amount of ball possession) (Arjol-Serrano et al., 2021; Bradley et al., 2013), (vii) players availability (Windt et al., 2018), (viii) players physical fitness (Altmann et al., 2018; Bradley et al., 2010; Konefal et al., 2019a; Krustrup et al., 2005), (ix) distance traveled to play (Augusto et al., 2021) and (x) coach dismissal (Augusto et al., 2021; Zart & Gullich, 2022) and are all factors that may impact teams and players match output.

Insights from training

High intensity training (HIT) comprises different modes of high-intensity exercise, namely high-intensity aerobic training (HIA), speed endurance training (SE) and repeated sprint ability training (RSA) (Bishop, Girard & Mendez-Villanueva, 2011; Mohr et al., 2022; Spencer et al., 2005). Generally, the common factors between modes are the high degree of physiological stress and the sharing of some similar physiological and functional training-induced adaptations imposed by the acute and chronic effects of the high-intensity bouts. HIT is a useful training method, providing a high training stimulus (Bangsbo et al., 2009; Buchheit & Laursen, 2013a; Christensen et al., 2011; Iaia & Bangsbo, 2010; Iaia et al., 2009a) on both the cardiopulmonary (Buchheit & Laursen, 2013a) and neuromuscular levels (Buchheit & Laursen, 2013b), thereby promoting physiological and performance adaptations that allow players to more successfully cope with the match and training demands (Castagna et al., 2009; Girard, Mendez-Villanueva & Bishop, 2011; Gunnarsson et al., 2012; Helgerud et al., 2001; Iaia, Rampinini & Bangsbo, 2009; Impellizzeri et al., 2006; Ingebrigtsen et al., 2013b; Krstrup et al., 2005; Mohr, Krstrup & Bangsbo, 2003; Rampinini et al., 2007a).
**Preseason**

HIA, both in general (interval running; HIA<sub>General</sub>) (Helgerud et al., 2001; Impellizzeri et al., 2006) and more specific modes (small-sided games and soccer-specific dribbling circuits; HIA<sub>Specific</sub>) (Impellizzeri et al., 2006; McMillan et al., 2005), induces an improvement in several of the above analyzed physiological determinants (e.g., VO<sub>2max</sub> and AT) and performance measures (e.g., YO-YO tests; Ekblom’s circuit test) in high level juniors and professional players. Moreover, the same as been observed when performing other forms of HIT (Dupont, Akakpo & Berthoin, 2004; Wells et al., 2014) or the concurrent performance of HIT with strength training (Helgerud et al., 2011; McGawley & Andersson, 2013; Wong et al., 2010). The latter seems to result in moderate (MAS and YYIR2) to very large (YYIR1) improvements endurance-related parameters (Silva, 2019). However, when adopting a concurrent training paradigm, soccer-related technical staff should implement an integrated approach when defining the exercise timing of the strength-based element of the session (see former Insights from training). Additionally, Bogdanis et al. (2011) observed improvements in physiological determinants (VO<sub>2max</sub>) and endurance performance (YYIE2 and Hoff’s dribbling track test) by professional players after pre-season strength training independently of the target of adaptations (hypertrophy vs neural adaptations). Studies examining changes in the anaerobic running capacity are scarce. Nevertheless, improvements in 200- and 400-m running distances (Sporis, Ruzic & Leko, 2008a) and both the performance time and the ability to tolerate higher [La] during 300-y shuttle run test were reported to improve after pre-season HIA<sub>Specific</sub> (Sporis, Ruzic & Leko, 2008a, 2008b). Furthermore, enhancements in a running-based anaerobic sprint test after 6-weeks pre-season HIA<sub>Specific</sub> of professional players have also been described (Ostojic et al., 2009). There are reports that pre-season HIA<sub>Specific</sub> improves high-level junior players performances of other forms of in-line running exercises (e.g., 800, 1,200 and 2,400-m) with an important aerobic contribution (Sporis, Ruzic & Leko, 2008a, 2008b).

**In-season**

As was already mentioned, most longitudinal studies (Aziz, Tan & Teh, 2005; Casajus, 2001; Metaxas et al., 2006; Mohr, Krstrup & Bangsbo, 2002; Silvestre et al., 2006) and studies analyzing adaptations from specific training methodologies (Impellizzeri et al., 2006) did not detect significant further improvements after the initial increase in VO<sub>2max</sub> found after the pre-season phase. In fact, extending the preseason HIA of high-level junior players trough the initial weeks of in-season (7–8 weeks) did not produce any further substantial increase in the mean VO<sub>2max</sub> (2006). However, Dupont, Akakpo & Berthoin (2004) observed that professional players performing 2 weekly sessions of HIT for 10-weeks during the in-season period substantial increased MAS (~9%). Furthermore, Jensen et al. (2009) observed that U-20 elite players performing just one session of HIA<sub>Specific</sub> (30-min session per week) during the last 12-weeks of the competitive season, rather than the 2–3 weekly sessions traditionally applied in the other studies (Dupont, Akakpo & Berthoin, 2004; Helgerud et al., 2001; Helgerud et al., 2011; Iaia, Rampinini & Bangsbo, 2009; Impellizzeri et al., 2006; Lopez-Segovia, Palao Andres & Gonzalez-Badillo, 2010; McMillan et al., 2005; Owen et al., 2012; Sporis, Ruzic & Leko, 2008a, 2008b; Wong et al., 2010),
substantial increase \( VO_{2\text{max}} \) in addition to YYIR2 performance and improved fatigue time during RSA test. Additionally, an improvement in physiological measures (%HR\(_{\text{max}}\) and blood lactate concentrations) during a sub-maximal version of the YYIR1 were observed (87.3% to 81.3% HR\(_{\text{max}}\) and from 5 to 2.5 mmol/l, respectively) (Jensen et al., 2009). Particularly, it is likely that these different findings regarding in-season increments, namely in \( VO_{2\text{max}} \) may be, among other factors, partially associated with the initial in-season \( VO_{2\text{max}} \) of the distinct group of players (initial values of 52.8–55.7 ml/kg/min in Ferrari Bravo et al. (2008) and 59.7–61.4 in Impellizzeri et al. (2006)). In this regard, Wells et al. (2014) observed that the addition of 6-week speed endurance-based HIT to in-season training routines of professional players increased power, maximal speed, TE recorded during a maximal anaerobic sprint test, without improvement in certain physiological determinants of aerobic performance being examined (e.g., \( VO_{2\text{max}}, \text{MAS} \)) (Wells et al., 2014). Within this period, a substantial increase in YYIR2 performance was also observed. Moreover, improvement in this field test was only associated with improvements in anaerobic capabilities (Wells et al., 2014). Furthermore, Owen et al. (2012) observed that HIA\(_{\text{Specific}}\), conducted two times per week, during a four week in-season break, resulted in substantial improvements the total sprint time (1.8%) and the percentage of decrement score (~2.4 vs 1.5%) in an RSA test of elite professional players.

Among other factors, another important aspect is that most of the studies do not quantify the overall training load (e.g., session and weekly training load) to which the players are exposed; that information may allow a better understanding of the different results between studies (Martin et al., 2022). Indeed, the time spent at high training intensities (pre-season) has been advocated as a powerful indicator for training monitoring; a positive association between physiological and performance improvements and the time spent training at high training intensities (e.g., >90%HR\(_{\text{max}}\)) has been reported (Casamichana et al., 2013; Castagna et al., 2011; Castagna et al., 2013; Manzi et al., 2013). It has been recommended that professional players should spend at least a range of 7–8% of their total training volume during the pre-season in the high-intensity category (Castagna et al., 2013). Additionally, it seems that the weekly magnitude of the individualized training load (TRIMPI) of professional players should be higher than 500 AU, to substantially improve aerobic fitness and performance variables during the precompetitive season (Manzi et al., 2013). Moreover, an increase in weekly load by approximately 150-min in duration, 700 AU in sRPE, 12-km in total distance (TD), 2-km in HSR (>15 km/h; HSR) or 0.8-km min VHSR (>20 km/h) is required to increase the chances of obtaining a 0.5 mmol/l–1 improvement in the lactate accumulation during a 6 min constant speed running test (13.5 km/h) (Martin et al., 2022). Within this specific season period, an increase by 40-min in duration, 150 AU in sRPE, 3-km in TD, 1-km in HSR or 0.5-km in VHSR is required to increase the chances of obtaining a 0.5 mmol/l–1 improvement in the lactate accumulation during a high-intensity intermittent shuttle test (Martin et al., 2022).

Notwithstanding the previous studies, investigation of the effect of training programs in professional players is scarce, with more evidence during the preseason period. This is not surprising given that in professional/elite context due to the obvious limiting factors (e.g,
physical demands of testing, limited time available, congested competition schedules) during in-season emphasis is given to prepare the strategy for next match and recovery from the stress of the last competitive match. Given these contextual limitations and that there is no common perspective or terminology to characterize the caliber and training status of an individual or cohort (McKay et al., 2022), interpret the existent training studies with a critical perspective is a crucial step for informed decision making.

In summary, during the preparation phase players “recover” cardiorespiratory capacity and the ability to perform and recover from high-intensity intermittent exercise. Improvements of moderate magnitude in velocity at fixed blood lactate concentrations ($V_2$–$4$mmol/l) and of large magnitude in VO$_{2\text{max}}$ maximal aerobic speed (MAS) and intense intermittent exercise performance (IE) are observed after preseason. During in-season, in MCP, are observed generally better scores when compared to PPS; improvements of moderate magnitude in VO$_{2\text{max}}$ and submaximal intensity exercise and large in MAS and IE. At ECP, increases are of moderate magnitude in all the examined outcomes. Although more scarcely investigated, from BCP to MCP, there are observed alterations of trivial magnitude in MAS (decrease) and VO$_{2\text{max}}$ (increase) and of small magnitude in IE (decrease) and sub-maximal exercise (increase). From the MCP to ECP, the different outcomes decrease with trivial ($V_2$–$4$mmol/l and MAS) and small (VO$_{2\text{max}}$ and IE). Match performance may vary during the season. At the MCP the observed alterations are considered of trivial magnitude. However, it seems that at the ECP increments in TD (small), HSR (moderate), VHSR (small), and sprint (moderate) are of substantial magnitude compared the BCP. From the middle to the ECP, the observed increments are of small (TD, VHSR and sprint) and moderate magnitude (HSR). Although, the variability between studies is clear for TD, VHSR and sprint, all the studies observed substantial increments in HSR between the two previous time points. Different training methods or combination of methods may improve (pre-season) and assist in the maintenance or further improvement (in-season) of physiological determinants and endurance performance during the season.

**WHAT ARE THE CHALLENGES?**

**Research**

Research in soccer uncovers the complexity of interactions established between the different performance dimensions and the factors that are intrinsic to each player and team. However, the paucity of in-season data on specific anaerobic/neuromuscular qualities (e.g., anaerobic power, relative force, rate force development, maximal speed) and physiological and endurance-related parameters (e.g., RE, VO$_2$ kinetics, cardiac autonomic adaptations; short heart-rate recovery) that may be relevant in improving running capacity, should be investigated to allow for a better understanding of seasonal variations in physical fitness, more robustly, through the in-season phases. As example, overall systematic analyses of the data revealed better scores in multi-joint, power-based, dynamic efforts during in-season periods. In part, these observations may lead to the following proposals: (i) neuromuscular adaptations affecting SSC mechanisms (phase analysis) may occur throughout the in-season period; and (ii) a composite score of power-based efforts...
may be more relevant for tracking the training status of professional players than a single measure, *per se*. Future research should also aim to understand seasonal changes in force capabilities during various velocities conditions and during specific motor tasks (jumping and sprinting) (*Morin, 2019*); efforts are already being developed in this direction (*Haugen, 2018; Jimenez-Reyes et al., 2022*). Moreover, studies aiming in improve the understanding of acute and chronic neuromuscular and endurance adaptations of professional players triggered by different in-season concurrent training modes (e.g., two instead of one: build power and endurance at the same time) is necessary. Research examining the effect of match exposure throughout the season on the performance adaptation kinetics of professional players is warranted; match-playing time may influence adaptations of specific and non-specific neuromuscular and neuromuscular parameters during the season (*Hader et al., 2019; Morgans, Di Michele & Drust, 2017; Silva et al., 2011; Sporis et al., 2011*). Furthermore, understand how the distinct internal and external load parameters (Level 1, 2 and 3 metrics) experienced by each individual player during the optimization of the distinct performance dimensions (e.g., tactical) impact players fitness status will be key for optimize the full spectrum of the physical potential of the players (mechanical and metabolic). Studies characterizing the periodization of training loads (overall) during the pre-season and in-season periods of professional players are necessary. Moreover, considering the off-season detraining effects, a “reorganization” of the periodization during the transition period is necessary (*Silva et al., 2016*). In fact, these findings could lead one to question what the usefulness of such a loss of individual (collective) performance potential during off-season? We recently, made a call to action to understand how the prescription of off-season individualized training programs may influence seasonal performance (*Silva et al., 2016*). We highlighted that this period should be viewed as a ‘window of opportunity’ for players to recover and to ‘rebuild’ for the following season (*Silva et al., 2016*). ‘Rebuild’ for a more efficient and consistent in-season performance.

The perceptible increase in HSR towards the end-of-season period can be influenced, at least in part, by an improvement of pacing strategies in some form by professional players. As such, the development and improvement of conscious and/or sub-conscious pacing strategies (*Carling & Bloomfield, 2010; Edwards & Noakes, 2009; Mugglestone et al., 2012*) that seems to take place during matches cannot be excluded; there are contradictions regarding the concept of team sport players pacing their effort throughout the game (*Aughey, 2010*). This fact seems consistent with the higher physical performance in games towards the end of the season (*Mohr, Krstrup & Bangsbo, 2003; Rampinini et al., 2007b; Silva et al., 2013b*) and in other football codes (*Aughey, 2011*), without improvements in the majority of physiological and functional parameters; evidence of increases in certain stress biomarkers have also been reported (*Handziski et al., 2006; Heisterberg et al., 2012; Kraemer et al., 2004; Meyer & Meister, 2011; Reinke et al., 2009; Silva et al., 2014; Suda et al., 2012*). However, the well know context of the final stage of the competitive season (e.g, definition of team rank and contract renewal) as obvious impact in players "motivation" to perform. In these specific periods there is no space to “error”, and most likely “Mind will prevail over Muscle” (*Marcora & Staiano, 2010; Pessiglione et al., 2007*).
As so, caution is needed when estimating players “readiness” from overall match activity profile. Research on these factors is necessary.

A better understanding of roles and tactics of team organization and an improvement in decision-making during season matches should be taken in account as central variables that may impact performance throughout the season (Vigne et al., 2012). Interestingly, data on longitudinal changes in match activity throughout the season seem to suggest an increased match efficiency (ranging from 2.6–6%) during the in-season period (Mohr, Krstrup & Bangsbo, 2003; Rampinini et al., 2007b; Silva et al., 2013b). Another interesting factor is that high-level soccer players seem to exhibit superior anticipation capacity accompanied by more effective search behaviors and elaborative thought processes (Casanova et al., 2013). Nevertheless, the state of research regarding improvements in perceptual-cognitive processes in highly trained players and the influence of pacing and match activity remains very scarce. Curiously, elite players with long-term careers, parallely to a annual gradual decrease in match-related physical output (0.56–1.8% by year) improve technical–tactical skills with increasing age (Rey et al., 2022).

‘Integrated’ approaches that contextualizes physical demands in relation to key tactical activities for each position and collectively for the team are warranted; understanding the physical performance in relation to the tactical roles (Bradley & Ade, 2018). In fact, is not the match running performance alone that is important for achieving success, but rather its relation to technical/tactical skills (Hoppe et al., 2015). Finally, the causative factors of the observed long-term changes (evolutionary trends) are not known and can be related, among others, with processes of players selection (e.g., towards more “highly impulsive” players), improvements in facilities and equipment’s (e.g., grass conditions) and training-related processes (e.g., better physical conditioning, training monitorization and players nutrition and recovery support). Research into the previous components is necessary.

Training

Although one normally expects than within the season (from BCP to MCP or MCP to ECP) the consistent training of the physical, tactical, and technical dimensions of performance and as well the stimulus provided by competitive matches, could lead to a further optimization of players performance, more robustly concerning the start of competition phase (e.g., BCP to MCP). However, within these periods there are by average observed changes of trivial magnitude. Specifically, substantial alterations where evident only for IE (decreased) and sub-maximal exercise performance (improved). From MCP to ECP all the examined parameters tend to decrease with a trivial magnitude and substantial negative alterations been observed for VO$_{2\text{max}}$ and IE. This undesirable dynamic in certain physiological determinants and endurance-related performance measures could be explained by the tight in-season schedule, with most of the time dedicate to recover from the previous match and prepare the strategy for the next opponent. In this regard, if a “window of opportunity” occurs (e.g., player ban as result of a red card and players not selected for national team breaks) further in-season improvements in aerobic and
anaerobic qualities determinant for the running capacity and sub-maximal and maximal soccer-running performances than can be achieved through normal training routines may be obtained by incorporation of short duration HIT blocks (Christensen et al., 2011; Wahl, Guldner & Mester, 2014). As an example, although positive adaptations in running economy have mainly been reported and investigated during the pre-season, there are recent reports of increased running economy (75% of MAS) in players after performing 2 weeks of intense HIT executed just after the competitive season ended (Christensen et al., 2011); this result suggests that players still have significant physiological and performance adaptation potential to be explored. Nevertheless, caution is needed when extrapolating these findings for professional players as these experimental studies were performed by amateur and semi-professional players (Christensen et al., 2011; Wahl, Guldner & Mester, 2014). Nonetheless, it seems that special attention should be given to neuromuscular involvement during HIT (Bogdanis et al., 2009; Bogdanis et al., 2011) and to the concurrent effect of HIT (McGawley & Andersson, 2013), as it may be a determinant of the gains in running capacity during a short in-season intervention period. Nevertheless, being a very sensible process, these intervention periods require individualized management of the training/match load (Silva & Rebelo, 2019). In fact, within the same team a player may “underperform” as result of an over exposure while other player could be “underperforming” because of a detraining-related condition (Silva & Rebelo, 2019). Finally, the observations of a long-term persistent trend towards faster players and increased game speed (shorter and more “explosive” sprints and higher maximal running speeds) as well specific technical variables (e.g., passing rates) should be reflected not only on players selection but also in the training organization (e.g., physical conditioning). Regarding the latter, training should “feed” the players ability to perform maximal neuromuscular efforts and to repeat them over time; with the level of perceptual-cognitive demands varying according to each individual player needs.

**Monitoring**

Notwithstanding some techniques applied in research settings provide valuable information (valid, reliable), its utilization in routine operations within the club setting is limited (Silva & Rebelo, 2019). The imposed physical demands (e.g., maximal tests) and the invasive nature may explain at least in part the scarce applicability of several techniques in the real-world scenario (Carling et al., 2018). How motivated a player is for performing an end of season maximal testing session? This has obviously implications in the analyzed performance measures derived from testing sessions and match analysis, more influential through ECP assessments. Training may represent the perfect ecological setup to use as a ‘lab’ and shed some light as to the training status of the player (Silva & Rebelo, 2019). To this aim, a more action-oriented approach is needed; information derived from training sessions with tools that allow the simultaneous, instantaneous and non-invasive capture of multiple sources of information (Carling et al., 2018; Morin et al., 2021). As example, there are specific periods such as the warm-up and/or the main part of the training session (during gym or field sessions) that can be used to collect more precise information (neuromuscular and cardiorespiratory) regarding the players training status (Silva &
Rebelo, 2019). As example, Morin et al. (2021) recently investigate an in-situ approach to directly assess individual acceleration-speed profile. Moreover, standardized drills with planned (e.g., sub-maximal running drill and or passing drills) (Buchheit et al., 2013) and unplanned (e.g., small-sided-games) external load (precise and imprecise behaviors, respectively) can be applied within those parts of training practice to gain insight on players training status (Brink et al., 2012; Morin et al., 2021; Rago et al., 2017; Rago et al., 2018; Rowell et al., 2018b). As example, given the clear disconnection between running economy assessment methodology and soccer-specific activity during training and matches, there is some evidence that soccer-specific work economy may somewhat improve during the season; the relevant gains may not be detectable by conventional treadmill testing (Helgerud et al., 2001; McMillan et al., 2005). Nevertheless, although this monitoring strategy is not applicable without the coach’s approval, it builds an avenue for increased player “buy in” (Silva & Rebelo, 2019). A wide range of information can be collected during a standardized warm-up (Buchheit et al., 2013) that can inform on the training status of the athlete (Halson, 2014). As an example, the examination of physiological (HR) and perceptual (RPE) indicators of load in sub-maximal running exercise can provide valuable information on players cardiorespiratory fitness and fatigue level (Halson, 2014). Additionally, information on neuromuscular training status can be collected within this training stage and other periods (e.g., standardized small-sided game) by means of GPS and accelerometer-derived metrics (e.g., load per minute, load triaxial contributions) (Cormack et al., 2013; Morin et al., 2021; Rowell et al., 2018b). This latter monitoring strategy when applied during specific moments of the microcycle offers a great ecological and valid option for monitoring training status (Rago et al., 2017; Rago et al., 2018; Rowell et al., 2018b). In fact, this has been recently investigated in order to overcome the limitations (e.g., time for testing, isolated tests) of assessing elite players when using more traditional moments and tools (Rago et al., 2017; Rago et al., 2018; Rowell et al., 2018a). Nevertheless, when using standardized small-sided games, well-known factors that affect players exercise intensity need to be regarded (e.g., space, duration and team structure), but also team constitution should be maintained stable (if possible the same players in each team) (Silva & Rebelo, 2019).

LIMITATIONS

It is important to highlight some limitations inherent to this work. In this review, we aggregate teams from distinct soccer leagues (e.g., European, and Asian). Although we included adults (>19 years) soccer players described has professional or elite player, given that there is no common perspective or terminology to characterize the caliber and training status of an individual or cohort, we need to consider that a considerable variation in training load and training history may exist between the included teams (McKay et al., 2022). Secondly, the time length between the different season moments may vary between studies. As example, in some studies the preparation period could last four weeks and in others height weeks. Furthermore, season organization may diverge. In some studies players could had an extended mid-season break (e.g., 2 weeks) due to the winter environmental conditions (e.g., Romanian League, and German Bundesliga), while in
others just a short number of days for Christmas festivities (e.g., Portuguese, or Spanish leagues) or even mid-season being one of the most congested periods of the competition (e.g., English premier league).

**CONCLUSION**

Both short- and long-term detraining during the off-season period seem to have negative effects on body composition with alterations of small magnitude in body mass, body fat and decrements of moderate magnitude in lean body mass. The transition period also results in deteriorations of small to moderate magnitude in jump ability (Non-CMJ and CMJ\textsuperscript{Based}), linear (acceleration and maximal velocity phase) and multidirectional speed. Furthermore, a large magnitude in physiological determinants and endurance performance measures (large for VO\textsubscript{2max} and time to exhaustion and moderate and very large for intense intermittent exercise) have also been reported. These detraining effects may influence how players prepare during the pre-season and in-season and, in a certain way, affect their performance levels, especially in the first matches of the competitive season (Kraemer et al., 2004).

During the preparation phase players “recover” competitive capacity. The different investigations suggest that no unique and specific pattern of variation in body composition profile occur during the pre-season and in-season periods. Nevertheless, the general picture suggests that professional players may maintain their BM after the start of the training period through improvements of small magnitude in LBM and BF and with no substantial alterations within the in-season moments. These biometric alterations signify that chronic exposure of professional players to training and competition results in improved muscular and adiposity profiles and therefore a better overall body composition. Neuromuscular adaptations have been observed throughout absolute and relative measures of force production (1RM and relative force) as well as through jump, sprint, and COD tests. Specifically, by average, improvements of small magnitude in non-CMJ and CMJ\textsuperscript{Based} jumps, and the acceleration and maximal velocity phase of the sprint are observed when preparing to competition phase. In the middle of the competition period, small (CMJ\textsuperscript{Based} and ACC\textsubscript{Phase}), and moderate (non-CMJ and MV\textsubscript{Phase}) improvements were observed, compared to the start of the preseason phase. However, alterations towards the end of season (ECP) seem to be force-velocity dependent; CMJ\textsuperscript{Based} and maximal speed improve to a small extent with non-CMJ and sprint acceleration phase revealing moderate performance increments compared to PPS. A general analysis suggest that trivial alterations occur withing the in-season (BCP to MCP and MCP to ECP) in these performance parameters. However, these is the result of the variability observed between studies; more evident when monitoring the CMJ performance.

Improvements of moderate magnitude in the velocity at fixed blood lactate concentrations (V\textsubscript{2–4mmol/l}) and of large magnitude in VO\textsubscript{2max}, MAS and IE are by average observed after preseason. During in-season, in the MCP, are observed generally better scores when compared to the PPS; by average, improvements of moderate magnitude in VO\textsubscript{2max} and submaximal intensity exercise and large in MAS and IE. At the ECP, the increases in the abovementioned parameters are of moderate magnitude in all the
examined outcomes. Although more scarcely investigated, from BCP to MCP, there are observed by average alterations of trivial magnitude in MAS (decrease) and VO₂max (increase) and changes of small magnitude in IE (decrease) and sub-maximal intermittent exercise (increase). From the MCP to ECP, the different outcomes decrease by average with trivial (V₂₋₄mmol/l and MAS) and small magnitudes (VO₂max and IE). Match performance may vary during the season. At the MCP the observed alterations are by average considered of trivial magnitude. However, it seems that at the ECP, increments in TD (small), HSR (moderate), VHSR (small) and sprint (moderate) speed zones are of substantial magnitude compared the BCP. From the middle to the ECP, the observed increments are by average of small (total distance, VHSR and sprint) and moderate magnitude (HSR). Although, the variability between studies is clear for TD, VHSR and sprint, all the studies observed substantial increments in HSR between the two previous time points. Finally, studies examining evolutionary trends by means of exercise and competition performance measures suggests of a heightened importance of neuromuscular factors in soccer.

In conclusion, although an extraordinary growth in the number of scientific investigations concerning soccer has been observed in the 3rd millennium, there is still much to elucidate regarding the complexity of interactions established between the different performance dimensions and the factors that are intrinsic to each player and team. Notwithstanding the fundamental role of the most-up-to date evidence-based training practices and monitoring tools for assure an efficient a proficient training process, high-level teams’ success, and players excellence achievement, will be always closely dependent of the specificity of the training stimulus provided (e.g., nature of the content) and sensibility of the technical staff (e.g., mastery of coach managing players match/training load) on driving the training process.

### ADDITIONAL INFORMATION AND DECLARATIONS

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**Competing Interests**
The authors declare that they have no competing interests.

**Author Contributions**
• Joao Renato Silva conceived and designed the experiments, performed the experiments, analyzed the data, prepared figures and/or tables, authored or reviewed drafts of the article, and approved the final draft.

**Data Availability**
The following information was supplied regarding data availability:

This is a literature review without raw data.
REFERENCES

Abt G, Lovell R. 2009. The use of individualized speed and intensity thresholds for determining the distance run at high-intensity in professional soccer. Journal of Sports Sciences 27(9):893–898 DOI 10.1080/02640410902998239.

Akyildiz Z, Nobari H, Gonzalez-Fernandez FT, Praca GM, Sarmento H, Guler AH, Saka EK, Clemente FM, Figueiredo AJ. 2022. Variations in the physical demands and technical performance of professional soccer teams over three consecutive seasons. Scientific Reports 12(1):2412 DOI 10.1038/s41598-022-06365-7.

Al Attar WSA, Soomro N, Sinclair PJ, Pappas E, Sanders RH. 2017. Effect of injury prevention programs that include the nordic hamstring exercise on hamstring injury rates in soccer players: a systematic review and meta-analysis. Sports Medicine 47(5):907–916 DOI 10.1007/s40279-016-0638-2.

Allen WJC, De Keijzer KL, Raya-Gonzalez J, Castillo D, Coratella G, Beato M. 2021. Chronic effects of flywheel training on physical capacities in soccer players: a systematic review. Research in Sports Medicine 11(1):1–21 DOI 10.1080/15438627.2021.1958813.

Altmann S, Kuberczyk M, Ringhof S, Neumann R, Woll A. 2018. Relationships between performance test and match-related physical performance parameters. German Journal of Exercise and Sport Research 48(2):218–227 DOI 10.1007/s12662-018-0519-y.

Altmann S, Neumann R, Hartel S, Woll A, Buchheit M. 2021. Using submaximal exercise heart rate for monitoring cardiorespiratory fitness changes in professional soccer players: a replication study. International Journal of Sports Physiology and Performance 16(8):1096–1102 DOI 10.1123/ijspp.2020-0554.

Altmann S, Neumann R, Woll A, Hartel S. 2020. Endurance capacities in professional soccer players: are performance profiles position specific? Frontiers in Sports and Active Living 2:549897 DOI 10.3389/fspor.2020.549897.

Andrzejewski M, Chmura P, Konefal M, Kowalcuk E, Chmura J. 2018. Match outcome and sprinting activities in match play by elite German soccer players. The Journal of Sports Medicine and Physical Fitness 58(6):785–792 DOI 10.23736/S0022-4707.17.07352-2.

Arjol-Serrano JL, Lampre M, Diez A, Castillo D, Sanz-Lopez F, Lozano D. 2021. The influence of playing formation on physical demands and technical-tactical actions according to playing positions in an elite soccer team. International Journal of Environmental Research and Public Health 18(8):4148 DOI 10.3390/ijerph18084148.

Asking C, Karlsson J, Thorstensson A. 2003. Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. Scandinavian Journal of Medicine & Science in Sports 13(4):244–250 DOI 10.1034/j.1600-0838.2003.00312.x.

Aughey RJ. 2010. Australian football player work rate: evidence of fatigue and pacing? International Journal of Sports Physiology and Performance 5(3):394–405 DOI 10.1123/ijspp.5.3.394.

Aughey RJ. 2011. Increased high-intensity activity in elite Australian football finals matches. International Journal of Sports Physiology and Performance 6(3):367–379 DOI 10.1123/ijspp.6.3.367.

Augusto D, Brito J, Aquino R, Figueiredo P, Eiras F, Tannure M, Veiga B, Vasconcellos F. 2021. Contextual variables affect running performance in professional soccer players: a brief report. Frontiers in Sports and Active Living 3:778813 DOI 10.3389/fspor.2021.778813.

Azcarate U, Los Arcos A, Jimenez-Reyes P, Yanci J. 2020. Are acceleration and cardiovascular capacities related to perceived load in professional soccer players? Research in Sports Medicine 28(1):27–41 DOI 10.1080/15438627.2019.1644642.
Aziz AR, Mukherjee S, Chia MY, Teh KC. 2008. Validity of the running repeated sprint ability test among playing positions and level of competitiveness in trained soccer players. *International Journal of Sports Medicine* 29(10):833–838 DOI 10.1055/s-2008-1038410.

Aziz A, Tan F, Teh K. 2005. Variation in selected fitness attributes of professional soccer players during a league season. In: Reilly T, Araújo D, Cabri J, eds. *Science and Football V*. London/New York: E and FN Spon, 134–138.

Bangsbo J, Gunnarsson TP, Wendell J, Nybo L, Thomassen M. 2009. Reduced volume and increased training intensity elevate muscle Na+-K+ pump alpha2-subunit expression as well as short- and long-term work capacity in humans. *Journal of Applied Physiology* 107(6):1771–1780 DOI 10.1152/japplphysiol.00358.2009.

Bangsbo J, Iaia FM, Krustrup P. 2007. Metabolic response and fatigue in soccer. *International Journal of Sports Physiology and Performance* 2(2):111–127 DOI 10.1123/ijspp.2.2.111.

Bangsbo J, Iaia FM, Krustrup P. 2008. The Yo-Yo intermittent recovery test: a useful tool for evaluation of physical performance in intermittent sports. *Sports Medicine* 38(1):37–51 DOI 10.2165/00007256-200838010-00004.

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

Barnes C, Archer DT, Hogg B, Bush M, Bradley PS. 2014. The evolution of physical and technical performance parameters in the English Premier League. *International Journal of Sports Medicine* 35:1095–1100 DOI 10.1055/s-00000028.

Berthon P, Fellmann F. 2002. General review of maximal aerobic velocity measurement at laboratory: proposition of a new simplified protocol for maximal aerobic velocity assessment. *The Journal of Sports Medicine and Physical Fitness* 42:257–266.

Billat LV, Koralsztein JP. 1996. Significance of the velocity at VO2max and time to exhaustion at this velocity. *Sports Medicine* 22(2):90–108 DOI 10.2165/00007256-199622020-00004.

Bishop D, Girard O, Mendez-Villanueva A. 2011. Repeated-sprint ability – Part II: recommendations for training. *Sports Medicine* 41(9):741–756 DOI 10.2165/11590560-000000000-00000.

Bogdanis GC, Papaspyrou A, Souglis A, Theos A, Sotiropoulos A, Maridaki M. 2009. Effects of hypertrophy and a maximal strength training programme on speed, force and power of soccer players. In: Reilly T, Korkusuz F, eds. *Science and Football VI The Proceedings of the Sixth World Congress on Science and Football*. New York: Routledge, 290–295.

Bogdanis GC, Papaspyrou A, Souglis AG, Theos A, Sotiropoulos A, Maridaki M. 2011. Effects of two different half-squat training programs on fatigue during repeated cycling sprints in soccer players. *Journal of Strength and Conditioning Research* 25(7):1849–1856 DOI 10.1519/JSC.0b013e3181e83a1e.

Bonuccelli A, Causarano A, Marzatico F, Catanese S, D’Urbano G, Beschi S, Ziegenfuss T, Buonocore D, Focarelli A, Angelini F. 2012. Innovative assessment of seasonal variations in body composition of elite soccer players with the integrated analysis DXA-BIVA. *Journal of the International Society of Sports Nutrition* 9(Suppl 1):P1 DOI 10.1186/1550-2783-9-S1-P1.

Boullosa DA, Abreu L, Nakamura FY, Munoz VE, Dominguez E, Leicht AS. 2013. Cardiac autonomic adaptations in elite Spanish soccer players during preseason. *International Journal of Sports Physiology and Performance* 8(4):400–409 DOI 10.1123/ijspp.8.4.400.

Bradley PS, Ade JD. 2018. Are current physical match performance metrics in elite soccer fit for purpose or is the adoption of an integrated approach needed? *International Journal of Sports Physiology and Performance* 13(5):656–664 DOI 10.1123/ijspp.2017-0433.
Bradley PS, Archer DT, Hogg B, Schuth G, Bush M, Carling C, Barnes C. 2016. Tier-specific evolution of match performance characteristics in the English Premier League: it’s getting tougher at the top. *Journal of Sports Sciences* 34(10):980–987 DOI 10.1080/02640414.2015.1082614.

Bradley PS, Lago-Penas C, Rey E, Gomez Diaz A. 2013. The effect of high and low percentage ball possession on physical and technical profiles in English FA Premier League soccer matches. *Journal of Sports Sciences* 31(12):1261–1270 DOI 10.1080/02640414.2013.786185.

Bradley PS, Mascio MD, Bangsbo J, Krstrup P. 2011. The maximal and sub-maximal versions of the Yo-Yo intermittent endurance test level 2 are simply reproducible, sensitive and valid. *European Journal of Applied Physiology* 111(6):969–978 DOI 10.1007/s00421-010-1721-2.

Bradley PS, Mohr M, Bendiksen M, Randers MB, Flindt M, Barnes C, Hood P, Gomez A, Andersen JL, Di Mascio M, Bangsbo J, Krstrup P. 2010. Sub-maximal and maximal Yo-Yo intermittent endurance test level 2: heart rate response, reproducibility and application to elite soccer. *European Journal of Applied Physiology* 111(6):969–978 DOI 10.1007/s00421-010-1721-2.

Bradley PS, Noakes TD. 2013. Match running performance fluctuations in elite soccer: indicative of fatigue, pacing or situational influences? *Journal of Sports Sciences* 31(15):1627–1638 DOI 10.1080/02640414.2013.796062.

Bradley PS, Sheldon W, Wooster B, Olsen P, Boanas P, Krustrup P. 2009. High-intensity running in English FA Premier League soccer matches. *Journal of Sports Sciences* 27(2):159–168 DOI 10.1080/02640410802512775.

Brink MS, Visscher C, Coutts AJ, Lemmink KA. 2012. Changes in perceived stress and recovery in overreached young elite soccer players. *Scandinavian Journal of Medicine & Science in Sports* 22(2):285–292 DOI 10.1111/j.1600-0838.2010.01237.x.

Brocherie F, Girard O, Forchino F, Al Haddad H, Dos Santos GA, Millet GP. 2014. Relationships between anthropometric measures and athletic performance, with special reference to repeated-sprint ability, in the Qatar national soccer team. *Journal of Sports Sciences* 32(13):1–12 DOI 10.1080/02640414.2013.862840.

Buchheit M. 2010. The 30-15 intermittent fitness test: 10 year review. *Myorobie Journal* 1:1–9.

Buchheit M. 2014. Monitoring training status with HR measures: do all roads lead to Rome? *Frontiers in Physiology* 5:73 DOI 10.3389/fphys.2014.00073.

Buchheit M, Bishop D, Haydar B, Nakamura FY, Ahmaidi S. 2010. Physiological responses to shuttle repeated-sprint running. *International Journal of Sports Medicine* 31(6):402–409 DOI 10.1055/s-0030-1249620.

Buchheit M, Laursen PB. 2013a. High-intensity interval training, solutions to the programming puzzle: part I: cardiopulmonary emphasis. *Sports Medicine* 43(5):313–338 DOI 10.1007/s40279-013-0029-x.

Buchheit M, Laursen PB. 2013b. High-intensity interval training, solutions to the programming puzzle. Part II: anaerobic energy, neuromuscular load and practical applications. *Sports Medicine* 43(10):927–954 DOI 10.1007/s40279-013-0066-5.

Buchheit M, Rabbani A. 2014. The 30-15 intermittent fitness test versus the Yo-Yo intermittent recovery test level 1: relationship and sensitivity to training. *International Journal of Sports Physiology and Performance* 9(3):522–524 DOI 10.1123/ijispp.2012-0335.

Buchheit M, Racinais S, Bilsborough JC, Bourdon PC, Voss SC, Hocking J, Cordy J, Mendez-Villanueva A, Coutts AJ. 2013. Monitoring fitness, fatigue and running performance during a pre-season training camp in elite football players. *Journal of Science and Medicine in Sport* 16(6):550–555 DOI 10.1016/j.jsams.2012.12.003.
Buchheit M, Simpson BM. 2017. Player-tracking technology: half-full or half-empty glass? *International Journal of Sports Physiology and Performance* 12(s2):S235–S241 DOI 10.1123/ijspp.2016-0499.

Buchheit M, Simpson BM, Lacome M. 2020. Monitoring cardiorespiratory fitness in professional soccer players: is it worth the prick? *International Journal of Sports Physiology and Performance* 15(10):1437–1441 DOI 10.1123/ijspp.2019-0911.

Bunc V, Hráský P, Skalská M. 2015. Changes in body composition, during the season, in highly trained soc-cer players. *The Open Sports Sciences Journal* 8(1):18–24 DOI 10.2174/1875399X01508010018.

Bush M, Barnes C, Archer DT, Hogg B, Bradley PS. 2014. Evolution of match performance parameters for various playing positions in the English Premier League. *Human Movement Science* 39C:1–11 DOI 10.1016/j.humov.2014.10.003.

Byrne C, Twist C, Eston R. 2004. Neuromuscular function after exercise-induced muscle damage: theoretical and applied implications. *Sports Medicine* 34(1):49–69 DOI 10.2165/00007256-200434010-00005.

Caldwell BP, Peters DM. 2009. Seasonal variation in physiological fitness of a semiprofessional soccer team. *Journal of Strength and Conditioning Research* 23(5):1370–1377 DOI 10.1519/JSC.0b013e3181a4e82f.

Campos-Vazquez MA, Toscano-Bendala FJ, Mora-Ferrera JC, Suarez-Arrones L. 2016. Relationship between internal load indicators and changes on intermittent performance after the preseason in professional soccer players. *Journal of Strength and Conditioning Research* 31(6):1477–1485 DOI 10.1519/JSC.0000000000001613.

Carling C, Bloomfield J. 2010. The effect of an early dismissal on player work-rate in a professional soccer match. *Journal of Science and Medicine in Sport* 13(1):126–128 DOI 10.1016/j.jsams.2008.09.004.

Carling C, Lacome M, McCall A, Dupont G, Le Gall F, Simpson B, Buchheit M. 2018. Monitoring of post-match fatigue in professional soccer: welcome to the real world. *Sports Medicine* 48(12):2695–2702 DOI 10.1007/s40279-018-0935-z.

Carling C, Orhant E. 2010. Variation in body composition in professional soccer players: interseasonal and intraseasonal changes and the effects of exposure time and player position. *Journal of Strength and Conditioning Research* 24(5):1332–1339 DOI 10.1519/JSC.0b013e3181cc6154.

Casado Yebras M, Lázaro Ramírez JL, Raya González J, Santalla A, Suárez-Arrones L. 2014. 30-15 intermittent fitness test vs. Yo-Yo IR2: relationship and ability to discriminate performance levels. *Cultura, Ciencia y Deporte* 9(25):S64.

Casajus JA. 2001. Seasonal variation in fitness variables in professional soccer players. *The Journal of Sports Medicine and Physical Fitness* 41:463–469.

Casamichana D, Castellano J, Calleja-Gonzalez J, San Roman J, Castagna C. 2013. Relationship between indicators of training load in soccer players. *Journal of Strength and Conditioning Research* 27(2):369–374 DOI 10.1519/JSC.0b013e3182548af1.

Casanova F, Garganta J, Silva G, Alves A, Oliveira J, Williams AM. 2013. Effects of prolonged intermittent exercise on perceptual-cognitive processes. *Medicine & Science in Sports & Exercise* 45(8):1610–1617 DOI 10.1249/MSS.0b013e31828b2ce9.

Castagna C, Impellizzeri F, Cecchini E, Rampinini E, Alvarez JC. 2009. Effects of intermittent-endurance fitness on match performance in young male soccer players. *Journal of Strength and Conditioning Research* 23(7):1954–1959 DOI 10.1519/JSC.0b013e3181b7f743.
Castagna C, Impellizzeri F, Chamari K, Carlomagno D, Rampinini E. 2006. Aerobic fitness and Yo-Yo continuous and intermittent tests performances in soccer players: a correlation study. *Journal of Strength and Conditioning Research* 20:320–325 DOI 10.1519/R-18065.1.

Castagna C, Impellizzeri FM, Chauachi A, Bordon C, Manzi V. 2011. Effect of training intensity distribution on aerobic fitness variables in elite soccer players: a case study. *Journal of Strength and Conditioning Research* 25(1):66–71 DOI 10.1519/JSC.0b013e3181fef3d3.

Castagna C, Impellizzeri FM, Chauachi A, Manzi V. 2013. Pre-season variations in aerobic fitness and performance in elite standard soccer players: a team-study. *Journal of Strength and Conditioning Research* 27(11):2959–2965 DOI 10.1519/JSC.0b013e31828d61a8.

Chmura P, Konefal M, Wong DP, Figueiredo AJ, Kowalczuk E, Rokita A, Chmura J, Andrzejewski M. 2019. Players' physical performance decreased after two-thirds of the season: results of 3 consecutive seasons in the German First Bundesliga. *International Journal of Environmental Research and Public Health* 16(11):2044 DOI 10.3390/ijerph16112044.

Christensen PM, Krstrup P, Gunnarsson TP, Kiilerich K, Nybo L, Bangsbo J. 2011. VO2 kinetics and performance in soccer players after intense training and inactivity. *Medicine & Science in Sports & Exercise* 43(9):1716–1724 DOI 10.1249/MSS.0b013e318211c01a.

Clark N, Edwards AM, Morton R, Butterly J. 2008. Season-to-season variation of physiological fitness within a squad of professional male soccer players. *Journal of Sports Science and Medicine* 7:157–165.

Clemente FM, Gonzalez-Fernandez FT, Ceylan HI, Silva R, Younesi S, Chen YS, Badicu G, Wolanski P, Murawska-Cialowicz E. 2021. Blood biomarkers variations across the pre-season and interactions with training load: a study in professional soccer players. *Journal of Clinical Medicine* 10(23):5576 DOI 10.3390/jcm10235576.

Cohen J. 1998. *Statistical power analysis for the behavioral sciences*. Hillsdale: Lawrence Erlbaum.

Cometti G, Maffiuletti NA, Pousson M, Chatard JC, Maffulli N. 2001. Isokinetic strength and anaerobic power of elite, subelite and amateur soccer players. *International Journal of Sports Medicine* 22(1):45–51 DOI 10.1055/s-2001-11331.

Cormack SJ, Mooney MG, Morgan W, McGuigan MR. 2013. Influence of neuromuscular fatigue on accelerometer load in elite Australian football players. *International Journal of Sports Physiology and Performance* 8(4):373–378 DOI 10.1123/ijspp.8.4.373.

D’Ascenzi F, Pelliccia A, Cameli M, Lisi M, Natali BM, Focardi M, Giorgi A, D’Urbano G, Causarano A, Bonifazi M, Mondillo S. 2013. Dynamic changes in left ventricular mass and in fat-free mass in top-level athletes during the competitive season. *European Journal of Preventive Cardiology* 22(1):127–134 DOI 10.1177/2047487313505820.

Dauty M, Potiron Josse M. 2004. Correlations and differences of performance between soccer players, professionals, young players and amateurs, from the 10-meter sprint test and knee isokinetic assessment. *Science & Sports* 19(2):75–79 DOI 10.1016/j.scispo.2003.09.014.

de Hoyo M, Pozzo M, Sanudo B, Carrasco L, Gonzalo-Skok O, Dominguez-Cobo S, Moran-Camacho E. 2015a. Effects of a 10-week in-season eccentric-overload training program on muscle-injury prevention and performance in junior elite soccer players. *International Journal of Sports Physiology and Performance* 10(1):46–52 DOI 10.1123/ijspp.2013-0547.

de Hoyo M, Sanudo B, Carrasco L, Dominguez-Cobo S, Mateo-Cortes J, Cadenas-Sanchez MM, Nimphius S. 2015b. Effects of traditional versus horizontal inertial flywheel power training on common sport-related tasks. *Journal of Human Kinetics* 47(1):155–167 DOI 10.1515/hukin-2015-0071.

de Hoyo M, Sanudo B, Carrasco L, Mateo-Cortes J, Dominguez-Cobo S, Fernandes O, Del Ojo JJ, Gonzalo-Skok O. 2016. Effects of 10-week eccentric overload training on kinetic...
parameters during change of direction in football players. *Journal of Sports Sciences* **34**(14):1380–1387 DOI 10.1080/02640414.2016.1157624.

Dellal A, Keller D, Carling C, Chaouachi A, del Wong P, Chamari K. 2010. Physiologic effects of directional changes in intermittent exercise in soccer players. *Journal of Strength and Conditioning Research* **24**(12):3219–3226 DOI 10.1519/JSC.0b013e3181b94a63.

Devlin BL, Kingsley M, Leveritt MD, Belski R. 2017. Seasonal changes in soccer players’ body composition and dietary intake practices. *Journal of Strength and Conditioning Research* **31**(12):3319–3326 DOI 10.1519/JSC.0000000000001751.

Di Salvo V, Gregson W, Atkinson G, Tordoff P, Drust B. 2009. Analysis of high intensity activity in Premier League soccer. *International Journal of Sports Medicine* **30**(3):205–212 DOI 10.1055/s-00000028.

Di Salvo V, Pigozzi F, Gonzalez-Haro C, Laughlin MS, De Witt JK. 2012. Match performance comparison in Top English Soccer Leagues. *International Journal of Sports Medicine* **34**(6):526–532 DOI 10.1055/s-00000028.

Dupont G, Akakpo K, Berthoin S. 2004. The effect of in-season, high-intensity interval training in soccer players. *Journal of Strength and Conditioning Research* **18**:584–589 DOI 10.1519/1533-4287(2004)18<584:TEOIHI>2.0.CO;2.

Edwards AM, Macfadyen AM, Clark N. 2003. Lactate and ventilatory thresholds reflect the training status of professional soccer players where maximum aerobic power is unchanged. *Journal of Sports Science and Medicine* **2**:23–29.

Edwards AM, Noakes TD. 2009. Dehydration: cause of fatigue or sign of pacing in elite soccer? *Sports Medicine* **39**(1):1–13 DOI 10.2165/00007256-200939010-00001.

Elferink-Gemser MT, Huijgen BC, Coelho-e-Silva M, Lemmink KA, Visscher C. 2012. The changing characteristics of talented soccer players—a decade of work in Groningen. *Journal of Sports Sciences* **30**(15):1581–1591 DOI 10.1080/02640414.2012.725854.

Eliakim E, Doron O, Meckel Y, Nemet D, Eliakim A. 2018. Pre-season fitness level and injury rate in professional soccer—a prospective study. *Sports Medicine International Open* **2**(3):E84–E90 DOI 10.1055/a-0631-9346.

Eniseler N, Sahan C, Vurgun H, Mavi HF. 2012. Isokinetic strength responses to season-long training and competition in Turkish elite soccer players. *Journal of Human Kinetics* **31**(2012):159–168 DOI 10.2478/v10078-012-0017-5.

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

Ferrari Bravo D, Impellizzeri FM, Rampinini E, Castagna C, Bishop D, Wisloff U. 2008. Sprint vs. interval training in football. *International Journal of Sports Medicine* **29**(08):668–674 DOI 10.1055/s-2007-989371.

Fessi MS, Zarrouk N, Filetti C, Rebai H, Elloumi M, Moalla W. 2016. Physical and anthropometric changes during pre- and in-season in professional soccer players. *The Journal of Sports Medicine and Physical Fitness* **56**:1163–1170.

Foster C, Lucia A. 2007. Running economy: the forgotten factor in elite performance. *Sports Medicine* **37**(4):316–319 DOI 10.2165/00007256-200737040-00011.
Gaudino P, Iaia FM, Alberti G, Strudwick AJ, Atkinson G, Gregson W. 2013. Monitoring training in elite soccer players: systematic bias between running speed and metabolic power data. *International Journal of Sports Medicine* 34:963–968 DOI 10.1055/s-00000028.

Girard O, Mendez-Villanueva A, Bishop D. 2011. Repeated-sprint ability – part I: factors contributing to fatigue. *Sports Medicine* 41(8):673–694 DOI 10.2165/11590550-00000000-0000.

Gregson W, Drust B, Atkinson G, Salvo VD. 2010. Match-to-match variability of high-speed activities in premier league soccer. *International Journal of Sports Medicine* 31(4):237–242 DOI 10.1055/s-0030-1247546.

Gunnarsson TP, Christensen PM, Holse K, Christiansen D, Bangsbo J. 2012. Effect of additional speed endurance training on performance and muscle adaptations. *Medicine & Science in Sports & Exercise* 44(10):1942–1948 DOI 10.1249/MSS.0b013e31825ca446.

Hader K, Mendez-Villanueva A, Ahmaidi S, Williams BK, Buchheit M. 2014. Changes of direction during high-intensity intermittent runs: neuromuscular and metabolic responses. *BMC Sports Science, Medicine and Rehabilitation* 6(1) DOI 10.1186/s40798-019-0219-7.

Hader K, Rumpf MC, Hertzog M, Kilduff L, Girard O, Silva JR. 2019. Monitoring the athlete match response: May tracking variables predict post-match acute and residual fatigue in soccer? A systematic review with meta-analysis. *Sports Medicine – Open* 5(5) DOI 10.1186/s40798-019-0219-7.

Hagglund M, Walden M, Ekstrand J. 2005. Injury incidence and distribution in elite football—a prospective study of the Danish and the Swedish top divisions. *Scandinavian Journal of Medicine and Science in Sports* 15(1):21–28 DOI 10.1111/j.1600-0838.2004.00395.x.

Halson SL. 2014. Monitoring training load to understand fatigue in athletes. *Sports Medicine 44*(44(S2)):S139–S147 DOI 10.1007/s40279-014-0253-z.

Handziski Z, Maleska V, Petrovska S, Nikolik S, Mickoska E, Dalip M, Kostova E. 2006. The changes of ACTH, cortisol, testosterone and testosterone/cortisol ratio in professional soccer players during a competition half-season. *Bratislavské Lekarske Listy* 107:259–263.

Haritodinis K, Koutlianos N, Koudi E, Haritonidou M, Deligiannis A. 2004. Seasonal variation of aerobic capacity in elite soccer, basketball and volleyball players. *Journal of Human Performance* 46:289–302.

Haugen T. 2018. Soccer seasonal variations in sprint mechanical properties and vertical jump performance. *Kinesiology* 50(Suppl.1):102–108.

Haugen TA, Tonnessen E, Seiler S. 2013. Anaerobic performance testing of professional soccer players 1995–2010. *International Journal of Sports Physiology and Performance* 8(2):148–156 DOI 10.1123/ijspp.8.2.148.

Hedges L, Olkin I. 1985. *Statistical methods for meta-analysis*. New York: Academic press.

Heisterberg MF, Fahrenkrug J, Krustrup P, Storskov A, Kjaer M, Andersen JL. 2012. Extensive monitoring through multiple blood samples in professional soccer players. *Journal of Strength and Conditioning Research* 27(5):1260–1271 DOI 10.1519/JSC.0b013e3182653d17.

Helgerud J, Engen LC, Wisloff U, Hoff J. 2001. Aerobic endurance training improves soccer performance. *Medicine and Science in Sports and Exercise* 33(11):1925–1931 DOI 10.1097/00005768-200111000-00019.

Helgerud J, Rodas G, Kemi OJ, Hoff J. 2011. Strength and endurance in elite football players. *International Journal of Sports Medicine* 32(9):677–682 DOI 10.1055/s-0031-1275742.

Hill-Haas SV, Dawson B, Impellizzeri FM, Coutts AJ. 2011. Physiology of small-sided games training in football: a systematic review. *Sports Medicine 41*(3):199–220 DOI 10.2165/11539740-00000000-0000.
Hodgson C, Akenhead R, Thomas K. 2014. Time-motion analysis of acceleration demands of 4v4 small-sided soccer games played on different pitch sizes. Human Movement Science 33:25–32 DOI 10.1016/j.humov.2013.12.002.

Hoff J. 2005. Training and testing physical capacities for elite soccer players. Journal of Sports Sciences 23(6):573–582 DOI 10.1080/02640410400021252.

Hoff J, Helgerud J. 2004. Endurance and strength training for soccer players: physiological considerations. Sports Medicine 34(3):165–180 DOI 10.2165/00007256-200434030-00003.

Hoppe MW, Slomka M, Baumgart C, Weber H, Freiwald J. 2015. Match running performance and success across a season in German Bundesliga soccer teams. International Journal of Sports Medicine 36:563–566 DOI 10.1055/s-00000028.

Iaia FM, Bangsbo J. 2010. Speed endurance training is a powerful stimulus for physiological adaptations and performance improvements of athletes. Scandinavian Journal of Medicine & Science in Sports 20(Suppl 2):11–23 DOI 10.1111/j.1600-0838.2010.01193.x.

Iaia FM, Hellsten Y, Nielsen JJ, Fernstrom M, Sahlin K, Bangsbo J. 2009a. Four weeks of speed endurance training reduces energy expenditure during exercise and maintains muscle oxidative capacity despite a reduction in training volume. Journal of Applied Physiology 106(1):73–80 DOI 10.1152/japplphysiol.90676.2008.

Iaia FM, Rampinini E, Bangsbo J. 2009. High-intensity training in football. International Journal of Sports Physiology and Performance 4(3):291–306 DOI 10.1123/ijspp.4.3.291.

Iaia FM, Rostgaard T, Krustrup P, Bangsbo J. 2009b. Seasonal changes in intermittent exercise performance of soccer players evaluated by the Yo-Yo intermittent recovery test level 2. In: Reilly T, Korkusuz F, eds. Science and Football VI the Proceedings of the Sixth World Congress on Science and Football. London: Routledge, 357–359.

Iga J, Scott M, George K, Drust B. 2014. Seasonal changes in multiple indices of body composition in professional football players. International Journal of Sports Medicine 35:994–998 DOI 10.1055/s-00000028.

Impellizzeri FM, Marcora SM, Castagna C, Reilly T, Sassi A, Iaia FM, Rampinini E. 2006. Physiological and performance effects of generic versus specific aerobic training in soccer players. International Journal of Sports Medicine 27(6):483–492 DOI 10.1055/s-2005-865839.

Impellizzeri FM, Rampinini E, Castagna C, Bishop D, Ferrari Bravo D, Tibaudi A, Wisloff U. 2008. Validity of a repeated-sprint test for football. International Journal of Sports Medicine 29(11):899–905 DOI 10.1055/s-2008-1038491.

Ingebrigtsen J, Bendiksen M, Randers MB, Castagna C, Krustrup P, Holtemann A. 2012. Yo-Yo IR2 testing of elite and sub-elite soccer players: performance, heart rate response and correlations to other interval tests. Journal of Sports Sciences 30(13):1337–1345 DOI 10.1080/02640414.2012.711484.

Ingebrigtsen J, Brochmann M, Castagna C, Bradley P, Ade J, Krustrup P, Holtemann A. 2013a. Relationships between field performance tests in high-level soccer players. Journal of Strength and Conditioning Research 28(4):942–949 DOI 10.1519/JSC.0b013e3182a1f861.

Ingebrigtsen J, Shalfawi SA, Tonnessen E, Krustrup P, Holtemann A. 2013b. Performance effects of 6 weeks of aerobic production training in junior elite soccer players. Journal of Strength and Conditioning Research 27(7):1861–1867 DOI 10.1519/JSC.0b013e31827647bd.

Jensen J, Randers M, Krustrup P, Bangsbo J. 2009. Intermittent high-intensity drills improve in-seasonal performance of elite soccer players. In: Reilly T, Korkusuz F, eds. Science and Football VI the Proceedings of the Sixth World Congress on Science and Football. London: Routledge, 296–301.
Jimenez-Reyes P, Garcia-Ramos A, Parraga-Montilla JA, Morcillo-Losa JA, Cuadrado-Penafiel V, Castano-Zambudio A, Samozino P, Morin JB. 2022. Seasonal changes in the sprint acceleration force-velocity profile of elite male soccer players. *Journal of Strength and Conditioning Research* 36(1):70–74 DOI 10.1519/JSC.000000000003513.

Jones RM, Cook CC, Kilduff LP, Milanovic Z, James N, Sporis G, Fiorentini B, Fiorentini F, Turner A, Vuckovic G. 2013. Relationship between repeated sprint ability and aerobic capacity in professional soccer players. *The Scientific World Journal* 2013(4):952350 DOI 10.1155/2013/952350.

Jorge G, Garrafoli MT, Cal Abad CC. 2020. Seasonal repeated sprint ability with change of direction variations in U17 and U20 elite Brazilian soccer players: a comparative study. *Journal of Strength and Conditioning Research* 34(5):1431–1439 DOI 10.1519/JSC.0b013e3181da85a9.

Kalapotharakos VI, Ziogas G, Tokmakidis SP. 2011. Seasonal aerobic performance variations in elite soccer players. *Journal of Strength and Conditioning Research* 25(6):1502–1507 DOI 10.1519/JSC.0b013e318222f717.

Konefal M, Chmura P, Kowalczyk E, Figueiredo AJ, Sarmento H, Rokita A, Chmura J, Andrzejewski M. 2019a. Modeling of relationships between physical and technical activities and match outcome in elite German soccer players. *The Journal of Sports Medicine and Physical Fitness* 59(5):752–759 DOI 10.23736/S0022-4707.18.08506-7.

Konefal M, Chmura P, Zajac T, Chmura J, Kowalczyk E, Andrzejewski M. 2019b. A new approach to the analysis of pitch-positions in professional soccer. *Journal of Human Kinetics* 66(1):143–153 DOI 10.2478/hukin-2018-0067.

Koundourakis NE, Androulakis N, Spyridaki EC, Castanas E, Malliaraki N, Tsatsanis C, Margioris AN. 2014. Effect of different seasonal strength training protocols on circulating androgen levels and performance parameters in professional soccer players. *Hormones* 13(1):578–583 DOI 10.1007/BF03401326.

Kraemer WJ, French DN, Paxton NJ, Hakkinen K, Volek JS, Sebastianelli WJ, Putukian M, Newton RU, Rubin MR, Gomez AL, Vescovi JD, Ratamess NA, Fleck SJ, Lynch JM, Knuttgen HG. 2004. Changes in exercise performance and hormonal concentrations over a big ten soccer season in starters and nonstarters. *Journal of Strength and Conditioning Research* 18:121–128 DOI 10.1519/1533-4287(2004)018<0121:ciepah>2.0.co;2.

Krstrup P, Mohr M, Amstrup T, Rysgaard T, Johansen J, Steensberg A, Pedersen PK, Bangsbo J. 2003. The yo-yo intermittent recovery test: physiological response, reliability, and validity. *Medicine & Science in Sports & Exercise* 35(4):697–705 DOI 10.1249/01.mss.0000085441.94520.32.

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

Krstrup P, Mohr M, Nybo L, Jensen JM, Nielsen JJ, Bangsbo J. 2006. The Yo-Yo IR2 test: physiological response, reliability, and application to elite soccer. *Medicine & Science in Sports & Exercise* 38(9):1666–1673 DOI 10.1249/01.mss.0000227538.20799.08.

Lago-Penas C, Rey E, Lago-Ballesteros J, Casais L, Dominguez E. 2011. The influence of a congested calendar on physical performance in elite soccer. *Journal of Strength and Conditioning Research* 25(8):2111–2117 DOI 10.1519/JSC.0b013e3181eccdd2.
Lago-Peñas C, Rey E, Lago-Ballesteros J, Domínguez E, Casais L. 2013. Seasonal variations in body composition and fitness parameters according to individual percentage of training completion in professional soccer players. *International SportMed Journal* **14**:205–215 DOI 10.10520/EJC146800.

Lakens D. 2013. Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. *Frontiers in Psychology* **4**:863 DOI 10.3389/fpsyg.2013.00863.

Lees A, Asai T, Andersen TB, Nunome H, Sterzing T. 2010. The biomechanics of kicking in soccer: a review. *Journal of Sports Sciences* **28**(8):805–817 DOI 10.1080/02640414.2010.481305.

Lees A, Nolan L. 1998. The biomechanics of soccer: a review. *Journal of Sports Sciences* **16**:211–234 DOI 10.1080/026404198366740.

Link D, de Lorenzo MF. 2016. Seasonal pacing – match importance affects activity in professional soccer. *PLOS ONE* **11**(6):e0157127 DOI 10.1371/journal.pone.0157127.

Lopez-Segovia M, Palao Andres JM, Gonzalez-Badillo JJ. 2010. Effect of 4 months of training on aerobic power, strength, and acceleration in two under-19 soccer teams. *Journal of Strength and Conditioning Research* **24**(10):2705–2714 DOI 10.1519/JSC.0b013e3181cc237d.

Los Arcos A, Martinez-Santos R, Yan J, Mendiguchia J, Mendez-Villaneuva A. 2015. Negative associations between perceived training load and changes in physical fitness in professional soccer players. *Journal of Sports Science and Medicine* **14**:394–401.

Loturco I, Pereira LA, Kobal R, Zanetti V, Gil S, Kitamura K, Abad CC, Nakamura FY. 2015a. Half-squat or jump squat training under optimum power load conditions to counteract power and speed decrements in Brazilian elite soccer players during the preseason. *Journal of Sports Sciences* **33**(12):1–10 DOI 10.1080/02640414.2015.1022574.

Loturco I, Pereira LA, Kobal R, Zanetti V, Kitamura K, Abad CC, Nakamura FY. 2015b. Transference effect of vertical and horizontal plyometrics on sprint performance of high-level U-20 soccer players. *Journal of Sports Sciences* **33**(20):2182–2191 DOI 10.1080/02640414.2015.1081394.

Loturco I, Ugrinowitsch C, Tricoli V, Pivetti B, Roschel H. 2012. Different loading schemes in power training during the pre-season promote similar performance improvements in Brazilian elite soccer players. *Journal of Strength and Conditioning Research* **27**(7):1791–1797 DOI 10.1519/JSC.0b013e3182772da6.

Magal M, Smith RT, Dyer JJ, Hoffman JR. 2009. Seasonal variation in physical performance—related variables in male NCAA Division III soccer players. *Journal of Strength and Conditioning Research* **23**(9):2555–2559 DOI 10.1519/JSC.0b013e3181b3ddb.

Malliou P, Ispiridis I, Beneka A, Taxildaris K, Godolias G. 2003. Vertical jump and knee extensors isokinetic performance in professional soccer players related to the phase of the training period. *Isokinetics and Exercise Science* **11**(3):165–169 DOI 10.3233/IES-2003-0144.

Malone S, Hughes B, Doran D, Collins A, Gabbett T. 2019. Can the workload-injury relationship be moderated by improved strength, speed and repeated-sprint qualities? *Journal of Science and Medicine in Sport* **22**(1):29–34 DOI 10.1016/j.jsams.2018.01.010.

Malone S, Owen A, Mendes B, Hughes B, Collins K, Gabbett TJ. 2018. High-speed running and sprinting as an injury risk factor in soccer: can well-developed physical qualities reduce the risk? *Journal of Science and Medicine in Sport* **21**(3):257–262 DOI 10.1016/j.jsams.2017.05.016.

Malone S, Owen A, Newton M, Mendes B, Collins KD, Gabbett TJ. 2016. The acute: chronic workload ratio in relation to injury risk in professional soccer. *Journal of Science and Medicine in Sport* **20**(6):561–565 DOI 10.1016/j.jsams.2016.10.014.

Manzi V, Bovenzi A, Franco Impellizzeri M, Carminati I, Castagna C. 2013. Individual training-load and aerobic-fitness variables in premiership soccer players during the

---

Silva (2022), *PeerJ*, DOI 10.7717/peerj.14082

---

52/60
precompetitive season. *Journal of Strength and Conditioning Research* 27(3):631–636 DOI 10.1519/JSC.0b013e31825dbd81.

**Marcora SM, Staiano W. 2010.** The limit to exercise tolerance in humans: mind over muscle? *European Journal of Applied Physiology* 109(4):763–770 DOI 10.1007/s00421-010-1418-6.

**Marcos MA, Koula PM, Anthos ZI. 2018.** Preseason maximal aerobic power in professional soccer players among different divisions. *Journal of Strength and Conditioning Research* 32(2):356–363 DOI 10.1519/JSC.0000000000001810.

**Martin M, Rampinini E, Bosio A, Azzalin A, McCall A, Ward P. 2022.** Relationships between internal and external load measures and fitness level changes in professional soccer players. *Research Quarterly for Exercise and Sport* 14(2):1–13 DOI 10.1080/02701367.2022.2053646.

**Martinez-Hernandez D, Quinn M, Jones P. 2022.** Linear advancing actions followed by deceleration and turn are the most common movements preceding goals in male professional soccer. *Science and Medicine in Football* 6(1):1–9 DOI 10.1080/24733938.2022.2030064.

**Massard T, Eggers T, Lovell R. 2017.** Peak speed determination in football: is sprint testing necessary? *Science and Medicine in Football* 2:1–4 DOI 10.1080/24733938.2017.1398409.

**McGawley K, Andersson PI. 2013.** The order of concurrent training does not affect soccer-related performance adaptations. *International Journal of Sports Medicine* 34:983–990 DOI 10.1055/s-00000028.

**McKay AKA, Stellingwerff T, Smith ES, Martin DT, Mujico A, Goosey-Tolfrey VL, Sheppard J, Burke LM. 2022.** Defining training and performance caliber: a participant classification framework. *International Journal of Sports Physiology and Performance* 17(2):317–331 DOI 10.1123/ijspp.2021-0451.

**McMillan K, Helgerud J, Macdonald R, Hoff J. 2005.** Physiological adaptations to soccer specific endurance training in professional youth soccer players. *British Journal of Sports Medicine* 39(5):273–277 DOI 10.1136/bjsm.2004.012526.

**Meckel Y, Doron O, Eliakim E, Eliakim A. 2018.** Seasonal variations in physical fitness and performance indices of elite soccer players. *Sports* 6(1):14 DOI 10.3390/sports6010014.

**Mendez-Villanueva A, Buchheit M, Simpson B, Peltola E, Bourdon P. 2011.** Does on-field sprinting performance in young soccer players depend on how fast they can run or how fast they do run? *Journal of Strength and Conditioning Research* 25(9):2634–2638 DOI 10.1519/JSC.0b013e318201c281.

**Metaxas TI, Koutloumanos N, Sendelides T, Mandroukas A. 2009.** Preseason physiological profile of soccer and basketball players in different divisions. *Journal of Strength and Conditioning Research* 23(6):1704–1713 DOI 10.1519/JSC.0b013e3181b3e0c5.

**Metaxas T, Sendelides T, Koutloumanos N, Mandroukas K. 2006.** Seasonal variation of aerobic performance in soccer players according to positional role. *The Journal of Sports Medicine and Physical Fitness* 46:520–525.

**Meyer T, Meister S. 2011.** Routine blood parameters in elite soccer players. *International Journal of Sports Medicine* 32(11):875–881 DOI 10.1055/s-0031-1280776.

**Michalczyk M, Barbara Klapcinska B, Sadowska-Krep E, Jagsz S, Pilis W, Szoltysek-Boldys I, Jan Chmura J, Kimsa E, Kempa K. 2008.** Evaluation of the blood antioxidant capacity in two selected phases of the training cycle in professional soccer players. *Journal of Human Kinetics* 19(2008):93–108 DOI 10.2478/v10078-008-0007-9.

**Milanese C, Cavedon V, Corradini G, De Vita F, Zancanaro C. 2015.** Seasonal DXA-measured body composition changes in professional male soccer players. *Journal of Sports Sciences* 33(12):1219–1228 DOI 10.1080/02640414.2015.1022573.
Mills C, De Ste Croix M, Cooper S. 2017. The importance of measuring body composition in professional football players: a commentary. *Sports and Exercise Medicine – Open Journal* 3(1):24–29 DOI 10.17140/SEMOJ-3-144.

Mohr M, Krustup P, Bangsbo J. 2002. Physiological characteristics and exhaustive exercise performance of elite soccer players during a season. *Medicine & Science in Sports & Exercise* 34(5):S24 DOI 10.1097/00005768-200205001-00132.

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

Mohr M, Nybo L, Grantham J, Racinais S. 2012. Physiological responses and physical performance during football in the heat. *PLOS ONE* 7:e39202 DOI 10.1371/journal.pone.0039202.

Mohr M, Krustrup P, Bangsbo J. 2005. Fatigue in soccer: a brief review. *Journal of Sports Sciences* 23(6):593–599 DOI 10.1080/02640410400021286.

Mohr M, Nassis GP, Brito J, Randers MB, Castagna C, Parnell D, Krustup P. 2022. Return to elite football after the COVID-19 lockdown. *Managing Sport and Leisure* 27(1–2):172–180 DOI 10.1080/23750472.2020.1768635.

Morgans R, Adams D, Mullen R, Williams M. 2014. Changes in physical performance variables in an English Championship League team across the competitive season: the effect of possession. *International Journal of Performance Analysis in Sport* 14:493–503 DOI 10.1123/ijspp.2016-0412.

Morin JB. 2019. Strength for jump and sprint performance in football: what the Force !? In: *PSG Performance Summit 2018*.

Morin JB, Samozino P. 2016. Interpreting power-force-velocity profiles for individualized and specific training. *International Journal of Sports Physiology and Performance* 11:267–272 DOI 10.1123/ijspp.2015-0638.

Mugglestone C, Morris JG, Saunders B, Sunderland C. 2012. Half-time and high-speed running in the second half of soccer. *International Journal of Sports Medicine* 34(6):514–519 DOI 10.1055/s-00000028.

Nassis GP. 2013. Effect of altitude on football performance: analysis of the 2010 FIFA World Cup Data. *Journal of Strength and Conditioning Research* 27(3):703–707 DOI 10.1519/JSC.0b013e31825d999d.

Nedelec M, McCall A, Carling C, Legall F, Berthoin S, Dupont G. 2012. Recovery in soccer: part I – post-match fatigue and time course of recovery. *Sports Medicine* 42:997–1015 DOI 10.2165/11635270-000000000-00000.

Nedelec M, McCall A, Carling C, Legall F, Berthoin S, Dupont G. 2013. Recovery in soccer: part iI-recovery strategies. *Sports Medicine* 43(1):9–22 DOI 10.1007/s40279-012-0002-0.
Oliva-Lozano JM, Muyor JM, Fortes V, McLaren SJ. 2021a. Decomposing the variability of match physical performance in professional soccer: implications for monitoring individuals. *European Journal of Sport Science* 21(11):1588–1596 DOI 10.1080/17461391.2020.1842513.

Oliva-Lozano JM, Rojas-Valverde D, Gomez-Carmona CD, Fortes V, Pino-Ortega J. 2021b. Impact of contextual variables on the representative external load profile of Spanish professional soccer match-play: a full season study. *European Journal of Sport Science* 21(4):497–506 DOI 10.1080/17461391.2020.1751305.

Osgnach C, Poser S, Bernardini R, Rinaldo R, di Prampero PE. 2010. Energy cost and metabolic power in elite soccer: a new match analysis approach. *Medicine & Science in Sports & Exercise* 42(1):170–178 DOI 10.1249/MSS.0b013e3181ae5cfd.

Ostojic S. 2003. Seasonal alterations in body composition and sprint performance of elite soccer players. *Journal of Exercise Physiology Online* 6:24–27.

Ostojic S, Stojanovic M, Jukic I, Pasalic E, Jourkesh M. 2009. The effects of six weeks of training on physical fitness and performance in teenage and mature top-level soccer players. *Biology of Sport* 26(4):379–387 DOI 10.5604/20831862.901141.

Owen AL, del Wong P, Paul D, Dellal A. 2012. Effects of a periodized small-sided game training intervention on physical performance in elite professional soccer. *Journal of Strength and Conditioning Research* 26(10):2748–2754 DOI 10.1519/JSC.0b013e318242d2d1.

Owen AL, Lago-Penas C, Dunlop G, Mehdi R, Chtara M, Dellal A. 2018. Seasonal body composition variation amongst elite European professional soccer players: an approach of talent identification. *Journal of Human Kinetics* 62(1):177–184 DOI 10.1515/hukin-2017-0132.

Owen AL, Lago-Penas C, Dunlop G, Mehdi R, Chtara M, Dellal A. 2018. Seasonal body composition variation amongst elite European professional soccer players: an approach of talent identification. *Journal of Human Kinetics* 62(1):177–184 DOI 10.1515/hukin-2017-0132.

Padron-Cabo A, Rey E, Vidal B, Garcia-Nunez J. 2018. Work-rate analysis of substitute players in professional soccer: analysis of seasonal variations. *Journal of Human Kinetics* 65(1):165–174 DOI 10.2478/hukin-2018-0025.

Papadakis L, Patras K, Georgouli A. 2015. In-season concurrent aerobic endurance and CMJ improvements are feasible for both starters and non-starters in professional soccer players. *Journal of Australian Strength and Conditioning* 23:19–30.

Paul DJ, Bradley PS, Nassis GP. 2015. Factors affecting match running performance of elite soccer players: shedding some light on the complexity. *International Journal of Sports Physiology and Performance* 10(4):516–519 DOI 10.1123/ijsspp.2015-0029.

Pessiglione M, Schmidt L, Draganski B, Kalisch R, Lau H, Dolan RJ, Frith CD. 2007. How the brain translates money into force: a neuroimaging study of subliminal motivation. *Science* 316(5826):904–906 DOI 10.1126/science.1140459.

Pons E, Ponce-Bordon JC, Diaz-Garcia J, Lopez Del Campo R, Resta R, Peirau X, Garcia-Calvo T. 2021. A Longitudinal exploration of match running performance during a football match in the Spanish La Liga: a four-season study. *International Journal of Environmental Research and Public Health* 18(3):1133 DOI 10.3390/ijerph18031133.

Power K, Dunbar G, Treasure D. 2005. Differences in Fitness and Psychological markers as a function of playing level and position in two English premier league football clubs. In: Reilly T, Araújo D, Cabri J, eds. *Science and Football* V. London/New York: E and FN Spon, 129–133.

Rago V, Krustrup P, Martin-Acero R, Rebelo A, Mohr M. 2020. Training load and submaximal heart rate testing throughout a competitive period in a top-level male football team. *Journal of Sports Sciences* 38(11–12):1408–1415 DOI 10.1080/02640414.2019.1618534.
Rago V, Silva JR, Mohr M, Barreira D, Krstrup P, Rebelo AN. 2017. The inter-individual relationship between training status and activity pattern during small-sided and full-sized games in professional male football players. *Science and Medicine in Football* 2(2):1–8 DOI 10.1080/24733938.2017.1414953.

Rago V, Silva JR, Mohr M, Barreira D, Krstrup P, Rebelo AN. 2018. Variability of activity profile during medium-sized games in professional soccer. *The Journal of Sports Medicine and Physical Fitness* 59(4):547–554 DOI 10.23736/S0022-4707.18.08376-7.

Rampinini E, Bishop D, Marcorsa SM, Ferrari Bravo D, Sassi R, Impellizzeri FM. 2007a. Validity of simple field tests as indicators of match-related physical performance in top-level professional soccer players. *International Journal of Sports Medicine* 28(3):228–235 DOI 10.1055/s-2006-924340.

Rampinini E, Coutts AJ, Castagna C, Sassi A, Impellizzeri F. 2007b. Variation in top level soccer match performance. *International Journal of Sports Medicine* 28(12):1018–1024 DOI 10.1055/s-2007-965158.

Rampinini E, Sassi A, Morelli A, Mazzoni S, Fanchini M, Coutts AJ. 2009b. Repeated-sprint ability in professional and amateur soccer players. *Applied Physiology, Nutrition, and Metabolism* 34(6):1048–1054 DOI 10.1139/H09-111.

Randers MB, Mujika I, Hewitt A, Santisteban J, Bischoff R, Solano R, Zubillaga A, Peltola E, Krstrup P, Mohr M. 2010. Application of four different football match analysis systems: a comparative study. *Journal of Sports Sciences* 28(2):171–182 DOI 10.1080/02640410903428525.

Randers MB, Rostgaard T, Krstrup P. 2007. Physical match performance and Yo-Yo IR2 test results of successful and unsuccessful teams in the Danish Premier League. *Journal of Sports Science and Medicine* 6(Suppl. 10):70–71.

Reilly T, Drust B, Clarke N. 2008. Muscle fatigue during football match-play. *Sports Medicine* 38(5):357–367 DOI 10.2165/00007256-200838050-00001.

Reilly T, Ekblom B. 2005. The use of recovery methods post-exercise. *Journal of Sports Sciences* 23(6):619–627 DOI 10.1080/02640410400021302.

Reilly T, Williams AM, Nevill A, Franks A. 2000. A multidisciplinary approach to talent identification in soccer. *Journal of Sports Sciences* 18(9):695–702 DOI 10.1080/02640410050120078.

Reinke S, Karhausen T, Doehner W, Taylor W, Hottenrott K, Duda GN, Reinke P, Volk HD, Anker SD. 2009. The influence of recovery and training phases on body composition, peripheral vascular function and immune system of professional soccer players. *PLOS ONE* 4(3):e4910 DOI 10.1371/journal.pone.0004910.

Requena B, Garcia I, Suarez-Arrones L, Saez de Villarreal E, Naranjo Orellana J, Santalla A. 2017. Off-season effects on functional performance, body composition, and blood parameters in top-level professional soccer players. *Journal of Strength and Conditioning Research* 31(4):939–946 DOI 10.1519/JSC.0000000000001568.

Rey E, Lorenzo-Martinez M, Lopez-Del Campo R, Resta R, Lago-Penas C. 2022. No sport for old players. A longitudinal study of aging effects on match performance in elite soccer. *Journal of Science and Medicine in Sport* 25(6):535–539 DOI 10.1016/j.jsams.2022.03.004.

Ronnestad BR, Kvamme NH, Sunde A, Raastad T. 2008. Short-term effects of strength and plyometric training on sprint and jump performance in professional soccer players. *Journal of Strength and Conditioning Research* 22(3):773–780 DOI 10.1519/JSC.0b013e31816a5e86.
Ronnement BR, Nymark BS, Raastad T. 2011. Effects of in-season strength maintenance training frequency in professional soccer players. Journal of Strength and Conditioning Research 25:2653–2660 DOI 10.1519/JSC.0b013e31822dcd96.

Rowell AE, Aughey RJ, Clubb J, Cormack SJ. 2018a. A standardized small sided game can be used to monitor neuromuscular fatigue in professional a-league football players. Frontiers in Physiology 9:1011 DOI 10.3389/fphys.2018.01011.

Rowell AE, Aughey RJ, Hopkins WG, Esmaeili A, Lazarus BH, Cormack SJ. 2018b. Effects of training and competition load on neuromuscular recovery, testosterone, cortisol, and match performance during a season of professional football. Frontiers in Physiology 9:668 DOI 10.3389/fphys.2018.00668.

Saeterbakken A, Haug V, Fransson D, Grendstad HN, Gundersen HS, Moe VF, Ylvisaker E, Shaw M, Riiser A, Andersen V. 2019. Match running performance on three different competitive standards in Norwegian soccer. Sports Medicine International Open 3(03):E82–E88 DOI 10.1055/a-0943-3682.

Schmitz B, Pfeifer C, Kreitz K, Borowski M, Faldum A, Brand SM. 2018. The Yo-Yo intermittent tests: a systematic review and structured compendium of test results. Frontiers in Physiology 9:870 DOI 10.3389/fphys.2018.00870.

Shephard RJ. 1999. Biology and medicine of soccer: an update. Journal of Sports Sciences 17(10):757–786 DOI 10.1080/026404199365498.

Silva JR. 2019. Concurrent aerobic and strength training for performance in soccer. In: Schumann M, Ronnestad BR, eds. Concurrent Aerobic and Strength Training: Scientific Basics and Practical Applications. Berlin: Springer, 397–416.

Silva JR, Ascensao A, Marques F, Seabra A, Rebelo A, Magalhaes J. 2013a. Neuromuscular function, hormonal and redox status and muscle damage of professional soccer players after a high-level competitive match. European Journal of Applied Physiology 113(9):2193–2201 DOI 10.1007/s00421-013-2633-8.

Silva JR, Brito J, Akenhead R, Nassis GP. 2016. The transition period in soccer: a window of opportunity. Sports Medicine 46(3):305–313 DOI 10.1007/s40279-015-0419-3.

Silva JR, Magalhaes JF, Ascensao AA, Oliveire EM, Seabra AF, Rebelo AN. 2011. Individual match playing time during the season affects fitness-related parameters of male professional soccer players. Journal of Strength and Conditioning Research 25(10):2729–2739 DOI 10.1519/JSC.0b013e31820da078.

Silva JR, Magalhaes J, Ascensao A, Seabra AF, Rebelo AN. 2013b. Training status and match activity of professional soccer players throughout a season. Journal of Strength and Conditioning Research 27(1):20–30 DOI 10.1519/JSC.0b013e31824e1946.

Silva JR, Nassis GP, Rebelo A. 2015. Strength training in soccer with a specific focus on highly trained players. Sports Medicine – Open 2(1):1–27 DOI 10.1186/s40798-015-0006-z.

Silva JR, Rebelo A. 2019. Fatigue monitoring. In: Casa D, Curtis R, Huggins R, eds. Elite Soccer Players: Maximizing Performance and Safety. London: Routledge.

Silva JR, Rebelo A, Marques F, Pereira L, Seabra A, Ascensao A, Magalhaes J. 2014. Biochemical impact of soccer: an analysis of hormonal, muscle damage, and redox markers during the season. Applied Physiology, Nutrition, and Metabolism 39(4):432–438 DOI 10.1139/apnm-2013-0180.

Silva JR, Rumpf MC, Hertzog M, Castagna C, Farooq A, Girard O, Hader K. 2018. Acute and residual soccer match-related fatigue: a systematic review and meta-analysis. Sports Medicine 48(3):539–583 DOI 10.1007/s40279-017-0798-8.

Silvestre R, Kraemer WJ, West C, Judelson DA, Spiering BA, Vingren JL, Hatfield DL, Anderson JM, Maresh CM. 2006. Body composition and physical performance during a...
National Collegiate Athletic Association Division I men’s soccer season. *Journal of Strength and Conditioning Research* **20**(1):962–970 DOI 10.1519/00124278-200602000-00029.

Slimani M, Znazen H, Miarka B, Bragazzi NL. 2019. Maximum oxygen uptake of male soccer players according to their competitive level, playing position and age group: implication from a network meta-analysis. *Journal of Human Kinetics* **66**(1):233–245 DOI 10.2478/hukin-2018-0060.

Smith MR, Thompson C, Marcors SM, Skorski S, Meyer T, Coutts AJ. 2018. Mental fatigue and soccer: current knowledge and future directions. *Sports Medicine* **48**(7):1525–1532 DOI 10.1007/s40279-018-0908-2.

Spencer M, Bishop D, Dawson B, Goodman C. 2005. Physiological and metabolic responses of repeated-sprint activities: specific to field-based team sports. *Sports Medicine* **35**(12):1025–1044 DOI 10.2165/00007256-200535120-00003.

Sporis G, Jovanovic M, Omrcen D, Matkovic B. 2011. Can the official soccer game be considered the most important contribution to player’s physical fitness level? *The Journal of Sports Medicine and Physical Fitness* **51**:374–380.

Sporis G, Ruzic L, Leko G. 2008a. The anaerobic endurance of elite soccer players improved after a high-intensity training intervention in the 8-week conditioning program. *Journal of Strength and Conditioning Research* **22**(2):559–566 DOI 10.1519/JSC.0b013e3181660401.

Sporis G, Ruzic L, Leko G. 2008b. Effects of a new experimental training program on V.O2max and running performance. *The Journal of Sports Medicine and Physical Fitness* **48**:158–165.

Stanković M, Gušić M, Nikolić S, Barišić V, Krakan I, Sporiš G, Mikulić I, Trajković N. 2021. 30–15 intermittent fitness test: a systematic review of studies, examining the VO2max estimation and training programming. *Applied Sciences* **11**:11792 DOI 10.3390/app112411792.

Stolen T, Chamari K, Castagna C, Wisloff U. 2005. Physiology of soccer: an update. *Sports Medicine* **35**:501–536 DOI 10.2165/00007256-200535060-00004.

Suarez-Arrones L, Saez de Villarreal E, Nuñez FJ, Di Salvo V, Petri C, Buccolini A, Maldonado RA, Torreno N, Mendez-Villanueva A. 2018. In-season eccentric-overload training in elite soccer players: effects on body composition, strength and sprint performance. *PLOS ONE* **13**(10):e0205332 DOI 10.1371/journal.pone.0205332.

Suda Y, Umeda T, Watanabe K, Kuroiwa J, Sasaki E, Tsukamoto T, Takahashi I, Matsuzaka M, Iwane K, Nakaji S. 2012. Changes in neutrophil functions during a 10-month soccer season and their effects on the physical condition of professional Japanese soccer players. *Luminescence* **28**(2):121–128 DOI 10.1002/bio.2350.

Svensson M, Drust B. 2005. Testing soccer players. *Journal of Sports Sciences* **23**:601–618 DOI 10.1080/02640410400021294.

Tesch PA, Fernandez-Gonzalo R, Lundberg TR. 2017. Clinical applications of iso-inertial, eccentric-overload (YoYo™) resistance exercise. *Frontiers in Physiology* **8**:241 DOI 10.3389/fphys.2017.00241.

Thomas K, French D, Hayes PR. 2009. The effect of two plyometric training techniques on muscular power and agility in youth soccer players. *Journal of Strength and Conditioning Research* **23**(1):332–335 DOI 10.1519/JSC.0b013e318183a01a.

Tofari P, Kemp J, Cormack S. 2017. A self-paced team sport match simulation results in reductions in voluntary activation and modifications to biological, perceptual and performance measures at half-time, and for up to 96 hours post-match. *The Journal of Strength and Conditioning Research* **32**(12):3552–3563 DOI 10.1519/jsc.0000000000001875.

Tofari PJ, Kemp JG, Cormack SJ. 2020. Measuring the response to simulated fixture congestion in soccer. *Science and Medicine in Football* **4**(4):1–12 DOI 10.1080/24733938.2020.1746824.
Tonnessen E, Hem E, Leirstein S, Haugen T, Seiler S. 2013. Maximal aerobic power characteristics of male professional soccer players, 1989–2012. International Journal of Sports Physiology and Performance 8(3):323–329 DOI 10.1123/ijspp.8.3.323.

Tous-Fajardo J, Gonzalo-Skok O, Arjol-Serrano JL, Tesch P. 2016. Enhancing change-of-direction speed in soccer players by functional inertial eccentric overload and vibration training. International Journal of Sports Physiology and Performance 11(1):66–73 DOI 10.1123/ijspp.2015-0010.

Varley MC, Aughey RJ. 2013. Acceleration profiles in elite Australian soccer. International Journal of Sports Medicine 34:34–39 DOI 10.1055/s-0000028.

Vigne G, Gaudino C, Dellal A, Chamari K, Rogowski I, Alloatti G, Wong DP, Owen A, Hautier C. 2012. Physical outcome in a successful Italian Serie-A soccer Team over 3 consecutive seasons. Journal of Strength and Conditioning Research 27(5):1400–1406 DOI 10.1519/JSC.0b013e3182679382.

Vincenzo M, Franco I, Carlo C. 2013. Aerobic fitness ecological validity in elite soccer players: a metabolic-power approach. The Journal of Strength and Conditioning Research 28(4):914–919 DOI 10.1519/JSC.0000000000000239.

Wahl P, Guldner M, Mester J. 2014. Effects and sustainability of a 13-day high-intensity shock microcycle in soccer. Journal of Sports Science & Medicine 13:259–265.

Walden M, Krosshaug T, Bjorneboe J, Andersen TE, Faul O, Hagglund M. 2015. Three distinct mechanisms predominate in non-contact anterior cruciate ligament injuries in male professional football players: a systematic video analysis of 39 cases. British Journal of Sports Medicine 49(22):1452–1460 DOI 10.1136/bjsports-2014-094573.

Wells CM, Edwards AM, Winter EM, Fysh ML, Drust B. 2012. Sport-specific fitness testing differentiates professional from amateur soccer players where VO2max and VO2 kinetics do not. The Journal of Sports Medicine and Physical Fitness 52:245–254.

Windt J, Ekstrand J, Khan KM, McCall A, Zumbo BD. 2018. Does player unavailability affect football teams’ match physical outputs? A two-season study of the UEFA champions league. Journal of Science and Medicine in Sport 21(5):525–532 DOI 10.1016/j.jsams.2017.08.007.

Winter EM, Abt G, Brookes FB, Challis JH, Fowler NE, Knudson DV, Knuttgen HG, Kraemer WJ, Lane AM, van Mechelen W, Morton RU, Newton RU, Williams C, Yeadon MR. 2016. Misuse of “Power” and other mechanical terms in sport and exercise science research. The Journal of Strength and Conditioning Research 30:292–300 DOI 10.1519/JSC.0000000000001101.

Wong PL, Chaouachi A, Chamari K, Dellal A, Wisloff U. 2010. Effect of preseason concurrent muscular strength and high-intensity interval training in professional soccer players. Journal of Strength and Conditioning Research 24(3):653–660 DOI 10.1519/JSC.0b013e3181aa36a2.

Zart S, Gullich A. 2022. In-season head-coach changes have positive short- and long-term effects on team performance in men’s soccer—evidence from the Premier League, Bundesliga, and La Liga. Journal of Sports Sciences 40(6):696–703 DOI 10.1080/02640414.2021.2014688.

Ziogas GG, Patras KN, Stergiou N, Georgoulis AD. 2011. Velocity at lactate threshold and running economy must also be considered along with maximal oxygen uptake when testing elite soccer players during preseason. Journal of Strength and Conditioning Research 25(2):414–419 DOI 10.1519/JSC.0b013e3181bac3b9.
Zoppi CC, Hohl R, Silva FC, Lazarim FL, Neto JM, Stancanneli M, Macedo DV. 2006. Vitamin C and E supplementation effects in professional soccer players under regular training. *Journal of the International Society of Sports Nutrition* 3(2):37–44 DOI 10.1186/1550-2783-3-2-37.

Zouita S, Zouita AB, Kebsi W, Dupont G, Ben Abderrahman A, Ben Salah FZ, Zouhal H. 2016. Strength training reduces injury rate in elite young soccer players during one season. *Journal of Strength and Conditioning Research* 30(5):1295–1307 DOI 10.1519/JSC.0000000000000920.