The soccer season: performance variations and evolutionary trends

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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 will explore aspects relevant for training monitoring and we will 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_{Based}) and in the sprint acceleration (ACC_{Phase}) and maximal velocity phase (MV_{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; $V_{2-4mmol/l}$) and large magnitude in VO_{2max}, maximal aerobic speed (MAS) and intense intermittent exercise performance (IE). In the middle of competition phase (MCP), they are observed small (CMJ_{Based} and ACC_{Phase}), moderate (non-CMJ; MV_{Phase}; VO_{2max}; sub-maximal exercise) and large (MAS and IE) improvements compared to PPS. In the ECP, CMJ_{Based} and MV_{Phase} improve to a small extent with non-CMJ, and $ACC_{Phase,}$ VO_{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_{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 monitorization throughout the season.

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77 **Abstract**

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80 biological systems and fitness requirements of the players. In this review we examined variations

81 and evolutionary trends in body composition, neuromuscular and endurance-related parameters as

82 well as in game-related physical parameters of professional players. Further, we will explore

83 aspects relevant for training monitoring and we will reference how different training stimulus and

84 situational variables (e.g, competition exposure) affect the physiological and performance

85 parameters of players.

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87 jumps (CMJ$_{Based}$) and in the sprint acceleration (ACC$_{Phase}$) and maximal velocity phase (MV$_{Phase}$)

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94 maximal exercise) and large (MAS and IE) improvements compared to PPS. In the ECP,

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98   and endurance-related parameters between in-season assessments; only substantial alterations are

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100   magnitude, respectively) from BCP to MCP and in VO_{2max} and IE (decrements of small

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102   variability between studies is clear for TD, VHSR and sprint, all the studies observed substantial

103   increments in HSR between MCP and ECP. Finally, studies examining evolutionary trends by

104   means of exercise and competition performance measures suggests of a heightened importance of

105   neuromuscular factors. In conclusion, during the preseason players "recover" body composition

106   profile and neuromuscular and endurance competitive capacity. Within in-season, and more

107   robustly towards ECP, alterations in neuromuscular performance seem to be force-velocity

108   dependent, and in some cases, physiological determinants and endurance performance may be

109   compromised when considering other in-season moments**. Importantly, there is a substantial

110   variability in team responses that can be observed during in-season. Consequently, this informs on

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112   season.

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1. 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 are 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 et al. 2006; Kraemer et al. 2004; Reilly et al. 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

143 remain compatible with a high standard of performance (Shephard 1999). Nevertheless, a positive

144 body composition (e.g, low adiposity) and proficient neuromuscular (e.g, strength and power) and

145 endurance-related (e.g, high-intensity intermittent exercise) qualities provide a competitive

146 advantage, as they are associated with improved fatigue resistance during the game (Bangsbo et

147 al. 2008; Silva et al. 2018) faster post-match recovery (Hader et al. 2019; Owen et al. 2015; Tofari

148 et al. 2017) and injury prevention (Al Attar et al. 2017; Malone et al. 2019; Malone et al. 2016;

149 Zouita et al. 2016). As so, players perform intense training programs to potentiate these fitness

150 determinants to cope with the acute and chronic demands of a high-level soccer season cycle

151 (Brocherie et al. 2014; Chmura et al. 2019; Eliakim et al. 2018; Malone et al. 2018; Silva et al.

152 2014). Therefore, to prevent performance decline and to ensure that training programs are

153 effective, elite clubs should have as a required organizational practice the implementation of a

154 training monitoring system (e.g, performance tests, records of daily exercise intensity) and

155 effective strategies to aid in player recovery (Silva & Rebelo 2019).

156

157 **Rationale for the review**

158 Player's physical performance is one of the relevant performance domains and so, understanding

159 the dynamic nature of adaptations throughout the season is of relevance for the population of

160 soccer players. However, despite that there are important reviews concerning physiological

161 characteristics of soccer players (Shephard 1999; Stolen et al. 2005; Svensson & Drust 2005),

162 soccer biomechanics (Lees et al. 2010; Lees & Nolan 1998), determinants of players' performance

163 (Bangsbo et al. 2007; Bangsbo et al. 2006; Reilly et al. 2008), specific training-induced effects

164 (Hill-Haas et al. 2011; Hoff 2005; Hoff & Helgerud 2004; Iaia et al. 2009b; Silva et al. 2015), and

165 development of soccer fatigue and kinetics of recovery (Hader et al. 2019; Mohr et al. 2005;

166 Nedelec et al. 2012; Nedelec et al. 2013; Reilly et al. 2008; Reilly & Ekblom 2005; Silva et al.

167 2018), an understanding of seasonal adaptations and evolutionary trends on players' physical

168 fitness is still required.

169

170 **Intended audience and organization**

171 Understanding the different variables that affect the dynamic nature of adaptations during the

172 season may allow coaches, medical departments, and researchers to improve training periodization

173 and monitoring. We target this review for students (e.g., exercise physiology and strength and

174 conditioning), researchers, and all practitioners (coaches and medical department related staff) to

175 whom the knowledge about the physiological and functional characteristics of the players is a

176 matter of undeniable interest and understanding the different variables that affect the dynamic

177 nature of adaptations occurring within the training season may allow informed decisions on

178 training periodization and monitoring.

179 In this review we examined adaptations in body composition (body mass, body fat and lean body

180 mass) and different neuromuscular qualities of professional soccer players (force production,

181 jump, sprint and change of direction abilities). Subsequently, we analyzed seasonal alterations in

182 endurance-related physiological and performance parameters as well as in competition measures

183 of professional soccer players. Moreover, we will reference how different training stimulus and

184 situational variables (e.g., competition exposure) affect the physiological and performance

185 parameters of highly trained players. Further, we will explore aspects relevant for training

186 monitoring of professional players.

187

188 **2. Survey Methodology**
189 **2.1 Literature search strategy**

190
191 For the search for relevant scientific literature, a review was performed using the PubMed and

192 SportDiscus databases multiple times until June 2022. Additionally, Google Scholar and

193 bibliographic searches of relevant articles were also completed. The description of seasonal trends

194 comprises papers from January 2000 to April 2022 (table I and II). The search strategy included

195 the following search terms and Boolean operators using the term "soccer" AND "seasonal

196 alterations", OR "performance analysis", OR "competition", OR "physiology", OR "body

197 composition", OR "strength training", OR "neuromuscular performance", OR "fatigue", OR

198 "field tests", OR "intermittent endurance", OR "muscular power", OR "jump ability", OR "sprint

199 ability", OR "agility", OR "change of direction", OR "training period", OR "detraining", OR "off

200 season", OR "in season", OR "preseason" OR "competition period".

201 **2.2 Analysis and interpretation of the results**
202

203 Studies were included if they: i) investigated adults (>19 yrs) soccer players described has

204 professional or elite player ii) measured at least two season time points; specifically, the

205 preparation period (PPS), beginning of the competitive period (BCP), middle (MCP) or end of

206 competition period (ECP).

207   The mean and standard deviation for each measurement was extracted. In the case the necessary

208 statistics were represented in figures and graphs their value was extrapolated using a specific

209 software for the purpose (*webPlotDigitizer;* https://automeris.io/WebPlotDigitizer/). To evaluate

210 the magnitude of the effects, percent change was calculated for each dependent variable for each

211 study using the procedures defined elsewhere (Silva et al. 2018). Using the procedures defined in

212 Schmitz et al, (2018) we compute a global mean (by time-point and variation between moments)

213 based on the reported means of the individual studie for each outcome. We apply this procedure

214   assuming that the players from each research within the same group belong to the same population

215   and that their test results were extract from the same normal distribution (Schmitz et al. 2018).

216   Each global mean was computed as weighted mean of the individual reported mean, with weights

217   built by the number of subjects per investigation (Schmitz et al. 2018). Effect size (ES) were

218   computed to present standardized values on the outcome variables (Cohen 1998). The different ES

219   within individual studies were calculated with Cohen's d, by dividing the raw ES (difference in

220   means) by the pooled standard deviations, as proposed (Cohen 1998). To account for possible

221   overestimation of the true population ESs were corrected accounting for the magnitude of the

222   sample size of each study (Lakens 2013). Therefore, a correction factor was calculated as proposed

223   by Hedges and Olkin (1985). Threshold values for g were defined as trivial (<0.2), small (0.2-0.6),

224   moderate (0.6-1.2), large (1.2-2.0) and very large (>2.0) (Cohen 1998).

225   **3. Anthropometric and neuromuscular adaptations: why the relevance?**
226
227   Players body composition analysis is becoming increasingly widespread in professional football

228   and is considered important for help players reach optimal performance potential (Mills et al.

229   2017). As example, excessive BF may act as "dead weight" placing an unnecessary "load" and

230   stress on players every time they "compete" against gravity and opponents for conquer a positional

231   advantage during the game. Additionally, improved/increases in "lean body mass" (muscle mass)

232   may favor the execution of the high impulsive actions (e.g., sprint) that are essential from a

233   performance and recovery standpoint (e.g., greater fatigue resistance and decrease muscle damage)

234   (Malone et al. 2016; Owen et al. 2015; Silva 2019; Silva & Rebelo 2019).

235   The analysis of the players' activity during games and trainings, along with the physiological,

236   neuromuscular, and perceptual responses to training and competition demands, highlights the

237   important role of neuromuscular function for successful soccer performance (Nedelec et al. 2012;

238   Silva et al. 2018). The high-impulsive efforts, such as sprints, jumps, acceleration/deceleration,

239   and duels require maximal neuromuscular efforts (Cometti et al. 2001). These efforts have the goal

240   of maximize the impulse produced (Winter et al. 2016) as this determines the decisive decision-

241   making situations in professional soccer (e.g., speed) (Faude et al. 2012; Martinez-Hernandez et

242   al. 2022). Consequently, the impulse produced during these muscle actions of both concentric,

243   isometric, and eccentric nature, with more relevance to the latter impose significant stress on the

244   neuromuscular and physiological systems (Dellal et al. 2010; Gaudino et al. 2013; Hader et al.

245   2014; Hader et al. 2019). In effect, a massive mechanical and metabolic load is imposed on players

246   not only during the maximal intensities' phases of the game but also every time acceleration

247   occurs, even when speeds are low (Osgnach et al. 2010). These speed and direction of movement

248   changes performed during games place stress on the involved musculature from a metabolic

249   viewpoint, thereby affecting energy usage and resulting in a higher physiologic impact than

250   habitual forward movements (Buchheit et al. 2010; Dellal et al. 2010). From a mechanical

251   standpoint, an increased eccentric load is associated with exercise-induced muscle damage (Byrne

252   et al. 2004), contributing to more rapid development of fatigue (e.g., transient, and residual fatigue;

253   peripheral or central) and consequently increasing the odds of injury.

254   Other evidence of the relevance of neuromuscular function for actual soccer has been suggested

255   by reports that VO_{2max} values among professional players are not improving over time (Tonnessen

256   et al. 2013), and contrasting findings concerning sprinting velocity have been observed, e.g., small

257   but positive inter-seasonal development (Haugen et al. 2013). These facts lead to the suggestion

258   that neuromuscular and anaerobic-related parameters (e.g., sprinting ability) are assuming a greater

259   preponderance in modern soccer than other, more typical endurance parameters (e.g., VO_{2max}).

260   Interestingly, there are also indications for greater dominance of neuromuscular factors during

261   game (Barnes et al. 2014; Pons et al. 2021).

262   Although not universally confirmed (Metaxas et al. 2009), some reports suggest that superior

263   neuromuscular function can be observed in soccer players of a higher standard, which includes

264   greater strength (Cometti et al. 2001; Dauty & Potiron Josse 2004), short distance sprint speed

265   (Cometti et al. 2001; Dauty & Potiron Josse 2004; Haugen et al. 2013), agility or COD (Mujika et

266   al. 2008; Power et al. 2005; Reilly et al. 2000) and anaerobic endurance (Power et al. 2005). In

267   addition, these greater neuromuscular capabilities are not only suggested by the higher ability to

268   perform powerful contractions during isokinetic force production tasks but also during and

269   throughout repetitive stretch-shortening cycle activities (SSC) (Impellizzeri et al. 2008; Mujika et

270   al. 2008; Rampinini et al. 2009b). Given these factors, the recent observation that power and speed

271   abilities are determinants in defining result outcomes is not surprising (Faude et al. 2012; Martinez-

272   Hernandez et al. 2022) and should be considered when monitoring training plans. Moreover,

273   neuromuscular and anaerobic-related qualities of professional players (e.g., sprint capacity, power

274   production) have been associated with higher and improved soccer-specific running capacity and

275   are reflected by the following: (i) the ability to perform high-intensity intermittent endurance

276   exercise tests (Ingebrigtsen et al. 2013a; Wells et al. 2014); (ii) maximal speed and time to

277   exhaustion of the players during a maximal anaerobic running test being strongly associated with

278   YYIR2 performance (Wells et al. 2014); (iii) increments in the former neuromuscular and

279   anaerobic qualities being associated with improvements in YYIR2 (Wells et al. 2014); (iv) high

280   performance in certain game-related physical parameters (Altmann et al. 2018) as well as lower

281   fatigue development during the match (Silva et al. 2013b) and during the post-match recovery

282   period (Tofari et al. 2017; Tofari et al. 2020); and v) strength may acts as a moderator of injury

283   occurrence (Al Attar et al. 2017; de Hoyo et al. 2015a). Along this line of reasoning, recent reports

284   have revealed that professional players with higher chronic competition exposure may show higher

285   performance in muscle power actions (Morgans et al. 2017; Silva et al. 2011; Sporis et al. 2011).

286   These facts may also suggest that seasonal alterations in neuromuscular performance may be

287   influenced by competition time - match exposure represents a considerable and important

288   "training" stimulus for improving muscle-power-based actions (Morgans et al. 2017).

289   **4. Variations in physiological determinants and neuromuscular performance**

290   **4.1 Body composition**

291   Studies investigating seasonal changes in anthropometric variables, such as body mass (BM, n =

292   507) (Aziz et al. 2005; Bunc et al. 2015; Casajus 2001; Clemente et al. 2021; D'Ascenzi et al.

293   2013; Edwards et al. 2003; Fessi et al. 2016; Kalapotharakos et al. 2011; Koundourakis et al. 2014;

294   Lago-Peñas et al. 2013; Meckel et al. 2018; Metaxas et al. 2006; Michalczyk et al. 2008; Ostojic

295   2003; Ostojic et al. 2009; Reinke et al. 2009; Silva et al. 2011; Suda et al. 2012), body fat (BF, n

296   = 579) (Aziz et al. 2005; Bonuccelli et al. 2012; Bunc et al. 2015; Casajus 2001; Clemente et al.

297   2021; D'Ascenzi et al. 2013; Devlin et al. 2017; Fessi et al. 2016; Iga et al. 2014; Kalapotharakos

298   et al. 2011; Koundourakis et al. 2014; Lago-Peñas et al. 2013; Los Arcos et al. 2015; Meckel et al.

299   2018; Metaxas et al. 2006; Ostojic 2003; Ostojic et al. 2009; Owen et al. 2018; Papadakis et al.

300   2015; Reinke et al. 2009; Silva et al. 2011; Suda et al. 2012) and lean body mass (LBM, n = 226)

301   (Bonuccelli et al. 2012; Bunc et al. 2015; Casajus 2001; D'Ascenzi et al. 2013; Devlin et al. 2017;

302   Metaxas et al. 2006; Ostojic 2003; Owen et al. 2018; Reinke et al. 2009; Suda et al. 2012) are

303   presented in Table I and II and Figures 1, 2 and 3.

304   The overall analysis of a reasonable number of investigations seems to suggest that players' BM

305   (Fig. 1) is stable during the season; trivial effects from PPS to BCP (Δ= -0,79%, ES=-0.07), MCP

306   (Δ= -0,85%, ES=-0.04) and ECP (Δ= -1,33%, ES= -0.12) are examined by average.

307 Generally, both the absolute and relative BF decreases during the season (Fig 1 and 2). From the

308 observed studies, we might conclude that alterations of small magnitude are examined from PPS

309 to BCP (Δ= -9,6%, ES= -0.54), MCP (Δ= - 8,2%, ES= -0.57) and ECP (Δ= -8,7%, ES= -0.39) in

310 absolute BF. In this line of study, relative BF may decrease by a small magnitude in BCP (Δ=

311 8.9%, ES= 0.45), MCP (Δ= 9.9%, ES= 0.43) and ECP (Δ= 12%, ES= 0.53). Interestingly, at BCP

312 88% (16 in 18), at 94% (MCP 17 in 18) and at ECP 100% (12 in 12) of the ES reported are negative

313 and so pointing on a decrease in absolute BF. Moreover, there are reports of decrements by

314 moderate magnitude at BCP (Clemente et al. 2021; D'Ascenzi et al. 2013; Devlin et al. 2017;

315 Meckel et al. 2018; Ostojic 2003), MCP (D'Ascenzi et al. 2013; Devlin et al. 2017; Kalapotharakos

316 et al. 2011; Meckel et al. 2018) and ECP (D'Ascenzi et al. 2013; Koundourakis et al. 2014; Ostojic

317 2003; Papadakis et al. 2015). Although on average trivial changes in BF (absolute and relative)

318 may occur during in-season (BCP vs MCP and MCP vs ECP, Δ= -2,4% and − 1,8%, ES= -0.06

319 and -0,07, respectively), within the 16 studies that monitored in-season changes, both substantial

320 decrements (Casajus 2001; D'Ascenzi et al. 2013; Fessi et al. 2016; Kalapotharakos et al. 2011;

321 Koundourakis et al. 2014; Ostojic 2003; Papadakis et al. 2015; Suda et al. 2012) and increments

322 (Devlin et al. 2017; Papadakis et al. 2015; Suda et al. 2012) are reported.

323 In this line of evidence towards a more positive body composition profile during season, the overall

324 analysis of the studies suggest that players may substantially increase LBM during in-season. Our

325 analyses reveal increases of small magnitude at BCP (Δ= 1,3%, ES= 0.23), MCP (Δ= 1.8%, ES=

326 0.33) and ECP (Δ= 3.1%, ES= 0.37) concerning PPS. Importantly, there are no reports of

327 substantial decreases in LBM within the in-season assessments (BCP vs MCP and MCP vs ECP).

328 On average increments of trivial magnitude maybe observed from BCP to MCP (Δ= 0,67%, ES=

329 0.15) and MCP to ECP (Δ= 1.2%, ES= 0.12). Curiously, variations in body composition seems to

330   not be associated with the players' participation time (combined training and match exposure time)

331   and did not differ across seasons (Carling & Orhant 2010) and are independent of players position

332   (Milanese et al. 2015). In summary, the general picture (Fig. 1) may suggest that professional

333   players may maintain their BM after starting the training period through decreases in BF and

334   increases in LBM. Although off-season detraining seems to reverse these anthropometric

335   adaptations, with alterations of small magnitude in BM ($\Delta= 1.9\%$, ES= 0.2), BF ($\Delta= 1.6\%$, ES=

336   0.5) and decrements of moderate magnitude in LBM ($\Delta= 5\%$, ES= 0.9) (Silva et al. 2016) they

337   may return to "optimal" initial values for competition after the preparation period. Factors related

338   to training (e.g., the type of strength training), competition fixtures (e.g., extent of the pre-season

339   and/or in-season period, mid-season breaks) and diet (e.g., a Mediterranean diet) (Ostojic 2003)

340   may, among other factors, may explain part of the observed variability throughout the season (e.g.,

341   BF). Nevertheless, the computed values for the different BM, BF and LBM were derived from

342   diverse assessment method that have different measurements and precision errors associated (Mills

343   et al. 2017). Moreover, only a general picture has been provided and so, not capable to characterize

344   the different body regions and associated seasonal variations.

345   **4.2 Force production**

346   Longitudinal studies examining changes in the force production capacity of specific muscle groups

347   in professional players mainly relied on isokinetic assessments, despite the discrepancy in the

348   angular velocities analyzed (Table II) (Eniseler et al. 2012; Malliou et al. 2003; Silva et al. 2011).

349   Seasonal alterations in force production capabilities of specific muscles groups at angular

350   velocities of $60º/s^{-1}$ (Eniseler et al. 2012; Malliou et al. 2003), $90º/s^{-1}$ (Silva et al. 2011), $180º/s^{-1}$

351   (Malliou et al. 2003), $300º/s^{-1}$ and $500º/s^{-1}$ (Eniseler et al. 2012) have been analyzed. Off-season

352   induces alterations of small magnitude in knee extensors force production capacity at moderate

353 (180º/s^{-1}) angular velocities (KE, Δ = 3.9%, ES = 0.37); no substantial alterations were observed

354 at low angular velocities (60º/s^{-1}, Δ = -0.8%, ES = -0.07) (Malliou et al. 2003). During preseason,

355 trivial effects are by average observed in KE at angular velocities of 60º/s (ranging from 227-272

356 N·m and 222-229 N·m, respectively at PPS and BCP) (Malliou et al. 2003), 90º/s^{-1} (ranging from

357 239-242 N·m and 241 N·m, respectively at PPS and BCP) (Silva et al. 2011) and 180º/s (ranging

358 from 150-155 N·m and 157-158 N·m, respectively at PPS and BCP) (Malliou et al. 2003). The

359 same was observed for KF at 90º/s^{-1} (ranging from 129-131 N·m and 129-132 N·m, respectively at

360 PPS and BCP) (Silva et al. 2011). In this line of evidence, effects of trivial magnitude are by

361 average observed from PPS to MCP for KE and KF, respectively when evaluated at 90º/s (KE,

362 ranging from 241 N·m and KF ranging from 133-135 N·m at MCP) (Silva et al. 2011).

363 Interestingly, when profiling adaptation in the force-velocity continuum perspective from PPS to

364 ECP, small decrements at low (ranging from 272-273 N·m and 251-253 N·m, respectively)

365 (Eniseler et al. 2012), changes of trivial magnitude at moderate (ranging from 239-242 N·m and

366 244 N·m, respectively) (Silva et al. 2011) and very large alterations at high angular velocities

367 (ranging from 74-80 N·m and 136-150 N·m, respectively) (Eniseler et al. 2012) for KE strength

368 have been reported. Interestingly, a consistent substantial increment is KF force production from

369 PPS to ECP seems to take place independently of the angular velocity evaluated. Specifically, from

370 small magnitudes at low (≤60º/s^{-1}, ranging from 148-150 N·m and 159-178 N·m, respectively),

371 moderate at moderate angular velocities (90º/s^{-1}, ranging from 129-131 N·m and 134-138 N·m,

372 respectively) and moderate and at high (300º/s^{-1}, ranging from 97-107 N·m, respectively) and very

373 large at very high angular velocities (500º/s^{-1}, ranging from 148-150 N·m and 159-178 N·m,

374 respectively), respectively (Eniseler et al. 2012; Silva et al. 2011). This is particularly interesting,

375 since is well documented that soccer-related injuries likely occur under rapid movement

376 perturbations or actions requiring rapid force development and are more prevalent in hamstring

377 muscles group (Hagglund et al. 2005; Walden et al. 2015).

378 **4.3 Jump Ability**

379

380 Seasonal changes in jump ability (15 studies, 390 players, table I and II, Figure 4, 5 and 6) have

381 frequently investigated the performance on single non-countermovement jump (Non-CMJ, SJ and

382 SJWAS, Figure 7) (Aziz et al. 2005; Casajus 2001; Koundourakis et al. 2014; Lago-Peñas et al.

383 2013; Malliou et al. 2003) and single (CMJ$_{Based}$, CMJ and CMJWAS; Figure 8) (Casajus 2001;

384 Clark et al. 2008; Eliakim et al. 2018; Fessi et al. 2016; Koundourakis et al. 2014; Lago-Peñas et

385 al. 2013; Los Arcos et al. 2015; Malliou et al. 2003; Meckel et al. 2018; Ostojic et al. 2009;

386 Papadakis et al. 2015; Requena et al. 2017; Silva et al. 2011), and repeated countermovement

387 jumps (Casajus 2001; Clark et al. 2008)

388 **4.3.1 Non-countermovement Jump**

389 The Non-CMJ$_s$ (Fig. 5) improves with a small magnitude during preseason training (Δ=3.1%, ES

390 = 0.27) but greater magnitudes can be observed by average from PPS to MCP (Δ=7.8%, ES = 0.83)

391 and ECP (Δ=10%, ES = 1.04), respectively. Interestingly, at BCP 66% [one trivial (Malliou et al.

392 2003), small (Lago-Peñas et al. 2013) and moderate effect (Aziz et al. 2005)], at MCP [one small

393 (Lago-Peñas et al. 2013) and large (Aziz et al. 2005) and three moderate effects (Koundourakis et

394 al. 2014)] and at ECP [two moderate (Koundourakis et al. 2014) and two large (Aziz et al. 2005;

395 Koundourakis et al. 2014)] 100% of the ESs calculated are substantial and so suggestive of an

396 increase in non-CMJ ability. Although more scarcely investigated, trivial effects are by average

397 computed between in-season assessments (BCP vs MCP and MCP vs ECP).

398 **4.3.2 Countermovement Jump**

399 Generally, CMJ$_{Based}$ (Fig. 6) improves by average with a small magnitude from PPS to BCP

400 (Δ=1.8%, ES = 0.26), MCP (Δ=4.0%, ES = 0.47) and ECP (Δ=3,3%, ES = 0.43). Interestingly, at

401 BCP, 58% [seven in 12, six of small (Los Arcos et al. 2015; Meckel et al. 2018; Papadakis et al.

402 2015; Silva et al. 2011) and one of moderate magnitude (Fessi et al. 2016)], at MCP 61% [height

403 in 13, two of small (Koundourakis et al. 2014; Meckel et al. 2018) and six of moderate magnitude

404 (Clark et al. 2008; Fessi et al. 2016; Koundourakis et al. 2014; Papadakis et al. 2015)] and at ECP

405 78% [seven in nine, four of small (Clark et al. 2008; Koundourakis et al. 2014; Papadakis et al.

406 2015) and three of moderate magnitude (Koundourakis et al. 2014; Papadakis et al. 2015)] of the

407 ES computed are indicative of an substantial increase in CMJ$_{Based}$ performance. Although more

408 scarcely investigated, trivial effects are by average computed between in-season assessments (BCP

409 vs MCP and MCP vs ECP).

410 Moreover, it seems that the maximal mechanical power and ability to sustain fatigue during the

411 repeated performance of CMJ$_{Based}$ (average height during 20-s or mean power during a 15-s CMJ

412 test) may improve with moderate and small magnitudes from PPS to MCP (Δ=6.7%, ES= 0.74)

413 and ECP (Δ=2.2%, ES= 0.24), respectively (Casajus 2001; Clark et al. 2008).

414 The improvements in jump ability after players return to normal training routines are somewhat

415 expected as detraining or training cessation during off-season results in small to moderate

416 decrements in jump ability (Δ= 4 to 5.3%, ES= 0.4 to 0.8) (Silva et al. 2016). Importantly, we

417 would like to call the reader attention for the variability in responses that can be observed during

418 in season. With this intention we select the performance of CMJ to expound on this problematic.

419 Although CMJ return to "competition" values after players restart normal training routines, there

420 are quite inconsistent responses during in season. In fact, the overall trivial effects from BCP

421 (ranging from 37.5-55.8-cm) to MCP (ranging from 39.4-52.7-cm) are the result of three

422   decrements (Casajus 2001; Fessi et al. 2016; Silva et al. 2011) and increments of small magnitude

423   (Meckel et al. 2018; Papadakis et al. 2015) and one trivial effect (Lago-Peñas et al. 2013). From

424   MCP to ECP (ranging from 40.9-51.5-cm), the trivial changes are a product of the four decrements

425   (Clark et al. 2008; Papadakis et al. 2015), one improvement of small magnitude (Koundourakis et

426   al. 2014) and the four trivial effects examined (Koundourakis et al. 2014; Requena et al. 2017;

427   Silva et al. 2011). All these investigations inform on the substantial variability in team responses

428   that can be observed, and consequently, advise the practitioner on the need to provide players a

429   consistent neuromuscular stimulus throughout the season. Although not universally confirmed,

430   jump abilities may improve during the pre-season and can be further improved in-season when

431   some mode of strength/power intervention is applied to the normal training routines of highly

432   trained soccer players (Allen et al. 2021; Silva 2019; Silva et al. 2015). Given the large inter-

433   individual variability of responses to training programs and match stimulus, efforts are being

434   developed to optimize training programs at individual level (Haugen 2018; Jimenez-Reyes et al.

435   2022; Loturco et al. 2015a; Morin & Samozino 2016).

436   **4.4 Sprint ability**

437
438   *4.4.1 Linear Speed*

439
440   Seasonal changes in the sprint (Table I and II, Fig 4, n= 230 players) acceleration phase (ACC$_{Phase}$,

441   5-m to 20-m distances, Fig. 7) (Aziz et al. 2005; Fessi et al. 2016; Koundourakis et al. 2014; Los

442   Arcos et al. 2015; Requena et al. 2017; Silva et al. 2011) and maximal velocity phase (MV$_{Phase}$; 30

443   to 50-meters, Fig 8) (Fessi et al. 2016; Ostojic 2003; Silva et al. 2011; Zoppi et al. 2006) has been

444   analyzed. Traditionally, improvements in sprint ability after players return to normal training

445   routines are fairly expected as offseason results in moderate decrements (ES= 0.8 to 1.0) in

446   ACC$_{Phase}$ (~2.5%) and MV$_{Phase}$ (~7%) (Silva et al. 2016). Specifically, when ACC$_{Phase}$ and MV$_{Phase}$

447 are distinctly examined, the later, although more sparsely investigated, tends generally to result in

448 greater improvements and somewhat more substantial effects, as observed between:

449 • PPS (ranging from 0.97-1.04-s, 1.781.8-s, 1.832.29-s, 3.04-3.07-s, 4.16-4.9-s for 5, 10 15,

450   20 and 30-m sprint time) to BCP [Δ= 1.2% vs 3%; ES=0.36 vs 0.65, respectively for

451   ACC$_{Phase}$ and MV$_{Phase}$ (ranging from 0.95-1.06-s, 1.70-s, 2.27-s, 3.01-s, 4.22 to 4.7-s for

452   5, 10-, 15-, 20- and 30-meters sprint time)].

453 • PPS to MCP [Δ= 1.9% vs 3.1%; ES=0.49 vs 0.85, respectively for ACC$_{Phase}$ and MV$_{Phase}$

454   (ranging from 1.02-s, 1.70-1.76-s, 3.01-3.05-s, 4.14- 4.7-s for 5, 10, 20 and 30-m sprint

455   time)].

456 • PPS to ECP [Δ= 2.3% vs 3.3%; ES=0.58 vs 0.35, respectively for ACC$_{Phase}$ and MV$_{Phase}$

457   (ranging from 1.0-1.03-s, 1.73-1.76-s, 2.95-3.04-s and 4.16-s for 5, 10, 20 and 30-m sprint

458   time)].

459 Curiously, within the season the variations and magnitudes are almost identical; BCP to MCP (Δ=

460 1% ES= 0.23) and MCP to ECP (Δ= 0.7% and ES=0.04 vs 0.14, respectively for ACC$_{Phase}$ and

461 MV$_{Phase}$). However, the phase analysis results in the inclusion of a reduced number of studies

462 within each stage (more robustly in the MV$_{Phase}$) with obvious consequences in the interpretation

463 of the results. Importantly, we would like to call the reader attention for the variability in the

464 observed responses during in season. Moreover, recently examination of the force-velocity

465 profiling during sprint reported that sprint mechanical properties are subjected to change during

466 the season (Haugen 2018; Jimenez-Reyes et al. 2022). Particularly, the theoretical maximal

467 horizontal force production seems to be more compromised than maximal velocity towards the

468 end of the season. Accordingly, the authors suggest that specific training stimuli should be

469   consistently applied to increase maximal speed and acceleration (Haugen 2018; Jimenez-Reyes et

470   al. 2022).

471   *4.4.2. Change of direction speed*

472
473   COD seems to be negatively affected during the offseason (Δ= 1.6%, ES=0.6) (Silva et al. 2016).

474   During preseason training players may restore their COD when evaluated by the time to perform

475   a 4 x 10 m task (Δ = 2.5%, ES= 1.0) (Meckel et al. 2018). However, this was not observed when

476   evaluated by the T-test (Δ = 0.5%, ES= 0.12) (Silva et al. 2011). Contradictory findings were also

477   reported from PPS to MCP with trivial (Δ = 0.0%, ES = 0.0) (Meckel et al. 2018) and moderate

478   (Δ = 3.5%, ES = 0.95) (Silva et al. 2011) improvements being reported simultaneously. However,

479   they may stay consistent until ECP (Δ = 2.4%, ES= 0.67) when compared to PPS. Whitin the

480   season both moderate performance decrements (Δ = 2.5%, ES= 0.78) (Meckel et al. 2018) and

481   increments (Δ = 3.9%, ES= 1.0) (Silva et al. 2011) were recorded from BCP to MCP and a

482   performance decrement of small magnitude from MCP to ECP was reported (Δ = 1.1%, ES= 0.32)

483   (Silva et al. 2011).

484

485   *4.5. Insights from training*

486   *4.5.1 Preseason*

487   Pooled results from different experimental studies with professionals' players of different

488   standards suggests that by average soccer players may experience a large (ES= ~1.25) increase in

489   maximum dynamic strength performance during multi-joint exercises (~25% of $1RM_{Squat}$)

490   throughout preseason training (Silva 2019; Silva et al. 2015). In fact, studies examining the effects

491   of pre-season strength high-intensity strength training in force production, revealed that

492   professional players improved maximum dynamic strength performance (1RM) in half-squat

493   exercise (ranging from 11-26%) (Bogdanis et al. 2009; Ronnestad et al. 2008). The same evidence

494   was observed following pre-season concurrent high-intensity aerobic and high-intensity strength

495   training (~52%) (Helgerud et al. 2011). Moreover, improvements in relative force production (6-

496   16%; LLV; 1RM/LLV) (Bogdanis et al. 2009) after high-intensity strength training and after

497   concurrent high-intensity aerobic and high-intensity strength pre-season training are also reported

498   (47%) (Helgerud et al. 2011).

499   Studies examining pre-season strength training programs reveal substantial improvements in, jump

500   ability (5-10%) (Bogdanis et al. 2009; Loturco et al. 2012), acceleration (Bogdanis et al. 2009;

501   Loturco et al. 2012), maximal speed phases (ranging from 1 to 2%) (Bogdanis et al. 2009;

502   Ronnestad et al. 2011) and COD performance of profession al players (Bogdanis et al. 2009). More

503   specifically, a ~23% and ~18% increase in IRM during Squat exercise may on average result in a

504   ~7% and ~1,8% improvement in jump (CMJ and SJ) and sprint time (10 and 40 meters) (Silva et

505   al. 2015). Nevertheless, improvements in jump ability and in maximal speed during preparation

506   phase may be possibly associated with the type of strength training performed by players (weight

507   training plus plyometric training vs weight training only) (Ronnestad et al. 2008). On the other

508   hand, Helgerud et al. (2011) reported substantial improvements in CMJ (5%), and acceleration

509   phase (1.6-3.3%) performance after pre-season concurrent high-intensity aerobic and strength

510   training. Although already developed in the last millennium (Tesch et al. 2017) and with "proof-

511   of-concept" in soccer almost 20 years ago (Askling et al. 2003), the systematic study of the training

512   induced effects of isoinertial eccentric overload has been more recently implemented in soccer (de

513   Hoyo et al. 2015a; de Hoyo et al. 2015b; de Hoyo et al. 2016; Suarez-Arrones et al. 2018; Tous-

514   Fajardo et al. 2016). These previous studies reveal that this exercise model as shown to enhance

515   common soccer tasks to at least a similar magnitude to those typical reported during the

516   implementation of more traditional approaches during pre-season and in-season phases (Allen et

517   al. 2021; Silva et al. 2015).

518   **4.5.2.2 In-season**

519   Regarding in-season alterations in strength parameters, Ronnestad et al. (2011) observed that one

520   high-intensity strength training session per week during the first 12-wks of the in-season period

521   was enough to maintain pre-season (two wk sessions throughout 10-wks) gains in the strength

522   performance of professional players. However, a lower weekly in-season volume (one session

523   every second week) only avoided the loss of training adaptations in jump performance; i.e.,

524   strength and sprint performances decreased (Ronnestad et al. 2011). There are also reports of

525   substantial improvements in 10-m (1.1%) fastest times during an RSA test of professional players

526   after a periodized 4-week in-season specific high-intensity aerobic training intervention (Owen et

527   al. 2012). These findings lead to the interesting hypothesis that strength-based actions present in

528   SSG performance, e.g., accelerations and decelerations, may stress the neuromuscular system to a

529   point that allows in-season performance improvements in acceleration capacity (Thomas et al.

530   2009). In fact, a high mechanical and metabolic load (acceleration/deceleration) seems to be

531   imposed during soccer-specific scenarios (Hodgson et al. 2014; Osgnach et al. 2010). As early

532   mentioned, the different seasonal results during the performance of muscle-power-based efforts

533   may be explained, at least in part, by the different neuromuscular stresses that are placed in players

534   during the distinct periodization's applied by teams. Indeed, an extended longitudinal report

535   (Koundourakis et al. 2014) tracking 3 professional teams suggest that squads who periodized

536   training programs involving higher neuromuscular training loads during the season might show

537   subsequent performance improvements throughout the seasonal continuum in both sprinting and

538   jumping actions; differences in strength/power training stress between the analyzed teams were

539   mainly due to the higher employed volume of both soccer-specific strength and sprint sessions

540   performed by the different teams and not by the general resistance training contents. In this regard,

541   soccer player programs should target all the force-velocity potential/spectrum of the

542   neuromuscular system for a great transfer of this strength to sport activities; increasing player's

543   ability to use strength and power effectively and consistently (Silva et al. 2015). In fact, each player

544   needs an individually optimized approach; one may need to prioritize the development of maximal

545   force capabilities while others maximal velocity capabilities (Morin & Samozino 2016). Moreover,

546   adaptations at the neuromuscular level seem to not only be affected by training but also by the time

547   of match exposure of the players (Morgans et al. 2017; Silva et al. 2011; Sporis et al. 2011). Despite

548   the wide range of sprint distances evaluated, sprint ability may improve throughout the pre-season

549   and further in-season and those improvements may be more marked during the acceleration phase

550   (Silva et al. 2015). The latest evidence is even more curious taking into consideration that analysis

551   of games performed by young elite players (Mendez-Villanueva et al. 2011) reveals that athletes

552   may rarely reached their maximal sprint speed during the game. Nevertheless, these was not

553   observed in adult semi-professional players (Massard et al. 2017) and from our knowledge as not

554   yet been investigated in high-level adult players.

555   In conclusion, the implementation of strength training routines as shown to result in increases of

556   moderate magnitude in jump, linear speed (acceleration and maximal speed phases) and COD

557   (Silva 2019; Silva et al. 2015). Moreover, the magnitude of adaptation and the training efficiency

558   (% improvement by session) may be influenced by the chronic biomechanical and physiological

559   context of the training program (Loturco et al. 2015b; Silva et al. 2015). In fact, programs with

560   greater biomechanical specificity (e.g., force being applied in all the velocity continuum and planes

561   of motion) seems to result is greater improvements in the performance of the analyzed tasks (Silva

562   et al. 2015). Moreover, the physiological demands of the overall session organization (e.g, degree

563   of stress placed at the aerobic system) may affect the magnitude of adaptations (Loturco et al.

564   2015a; Silva 2019). As example, research investigating the training induced effects of concurrent

565   training programs observed that this training programs may produce increases of moderate

566   magnitude in jump (~5.6%), sprint (3.2%) and COD (2.6%) (Silva 2019). A systematic analysis

567   suggest that greater magnitudes of adaptation and training efficiency scores can be detected when

568   the physiological type of the session are more unidirectional (mechanical and metabolic sessions

569   are performed alternatively) than multidirectional (strength and endurance in the same session)

570   (Silva 2019). In fact, the former organization seems to result in more substantial magnitudes of

571   increases (moderate to large) in jump and sprint abilities that the later organization mode (small to

572   moderate). When this is the case, adaptations may vary according to the session arrangement

573   (Endurance + strength and vice versa). Nevertheless, this systematic analysis included studies with

574   professional and semi-professional players (Silva 2019). According to Silva et al. (2019)

575   practitioners should adopt a holistic approach when defining the exercise timing of the strength-

576   based component of the session. A couple of them are: i) Is the player returning from injury or

577   not? ii) What is the training priority within this exact training period? iii) Is the team in a congestive

578   schedule period or not? iv) What is the supposed metabolic/mechanical stress of the "overall"

579   session? iv) Does the player show enough technical competency to perform a complex strength

580   exercise in fatigued state? (Silva 2019). In summary, during the preparation phase players

581   "recover" body composition and neuromuscular competitive capacity. Generally, improvements

582   of small magnitude in non-CMJ and CMJ-based jumps and the acceleration (ACC_{Phase}) and

583   maximal velocity phase (MV_{Phase}) of the sprint are observed from PPS to BCP. In the middle of

584   competition phase, they are observed small (CMJ-based and ACC_{Phase}), and moderate (non-CMJ

585   and MV$_{Phase}$) improvements compared to PPS. However, alterations towards end of competition

586   phase seem to be force-velocity dependent; CMJ-based and MV$_{Phase}$ improve to a small extent with

587   non-CMJ and sprint ACC$_{Phase}$ revealing moderate increments compared to PPS. Trivial alterations

588   occur withing in-season in these parameters. However, these is the result of the variability

589   observed between studies; more evident when monitoring the CMJ performance. Different

590   resistance training methods or combination of methods may improve (pre-season) and assist in the

591   maintenance or further improvement (in-season) of physiological determinants and neuromuscular

592   performance during the season.

593   **5. Endurance: why the relevance?**

594   Activity pattern analysis of the players during the matches showed that elite soccer players cover

595   8 to 13-km during a competitive match (Bradley et al. 2009; Di Salvo et al. 2009; Rampinini et al.

596   2007b) at a mean intensity close to the anaerobic threshold (AT) (Stolen et al. 2005). Moreover,

597   energy expenditure during a match play averages 70-75% of the maximal oxygen consumption

598   (VO$_{2max}$), which suggests that a high level of physical performance in soccer may, in part, be

599   determined by aerobic fitness (Bangsbo et al. 2006; Reilly & Ekblom 2005).

600   The determination of VO$_{2max}$ and AT are two of the most frequent parameters used when

601   monitoring aerobic fitness in the laboratory settings. In addition, seasonal changes in the fitness of

602   soccer players have also been examined by records of time to exhaustion (TE) and maximal aerobic

603   speed (MAS) during maximal incremental tests performed in the laboratory or in field conditions.

604   Although, the power of VO$_{2max}$ to discriminate higher and lower-level players have not been

605   unanimously reported (Marcos et al. 2018; Rampinini et al. 2009a; Slimani et al. 2019; Tonnessen

606   et al. 2013; Wells et al. 2012; Ziogas et al. 2011), higher values of VO$_{2max}$ have been positively

607   associated with players in specific team position roles (midfielders) (Tonnessen et al. 2013). A

608   better cardiovascular capacity, measures by means of VO_{2max} and MAS seems related to a lower

609   perception of exercise intensity during trainings and games (Azcarate et al. 2020). Moreover,

610   players with poor aerobic fitness (Malone et al. 2018) or showing lower improvements during

611   specific phases of the season (preseason) may have a greater risk of injury than players with better-

612   developed aerobic fitness (Eliakim et al. 2018).

613   AT is defined as the highest exercise intensity, heart rate (HR) or VO_2, in which the production

614   and clearance of lactate is equal (Stolen et al. 2005). Several methods exist to determine AT,

615   including blood lactate and ventilatory measurements. Lactate threshold (LT) and ventilatory

616   threshold (VT) have been advocated as more sensible physiological parameters to detect changes

617   in the fitness of soccer players, rather than VO_{2max} (Clark et al. 2008; Edwards et al. 2003; Helgerud

618   et al. 2001); velocity at LT can better discriminate endurance characteristics of soccer teams of

619   different level (Ziogas et al. 2011). Moreover, LT might change without changes to VO_{2max}, and a

620   higher LT means, theoretically, that a player can maintain a higher average intensity in an activity

621   without the accumulation of lactate (Helgerud et al. 2001) and so, for the same external loads a

622   lower internal homeostatic disturbance.

623   To increase the ecological validity of the measurements, maximal and sub-maximal soccer-

624   specific field tests have been widely used to monitor the training status of professional soccer

625   players. Recent evidence suggests that the intermittent endurance capacity of players is improving

626   over time (Elferink-Gemser et al. 2012). Moreover, the level of competitiveness of the player is

627   related to the performance in: i) soccer-specific endurance tests, such as the 30-15 and the Yo-Yo

628   tests (Casado Yebras et al. 2014; Ingebrigtsen et al. 2012; Mohr et al. 2003; Rampinini et al. 2009a;

629   Wells et al. 2012), ii) repeated sprint ability tests with (RSSA) (Rampinini et al. 2009b; Wells et

630   al. 2012) or without (RSA) (Aziz et al. 2008) changes of direction and iii) to the intermittent

631   exercise performance during games (Mohr et al. 2003). Additionally, a positive relationship was

632   observed between team success in the league and the Yo-Yo intermittent endurance test level 2

633   (YYIE2) (Randers et al. 2007) and the Yo-Yo intermittent recovery test level 2 (YYIR2)

634   (Ingebrigtsen et al. 2012). Several studies reported significant correlations between the

635   performance on distinct intermittent endurance field tests and other physiological and performance

636   measurements, such as VO_{2max} (Castagna et al. 2006; Jones et al. 2013; Krustrup et al. 2006;

637   Rampinini et al. 2009a; Rampinini et al. 2009b; Stanković et al. 2021; Wells et al. 2014), VO_2

638   kinetics during high-speed running (HSR) (e.g., velocity at $80\%\Delta VO_2$) (Wells et al. 2014),

639   incremental treadmill test performance (ITT) (Krustrup et al. 2006), and TE during a maximal

640   anaerobic running test (Wells et al. 2014). Moreover, improvements in the YYIR2 were associated

641   with increases in power, TE and maximal speed during a maximal anaerobic running test (Wells

642   et al. 2014). Importantly, YYIR1 (Krustrup et al. 2003), YYIE2 (Bradley et al. 2010) and in

643   RS(S)A (Altmann et al. 2018; Rampinini et al. 2007b) performance have been shown to be

644   associated with game-related physical activity (e.g, TD, HSR and sprint) (Altmann et al. 2018;

645   Bradley et al. 2010; Krustrup et al. 2003; Krustrup et al. 2005; Rampinini et al. 2007a).

646   Additionally, correlations between changes in intermittent endurance field tests and changes in

647   match activity (e.g., HSR) during the season, which were not evident for VO_{2max} have been

648   reported (Bradley et al. 2011). However, contradictory findings regarding measures of proficient

649   match activity (HSR) have also been reported to correlate with laboratory fitness measures (ITT

650   and VO_{2max}) (Impellizzeri et al. 2006; Krustrup et al. 2003; Krustrup et al. 2005). Nevertheless, it

651   is important to note that most of the studies only detected moderate correlations and thus cannot

652   be used to establish a direct cause-effect relationship (Rampinini et al. 2007a). Nevertheless, a

653   greater discriminatory validity has been attributed to the field monitoring techniques and thus, at

654   least in part, makes them more important (specific) in monitoring soccer players (Buchheit 2010;

655   Ingebrigtsen et al. 2012; Svensson & Drust 2005; Wells et al. 2012). In addition, the examined

656   reliability and sensitivity to training of field derived sub-maximal HR measures make these

657   measures an important parameter for frequent, time-efficient, and non-exhaustive testing of

658   intermittent exercise capacity of high-level soccer players (Altmann et al. 2021; Buchheit 2014;

659   Buchheit et al. 2020; Ingebrigtsen et al. 2013a; Rago et al. 2020). In fact, in addition to better

660   physiological responses being observed in players of a higher standard (Ingebrigtsen et al. 2012),

661   they also seem to be associated with acute (Rago et al. 2020) and chronic physical match

662   performance (HSR) (Bradley et al. 2010). Notwithstanding the previous facts, it is important to

663   highlight those maximal (e.g, VO_{2max} and MAS) and sub-maximal aerobic fitness laboratory

664   parameters (e.g, AT) cannot be neglected. In fact, others (Altmann et al. 2018; Vincenzo et al.

665   2013) observed the ecological validity of these parameters via their association with match

666   categories of an aerobic and anaerobic nature. As so, practitioners should always consider a

667   cost/benefit approach (e.g. cost, ease of use, manpower and how it will impact the training

668   program) (Buchheit & Simpson 2017).

669   **6. Variations in physiological determinants and endurance performance**

670   **6.1 Maximal oxygen consumption**

671

672   Although with obvious limitations, e.g., just one study involves a longitudinal, inter-seasonal

673   examination of soccer players (12 seasons, 1545 players), it seems that among professional

674   players, VO_{2max} is not improving over time and perhaps has the tendency to decrease (players

675   tested from 2006-2012 showed 3.2% lower values than those tested from 2000-2006) (Tonnessen

676   et al. 2013).

677   Seasonal alterations in VO_{2max} have been extensively analyzed (Table II, Figure 9 and 10, n= 393)

678   (Aziz et al. 2005; Bunc et al. 2015; Casajus 2001; Castagna et al. 2013; Clark et al. 2008; Edwards

679   et al. 2003; Eliakim et al. 2018; Haritodinis et al. 2004; Kalapotharakos et al. 2011; Koundourakis

680   et al. 2014; Lago-Peñas et al. 2013; Manzi et al. 2013; Meckel et al. 2018; Metaxas et al. 2009;

681   Michalczyk et al. 2008; Mohr et al. 2002). Generally, during the pre-season, professional players

682   appear to regain their oxygen capacity and maintain it throughout the season as off-season seems

683   to induce a large impairment in this physiological parameter (Δ= 4.4%, ES= 1.4) (Silva et al. 2016).

684   Studies with players from different backgrounds exposed a large magnitude of improvements in

685   VO_{2max} from the PPS (ranging from 52.2-62.7 ml$^.$min$^{-1.}$kg^{-1}) to BCP (Δ= 7.3%, ES= 1.3, ranging

686   from 54.8-66.5 ml$^.$min$^{-1.}$kg^{-1}). Additionally, improvements of moderate magnitude were by

687   average observed in the MCP (Δ= 6.4%, ES= 1.0, ranging from 55.5-66.8 ml$^.$min$^{-1.}$kg^{-1}) and ECP

688   (Δ= 4.2%, ES= 0.8 ranging from 52.7-64.1 ml$^.$min$^{-1.}$kg^{-1}) compared with the PPS. Moreover,

689   increases in VO_{2max} (from PPS to BCP, MCP and ECP) seem to be independent of the position

690   role (Metaxas et al. 2006). Interestingly, just one of the 14 ES did not confirm the substantial

691   improvements at MCP and four on 13 at ECP compared to PPS assessments. Within the

692   competitive phase they are observed by average trivial changes from BCP to MCP (Δ= 0.5%, ES=

693   0.1) and a small decrement from MCP to ECP (Δ= -2.3%, ES= -0.28).

694   **6.2. Anaerobic threshold**
695   Studies examining changes in physiological parameters at sub-maximal intensities are presented

696   in Table II (13 studies, n = 249, Fig. 9) (Casajus 2001; Castagna et al. 2011; Clark et al. 2008;

697   Dunbar 2002; Edwards et al. 2003; Kalapotharakos et al. 2011; Los Arcos et al. 2015; Manzi et al.

698   2013; Meckel et al. 2018; Mohr et al. 2002; Papadakis et al. 2015; Zoppi et al. 2006).

699   From the large variety of parameters examined, some were shown to be sensitive in one but not in

700   other studies that used players of similar standards. Nevertheless, enhancements in the ability to

701   cope with sub-maximal internal and external loads regarding PPS performances were by average

702   detected by different parameters, as follows:

703   (i)   the percentage of VO_{2max} (76%VO_{2max}) and percentage of maximal heart rate

704   (87%HR_{max}) at a lactate concentration of 4 $mmol^{-1}$ at BCP (ES= 0.62 and 0.71, 78%

705   and 89%) and MCP (ES= 0.89 and 0.91, 78% and 89%), respectively) (Kalapotharakos

706   et al. 2011);

707   (ii)   Oxygen consumption at the LT (ES= 0.5 at ECP, ranging from 51.4-53.5 $ml \cdot min^{-1} \cdot kg^{-1}$

708   ^{1}) (Edwards et al. 2003) and VT [ES= 0.85 and 0.41 at BCP (ranging from 50.2-52.7

709                    $ml \cdot min^{-1} \cdot kg^{-1}$) and ECP (52.9 $ml \cdot min^{-1} \cdot kg^{-1}$), respectively] (Casajus 2001; Edwards et

710   al. 2003; Manzi et al. 2013);

711   (iii)   heart rate measures at speeds of 14-km/h (ES= 2.7), 16-km/h (ES= 2.6), and 18-km/h

712   (ES= 2.0) at MCP (Mohr et al. 2002);

713   (iv)   the speed at a fixed lactate concentration ($V_{[La]}$; Fig 9) of: **a)** 2 $mmol^{-1}$ [ES= 0.67, 0.66

714   and 0.68, at BCP (ranging from 11.4-14.5-km/h), MCP (ranging from 10.5-14.8-km/h),

715   and ECP (ranging from 10.8-13.9-km/h) regarding PPS (ranging from 9.5-14.3-km/h)

716   respectively] (Castagna et al. 2011; Castagna et al. 2013; Dunbar 2002; Kalapotharakos

717   et al. 2011; Manzi et al. 2013; Papadakis et al. 2015); **b)** 3 $mmol^{-1}$ (ES= 0.52, 0.20 and

718   -0,27 at BCP (ranging from 12.7-15.4-km/h), MCP (15.7 km/h), and ECP (15.0-km/h)

719   regarding PPS (ranging from 12.2-15.4-km/h), respectively) (Dunbar 2002; Los Arcos

720   et al. 2015); **c)** 4 mmol^{-1} [ES= 1.0, 1.41 and 1.27 at BCP (ranging from 13.6-14.9-

721   km/h), MCP (ranging from 13.6-14.4-km/h) and ECP (ranging from 13.5-14.3-km/h),

722   regarding PPS (ranging from 12.3-13.9-km/h), respectively] (Castagna et al. 2011;

723   Castagna et al. 2013; Kalapotharakos et al. 2011; Manzi et al. 2013; Papadakis et al.

724   2015);

725   (v)   The speed at the LT (ES= 1.9 at BCP, ranging from 10.5-13.8-km/h respectively)

726   (Zoppi et al. 2006) and VT [ES= 0.57 and 1.1, at BCP (ranging from 11.6-12.2-km/h)

727   and MCP (12.8-km/h) respectively] (Meckel et al. 2018).

728   Interesting, although a wide variety of submaximal parameters have been measured, substantial

729   improvements between BCP and MCP are consistently reported within the analyzed studies in

730   some form of physiological parameter (Casajus 2001; Dunbar 2002; Kalapotharakos et al. 2011;

731   Meckel et al. 2018; Papadakis et al. 2015). Nevertheless, alterations of trivial magnitude have also

732   been examined (Kalapotharakos et al. 2011; Papadakis et al. 2015). From the MCP to ECP distinct

733   alterations have been observed with both reports of trivial (Papadakis et al. 2015), small

734   improvements (Papadakis et al. 2015) and impairments (Dunbar 2002).

735   Interestingly, although trivial alterations in VO$_{2max}$ are by average observed from BCP to MCP, an

736   improvement of small magnitude (ES= 0.29) is observed between these time points, which suggest

737   that further improvement in sub-maximal exercise performance (e.g., LT), but not in VO$_{2max}$, are

738   likely related to a faster restoration or improvement of central factors (i.e., VO$_{2max}$) than peripheral

739   factors (i.e., muscle oxidative enzymes) (Impellizzeri et al. 2006). Furthermore, although

740   adaptations in RE being dependent on multi-dimensional factors (e.g., mechanical, and

741   neuromuscular skills) they may had occurred further in season, and so determinant for improving

742   running performance (Foster & Lucia 2007); RE can better discriminate soccer players of different

743   standards with similar VO_{2max} values (Ziogas et al. 2011).

744   In summary, these physiological determinants of endurance performance, improve during the first

745   part of the season (4-8 weeks) and generally remain stable throughout the season. Generally,

746   improvements in VO_{2max} occurred after a relatively short period of time (e.g., pre-season training),

747   while no significant further in-season increases are observed. Moreover, no increase was examined

748   in the VO_{2max} when players already possessed values of approximately 61-62 ml/kg/min. In fact,

749   the increases in VO_{2max} found in different standard of players during the in-season period (Caldwell

750   & Peters 2009; Jensen et al. 2009; Magal et al. 2009) occurred under this threshold and in players

751   of a lower standard. Additionally, when professional players began the competitive season with

752   values above this threshold (61-62 ml/kg/min), no improvements in the VO_{2max} throughout the

753   season were by average reported (Clark et al. 2008; Edwards et al. 2003). This may be related with

754   soccer training-specific constrains and/or demands, such as, the limited time for fitness training

755   due to the high density of in-season match commitments. Our analysis seems to corroborate the

756   observations of others (Tonnessen et al. 2013), indicating that VO_{2max} values of approximately 62-

757   64 ml/min/kg may fulfill the general demands for aerobic capacity in male professional soccer

758   players; nevertheless, characteristics related to the specific demands of different positional roles

759   should be considered, as reported values reflect team averages and large inter-individual variations

760   can be observed.

761   **6.3 Maximal aerobic speed**

762   MAS (Figure 9 and 11) (n= 143) (Boullosa et al. 2013; Bunc et al. 2015; Fessi et al. 2016;

763   Kalapotharakos et al. 2011; Lago-Peñas et al. 2013; Requena et al. 2017) reflects the maximum

764   aerobic capacity and combines VO_{2max} and RE into a single factor (Billat & Koralsztein 1996). As

765   such, MAS is a good indicator of aerobic performance (Billat & Koralsztein 1996), and the

766   determination of MAS gives a practical assessment of the aerobic demands during running

767   performance (Kalapotharakos et al. 2011). Off-season break may induce a decrement of moderate

768   magnitude in MAS (Δ= 4.6%, ES= 0.61) (Requena et al. 2017). Preseason training restores MAS

769   (Δ= 5%, ES= 1.3, ranging from 18.1-19.7-km/h), with substantial improvements still evident at

770   MCP (Δ= 4.3%, ES= 1.3, ranging from 17.4-19.6-km/h) and at ECP (Δ= 4.9%, ES= 1.05, ranging

771   from 17.3-18.4-km/h) regarding the PPS values (ranging from 16.5-19.2-km/h). Although, by

772   average no substantial improvements take place from BCP to MCP (Δ= -0.7%, ES= -0.11) and

773   from MCP to ECP (Δ= 0.6%, ES= -0.09), there are contradictory observations between BCP and

774   MCP, with both trivial (Δ= -0.4%, ES= -0.09) (Lago-Peñas et al. 2013), moderate impairments

775   (Δ= -3.3%, ES= -0.82) (Fessi et al. 2016) and improvements of small magnitude (Δ= 1.7%, ES=

776   0.59) (Kalapotharakos et al. 2011) reported. Interestingly, Boullosa et al. (2013) did not observed

777   changes in the MAS (18.1 to 18.2-km/h) in professional players after pre-season. The different

778   findings are, at least in part, associated with the dissimilar baseline MAS that were reported and

779   the applied protocols (Dupont et al. 2004; Fessi et al. 2016; Kalapotharakos et al. 2011; Wong et

780   al. 2010). We would like to highlight that in this narrative review we discussed the velocity at

781   VO_{2max} (vVO_{2max}) (Kalapotharakos et al. 2011), and final velocity reached (Vam-eval and Gacon

782   test) as one parameter (Boullosa et al. 2013; Bunc et al. 2015; Fessi et al. 2016; Lago-Peñas et al.

783   2013; Requena et al. 2017). Although they are highly correlated, with the two terms being often

784   used interchangeably, they refer to different physiological entities (Buchheit 2010) with MAS

785   maybe 10-15% greater than the vVO_{2max} (Berthon & Fellmann 2002)

786   In summary, despite the scarcity of research monitoring these performance parameters, MAS

787   increase after pre-season training and remain stable throughout the season. The magnitude of

788 alterations (MAS) may be associated with the baseline training status of players at the time of

789 intervention (Boullosa et al. 2013).

790
791 **6.4 High-intensity intermittent exercise**
792
793 A summary of studies examining changes in high intensity intermittent exercise (IE) tests is

794 presented in Table I and II and Figure 9 and 12 (Boullosa et al. 2013; Bradley et al. 2010; Campos-

795 Vazquez et al. 2016; Castagna et al. 2013; Iaia et al. 2009c; Krustrup et al. 2003; Krustrup et al.

796 2006; Manzi et al. 2013; Silva et al. 2011). Off-season seems to result in decrements of moderate

797 and very large magnitude in IE performance (Δ= 27.8% and 10%, ES= 1.0 and 2.2 for YYIE2 and

798 YYIR2, respectively). However, preseason phase by average induces large improvements IE

799 ($\Delta_{overall}$= 32.4%, ES= 1.8). Specifically, improvements of 56%, 60%, 18% and 5%, and effect sizes

800 of 4.1, 2.4, 1.1 and 1.25 for YYIR2 (ranging from 742-780-m and 1033-1160-m), YYIE2 (ranging

801 from 1120-2171-m and 2250-2411-m), YYIR1 (ranging from 1760-2475-m and 2211-2600-m)

802 and 30-15 (20.1 to 21.1 km/h), respectively]. These performance improvements are extended to

803 MCP ($\Delta_{overall}$ = 18.9%, ES= 1.5). Precisely, increases of 43.9%, and 17.9%, with magnitudes of

804 2.4 and 0.7 for YYIR2 (ranging from 742-780-m) and YYIE2 (ranging from 742-780-m)].

805 Interestingly, the magnitude of alterations is lower from PPS to ECP ($\Delta_{overall}$ = 22.5 %, ES= 1.0).

806 Specifically, increments of 11.9 %, 29.7% and 19.5% with magnitudes of 0.51, 0.96 and 1.56, for

807 YYIR2 (873-m), YYIE2 (ranging from 1640-2381-m), YYIR1 (2103-m), are examined. Within

808 the season, the ability to perform IE is by average impaired to a small extent from BCP to MCP

809 [$\Delta_{overall}$ = -2.4%, ES= -0.23 (Δ= -7.2% and 6.1%, ES= -0.47 and 0.24 for YYIR2 and YYIE2,

810 respectively)] and from MCP to ECP ($\Delta_{overall}$ = -7%, ES= -0.3) We would like to highlight again,

811 that within each team, a great inter-individual ability to perform repeated intense exercise can be

812   observed throughout the season, with some players improving, others decreasing and/or

813   maintaining their performance (Bangsbo et al. 2008).

814   Interestingly, Boullosa et al. (2013) did not report substantial changes in YYIR1 from PPS to BCP.

815   It should be observed that in this study, players started the season with a high YYIR1 performance

816   (2475-m), which may be related to the performance of an off-season program (five weeks/21

817   sessions). This previous evidence, at least in part, highly indicate the benefits of performing a

818   structured training program during the off-season (Silva et al. 2016). Moreover, it should be noted

819   that despite no significant improvements in YYIR1, the authors reported important changes in

820   certain indices of cardiac autonomic adaptations (e.g., short heart-rate recovery) after this period

821   of intensified training.

822   ***6.5 Repeated sprint ability***

823   Impellizzeri et al. (2008) observed that elite players improved different parameters in RSSA test

824   performance throughout the season. Namely, the mean time of the sprints (RSSA$_{mean}$) improved to

825   a moderate extent from PPS to BCP (Δ= 2.2 %, ES= 1.14), MCP (Δ= 1.4%, ES= 0.74) and ECP

826   (Δ= 1.6 %, ES= 0.29). The fatigue index improved to a small magnitude from PPS to BCP (Δ=

827   20.4 %, ES= 0.56), and in a moderate extent from PPS to MCP (Δ= 22.2 %, ES= 0.62) and ECP

828   (Δ= 25.9 %, ES= 0.71). The lower fatigability during repeated sprints performed during MCP and

829   ECP vs. PPS as also been verified when monitoring U20 elite players using the Bangsbo sprint

830   test (Jorge et al. 2020). Nevertheless, a small deterioration of the RSSA$_{mean}$ occurred from the BCP

831   to MCP (Δ= 0.84 %, ES= 0.41) with trivial changes been observed from MCP to ECP and for the

832   fatigue index within these specific in-season moments.

833   We intended to characterize the general ability of performing repeated intense exercise and with

834   this purpose we combined results of different specific IE tests that are widely used in professional

835   settings. We acknowledge the differences between protocols of each individual test and that they

836   might evaluate slightly different physical capacities (Buchheit & Rabbani 2014). As example,

837   YYIR1 leads to a maximal activation of the aerobic system, whereas YYIR2 determines an

838   individual's ability to recover from repeated exercise with a high contribution from the anaerobic

839   system (Bangsbo et al. 2008). Nevertheless, their sensitivity to training is almost certainly similar

840   (30-15 vs YYIR1) (Buchheit & Rabbani 2014) and given the very large correlations between tests

841   (YYIR1 vs YYIR2) practitioners have been advised to consider using only one of the Yo-Yo tests

842   and a RSA test in a general soccer-specific field test protocol (Ingebrigtsen et al. 2012;

843   Ingebrigtsen et al. 2013a).

844   **_6.6 Sub-maximal intermittent field exercise_**

845   It has been observed that soccer players $\%HR_{max}$ at the 6-min point of the YYIR1 decreased from

846   the PPS to the middle of the pre-season, BCP and ECP (Krustrup et al. 2003). Rago et al, (2020)

847   when applying the same protocol during the in-season period (four assessment moments from

848   MCP to ECP) observed a continuous moderate improvement in heart rate measurements towards

849   ECP. Moreover, others observed that even though professional players may show a decline in

850   VO_{2max} from the preparation period to the end of the season, their heart rate responses during the

851   sub-maximal version of the YYIE2 were not altered during 5 time-points of a soccer season (from

852   14 days pre-season to ECP) (Heisterberg et al. 2012).

853   **6.7 Game-related physical parameters**
854
855   Match analysis is a widely used instrument in professional soccer to study technical, tactical, and

856   physical performances of players (Abt & Lovell 2009). These instruments allow careful analysis

857   of player match performance, dependent of a large number of factors (e.g., training status, field

858   position, age) and allows for the investigation of seasonal changes in game-related physical

859   performance (Helgerud et al. 2001; Impellizzeri et al. 2006; Morgans et al. 2014; Padron-Cabo et

860   al. 2018; Rampinini et al. 2007b; Silva et al. 2013b) and study evolutionary trends over consecutive

861   seasons (Akyildiz et al. 2022; Barnes et al. 2014; Bradley et al. 2016; Bush et al. 2014; Pons et al.

862   2021; Vigne et al. 2012).

863   ***Seasonal Variations***

864   Seasonal alterations in distance covered in different speed zones during the game is presented in

865   Figure 13, 14 and 15 (Link & de Lorenzo 2016; Morgans et al. 2014; Padron-Cabo et al. 2018;

866   Rampinini et al. 2007b; Silva et al. 2013b). There are by average trivial changes in the TD from

867   BCP to MCP (Δ= -1,09 %, ES= 0.03, ranging from 9150-10513-m and 9350-10722-m,

868   respectively) with a small increment between BCP and ECP (Δ= 1.63 %, ES= 0.22, ranging from

869   9600-10921-m). A small increase in TD seems to occur from MCP to ECP (Δ= 1.5 %, ES= 0.47).

870   Interestingly, a clear variability exists, with both increments (Mohr et al. 2003; Rampinini et al.

871   2007b; Silva et al. 2013b) and decrements (Link & de Lorenzo 2016; Mohr et al. 2003; Padron-

872   Cabo et al. 2018) between these time-points. Importantly, within the season the variation ranged

873   from -2.4%-5.9% that are below for the reference value (10-15%) (Oliva-Lozano et al. 2021a) that

874   can establish a practical significance considering the high match-to match variability (Gregson et

875   al. 2010; Oliva-Lozano et al. 2021a).

876   The distance covered in HSR ($\sim$>14.4-15 km/h; Figure 13 and 15) during the match has been

877   proposed to be of great importance for performance in elite soccer because clearly distinguishes

878   players of different standards (Mohr et al. 2003; Saeterbakken et al. 2019). However, these

879   observations of HSR proficiency being associated with player standards have not been

880   unanimously confirmed (Di Salvo et al. 2012). The amount of HSR by average decreases with a

881 trivial magnitude from BCP to MCP (Δ= 2.1 %, ES= -0.14, ranging from 1350-2450-m and 1270-

882 2544-m, respectively) and increase to a moderate extent to ECP (Δ= 22.5 %, ES= 0.75, ranging

883 from 1900-2738-m) and from MCP to ECP (Δ= 25.9 %, ES=0.92). Interestingly all the studies,

884 although reporting different magnitudes (small to large), observed substantial alterations between

885 these two time-points (Mohr et al. 2003; Rampinini et al. 2007b; Silva et al. 2013b). Moreover,

886 the amount of HSR performed in the last fifteen-minute period of each half, indicative of the ability

887 to maintain performance during the game (Krustrup et al. 2005), was reported to be higher towards

888 the ECP (Silva et al. 2013b). Additionally, in the ECP, a greater distance in HSR was covered in

889 the peak and in the lowest fifteen-minute periods of the match than in the corresponding fifteen-

890 minute periods at other season time points (Silva et al. 2013b). Furthermore, Silva et al. (2013b)

891 observed that professional players were more engaged in high-intensity activities and had higher

892 peak 5-min periods of HIR during the matches towards the last quarter of the season (ECP).

893 Very-high speed running (>19.8-21 km/h; VHSR; Figure 15) is stable from the BCP to MCP (Δ=

894 3.8 %, ES=0.10, ranging from 465-916-m and 485-829-m, respectively) and ECP (Δ= 4.5 %,

895 ES=0.16, ranging from 481-977-m). Small increments in VHSR may take place from MCP to ECP

896 (Δ= 0.74 %, ES=0.29). Importantly, within the different season moments the variation ranged from

897 -18-20% that are below for the reference value of 60-64% informing that a real change take place

898 (Gregson et al. 2010; Oliva-Lozano et al. 2021a).

899   The sprint distance performed during the match (>24-30 km/h; Figure 15) (Morgans et al. 2014;

900 Padron-Cabo et al. 2018; Silva et al. 2013a) is by average stable from BCP to MCP (Δ= 4.5 %,

901 ES= 0.19, ranging from 98-201-m and 111-225-m, respectively) and increase with moderate and

902 small magnitude from BCP to ECP (Δ= 11%, ES= 0.69, ranging from 192-234-m) and MCP to

903 ECP (Δ= 6.1 %, ES= 0.55), respectively. However, within the three studies analyzed, two

904 (Morgans et al. 2014; Padron-Cabo et al. 2018) consistently report trivial changes between these

905 time-points. It should be again highlighted, that a large match-to-match variability in game-

906 physical parameters of elite players may occur, suggesting that only large sample sizes may allow

907 the clarification of systematic changes and that the "training stimulus" provided by the match is

908 largely variable (Gregson et al. 2010; Oliva-Lozano et al. 2021a).

909 ***Evolutionary Trends***

910 Evolutionary trends in match activity of professional players (Akyildiz et al. 2022; Barnes et al.

911 2014; Bradley et al. 2016; Bush et al. 2014; Pons et al. 2021; Vigne et al. 2012) has been analyzed

912 in different contexts. Vigne et al. (2012) examined an Italian Serie-A team (2004-05 to 2006-07).

913 The researchers observed significant progressive decreases in the distance covered per minute of

914 play in low intensity running from the first to the second and third seasons. In addition, a significant

915 decrease between the second and third seasons was also reported for moderate intensity running

916 (Vigne et al. 2012); distance running and high intensity activities in Serie-A were similar in the

917 three seasons. In spite no interaction between season and playing positions, and thus no signify

918 alterations across all 3 seasons, were observed for the distinct field positions in the latter study

919 (Vigne et al. 2012), others (Bush et al. 2014) performing a seven season longitudinal analysis

920 (2006-07 to 2012-13) observed that the time dependent increase in physical demands (e.g. increase

921 in HSR) in the English premier league was extended to all players positions; full backs

922 demonstrating the most pronounced increases. Barnes et al. (2014) carrying out the same design

923 of Bush et al. (2014) observed an evolution of physical parameters in the English Premier League

924 e.g., across seven seasons high intensity running distance and actions increased by ~30% and

925 ~50% and sprint distance and number increased by ~35% and ~85% respectively. Within this

926 period (2006-13), Bradley et al. (2016) investigating the evolution of physical and technical

927   performances in the same league with special reference to league ranking observed that physical

928   and technical performances have evolved more in the 2nd Tier that included the teams from 5th–8th

929   ranking than any other of the remaining three Tiers. According to the authors, this could indicate

930   a narrowing of the performance gap between the top Tiers (Bradley et al. 2016).

931   Pons et al. (2021) examined evolutionary trends from 2015/2016 to 2018/2019 in the top two

932   professional leagues of Spanish football. The authors observed a decrease in TD and an increase

933   in the high-intensity distances and number of sprints performed, although a clearer trend was

934   perceived in the top league. Additionally, VHSR and sprint distance increased during the second

935   halves in both professional soccer leagues. Nevertheless, other authors did not observe an

936   evolutionary trend in the Turkish league physical demands and independently of team's final

937   rankings (2015-2018) (Akyildiz et al. 2022). All these studies that independently investigate

938   seasonal alterations in match activity and evolutionary trends in physical match performance, point

939   out that players need more, to be ready to sustain activities involving a high metabolic and

940   neuromuscular "cost". Interestingly an evolutionary trend in technical variables has been

941   consistently reported (Akyildiz et al. 2022; Barnes et al. 2014), and that can be more evident in

942   specific league tiers (Bradley et al. 2016).

943   Notwithstanding the intrinsic cultural characteristics associated with each league, differences

944   between studies can be related, among other factors, to the (i) pre-defined thresholds of the

945   different intensity categories of each analysis system (e.g, high-intensity categories), (ii)

946   discrepancies between systems in the accuracy of the determination of the distance covered at HSR

947   (Randers et al. 2010), (iii) accuracy of the intensity of the pre-defined thresholds with

948   individualized thresholds of physiological stress of the players (Abt & Lovell 2009), (iv) different

949   game and situational conditions (Paul et al. 2015). In this regard, we need to highlight that several

950   influencing factors may affect team and player performances at a behavioral level. Some of them

951   are: i) match status (i.e., whether the team is winning, losing or drawing) (Andrzejewski et al.

952   2018; Augusto et al. 2021; Bradley & Noakes 2013; Oliva-Lozano et al. 2021b), ii) quality of

953   opposition (Lago-Penas et al. 2011), iii) match location (i.e., playing at home or away) (Augusto

954   et al. 2021; Oliva-Lozano et al. 2021b), v) fixture congestion (Julian et al. 2021; Lago-Penas et al.

955   2011; Oliva-Lozano et al. 2021b), v) environmental conditions (heat) and altitude (Mohr et al.

956   2012; Nassis 2013), vi) playing formation (e.g, 1-4-2-3-1 vs. 1-4-4-2) and style of play (e.g.

957   amount of ball possession) (Arjol-Serrano et al. 2021; Bradley et al. 2013), vii) players availability

958   (Windt et al. 2018), viii) players physical fitness (Altmann et al. 2018; Bradley et al. 2010; Konefal

959   et al. 2019a; Krustrup et al. 2005), ix) distance traveled to play (Augusto et al. 2021) and x) coach

960   dismissal (Augusto et al. 2021; Zart & Gullich 2022) and are all factors that may impact teams and

961   players match output.

962

963

964   *6.8. Insights from training*

965   High intensity training (HIT) comprises different modes of high-intensity exercise, namely high-

966   intensity aerobic training (HIA), speed endurance training (SE) and repeated sprint ability training

967   (RSA) (Bishop et al. 2011; Mohr et al. 2022; Spencer et al. 2005). Generally, the common factors

968   between modes are the high degree of physiological stress and the sharing of some similar

969   physiological and functional training-induced adaptations imposed by the acute and chronic effects

970   of the high-intensity bouts. HIT is a useful training method, providing a high training stimulus

971 (Bangsbo et al. 2009; Buchheit & Laursen 2013a; Christensen et al. 2011; Iaia & Bangsbo 2010;

972 Iaia et al. 2009a) on both the cardiopulmonary (Buchheit & Laursen 2013a) and neuromuscular

973 levels (Buchheit & Laursen 2013b), thereby promoting physiological and performance adaptations

974 that allow players to more successfully cope with the match and training demands (Castagna et al.

975 2009; Girard et al. 2011; Gunnarsson et al. 2012; Helgerud et al. 2001; Iaia et al. 2009b;

976 Impellizzeri et al. 2006; Ingebrigtsen et al. 2013b; Krustrup et al. 2005; Mohr et al. 2003;

977 Rampinini et al. 2007a).

978 ***6.8.1 Preseason***

979 HIA, both in general (interval running; $HIA_{General}$) (Helgerud et al. 2001; Impellizzeri et al. 2006)

980 and more specific modes (small-sided games and soccer-specific dribbling circuits; $HIA_{Specific}$)

981 (Impellizzeri et al. 2006; McMillan et al. 2005), induces an improvement in several of the above

982 analyzed physiological determinants (e.g., VO_{2max} and AT) and performance measures (e., YO-

983 YO tests; Ekblom's circuit test) in high level juniors and professional players. Moreover, the same

984 as been observed when performing other forms of HIT (Dupont et al. 2004; Wells et al. 2014) or

985 the concurrent performance of HIT with strength training (Helgerud et al. 2011; McGawley &

986 Andersson 2013; Wong et al. 2010). The latter seems to result in moderate (MAS and YYIR2) to

987 very large (YYIR1) improvements endurance-related parameters (Silva 2019). However, when

988 adopting a concurrent training paradigm, soccer-related technical staff should implement an

989 integrated approach when defining the exercise timing of the strength-based element of the session

990 (see point 3.3.). Additionally, Bogdanis et al. (2011) observed improvements in physiological

991 determinants (VO_{2max}) and endurance performance (YYIE2 and Hoff's dribbling track test) by

992 professional players after pre-season strength training independently of the target of adaptations

993 (hypertrophy vs neural adaptations). Studies examining changes in the anaerobic running capacity

994   are scarce. Nevertheless, improvements in 200- and 400-m running distances (Sporis et al. 2008a)

995   and both the performance time and the ability to tolerate higher [La] during 300-y shuttle run test

996   were reported to improve after pre-season HIA$_{Specific}$ (Sporis et al. 2008a; Sporis et al. 2008b).

997   Furthermore, enhancements in a running-based anaerobic sprint test after 6-wks pre-season

998   HIA$_{Specific}$ of professional players have also been described (Ostojic et al. 2009). There are reports

999   that pre-season HIA$_{Specific}$ improves high-level junior players performances of other forms of in-

1000   line running exercises (e.g., 800, 1200 and 2400-m) with an important aerobic contribution (Sporis

1001   et al. 2008a; Sporis et al. 2008b).

1002   *6.8.2 In-season*

1003   As was already mentioned, most longitudinal studies (Aziz et al. 2005; Casajus 2001; Metaxas et

1004   al. 2006; Mohr et al. 2002; Silvestre et al. 2006) and studies analyzing adaptations from specific

1005   training methodologies (Impellizzeri et al. 2006) did not detect significant further improvements

1006   after the initial increase in VO$_{2max}$ found after the pre-season phase. In fact, extending the

1007   preseason HIA of high-level junior players trough the initial weeks of in-season (7-8 weeks) did

1008   not produce any further substantial increase in the mean VO$_{2max}$ (2006). However, Dupont et al.

1009   (2004) observed that professional players performing 2 weekly sessions of HIT for 10-wks during

1010   the in-season period substantial increased MAS (~9%). Furthermore, Jensen et al. (2009) observed

1011   that U-20 elite players performing just one session of HIA$_{Specific}$ (30-min session per week) during

1012   the last 12-wks of the competitive season, rather than the 2-3 weekly sessions traditionally applied

1013   in the other studies (Dupont et al. 2004; Helgerud et al. 2001; Helgerud et al. 2011; Iaia et al.

1014   2009b; Impellizzeri et al. 2006; Lopez-Segovia et al. 2010; McMillan et al. 2005; Owen et al.

1015   2012; Sporis et al. 2008a; Sporis et al. 2008b; Wong et al. 2010), substantial increase VO$_{2max}$

1016   (~5%) in addition to YYIR2 performance and improved fatigue time during RSA test.

1017 Additionally, an improvement in physiological measures (%HR_{max} and blood lactate

1018 concentrations) during a sub-maximal version of the YYIR1 were observed (87.3% to 81.3%

1019 HR_{max} and from 5 to 2.5 mmol/l, respectively) (Jensen et al. 2009). Particularly, it is likely that

1020 these different findings regarding in-season increments, namely in VO_{2max} may be, among other

1021 factors, partially associated with the initial in-season VO_{2max} of the distinct group of players (initial

1022 values of 52.8-55.7 ml/kg/min in Ferrari-Bravo et al. (2008) and 59.7-61.4 in Impellizery et al.

1023 (2006). In this regard, Wells et al. (2014) observed that the addition of 6-week speed endurance-

1024 based HIT to in-season training routines of professional players increased power, maximal speed,

1025 TE recorded during a maximal anaerobic sprint test, without improvement in certain physiological

1026 determinants of aerobic performance being examined (e.g, VO_{2max}, MAS) (Wells et al. 2014).

1027 Within this period, a substantial increase in YYIR2 performance was also observed. Moreover,

1028 improvement in this field test was only associated with improvements in anaerobic capabilities

1029 (Wells et al. 2014). Furthermore, Owen et al. (2012) observed that $HIA_{Specific}$, conducted two times

1030 per week, during a four week in-season break, resulted in substantial improvements the total sprint

1031 time (1.8%) and the percentage of decrement score (~2.4 vs 1.5%) in an RSA test of elite

1032 professional players.

1033 Among other factors, another important aspect is that most of the studies do not quantify the overall

1034 training load (e.g., session and weekly training load) to which the players are exposed; that

1035 information may allow a better understanding of the different results between studies (Martin et

1036 al. 2022). Indeed, the time spent at high training intensities (pre-season) has been advocated as a

1037 powerful indicator for training monitoring; a positive association between physiological and

1038 performance improvements and the time spent training at high training intensities (e.g., >

1039 90%HR_{max}) has been reported (Casamichana et al. 2013; Castagna et al. 2011; Castagna et al.

1040   2013; Manzi et al. 2013). It has been recommended that professional players should spend at least

1041   a range of 7-8% of their total training volume during the pre-season in the high-intensity category

1042   (Castagna et al. 2013). Additionally, it seems that the weekly magnitude of the individualized

1043   training load (TRIMPi) of professional players should be higher than 500 AU, to substantially

1044   improve aerobic fitness and performance variables during the precompetitive season (Manzi et al.

1045   2013). Moreover, an increase in weekly load by approximately 150-min in duration, 700 AU in

1046   sRPE, 12-km in total distance (TD), 2-km in HSR (>15 km/h; HSR) or 0.8-km min VHSR (>20

1047   km/h) is required to increase the chances of obtaining a $0.5 \ mmol \cdot l^{-1}$ improvement in the lactate

1048   accumulation during a 6 min constant speed running test (13.5 km/h) (Martin et al. 2022). Within

1049   this specific season period, an increase by 40-min in duration, 150 AU in sRPE, 3-km in TD, 1-

1050   km in HSR or 0.5-km in VHSR is required to increase the chances of obtaining a $0.5 \ mmol \cdot l^{-1}$

1051   improvement in the lactate accumulation during a high-intensity intermittent shuttle test (Martin

1052   et al. 2022).

1053 Notwithstanding the previous studies, investigation of the effect of training programs in

1054 professional players is scarce, with more evidence during the preseason period. This is not

1055 surprising given that in professional/elite context due to the obvious limiting factors (e.g, physical

1056 demands of testing, limited time available, congested competition schedules) during in-season

1057 emphasis is given to prepare the strategy for next match and recovery from the stress of the last

1058 competitive match. Given these contextual limitations and that there is no common perspective or

1059 terminology to characterize the caliber and training status of an individual or cohort (McKay et al.

1060 2022), interpret the existent training studies with a critical perspective is a crucial step for informed

1061 decision making.

1062 In summary, during the preparation phase players "recover" cardiorespiratory capacity and the

1063 ability to perform and recover from high-intensity intermittent exercise. Improvements of

1064 moderate magnitude in velocity at fixed blood lactate concentrations ($V_{2\text{-}4\text{mmol/l}}$) and of large

1065 magnitude in VO_{2max}, maximal aerobic speed (MAS) and intense intermittent exercise

1066 performance (IE) are observed after preseason. During in-season, in MCP, are observed generally

1067 better scores when compared to PPS; improvements of moderate magnitude in VO_{2max} and

1068 submaximal intensity exercise and large in MAS and IE. At ECP, increases are of moderate

1069 magnitude in all the examined outcomes. Although more scarcely investigated, from BCP to MCP,

1070 there are observed alterations of trivial magnitude in MAS (decrease) and VO_{2max} (increase) and

1071 of small magnitude in IE (decrease) and sub-maximal exercise (increase). From the MCP to ECP,

1072 the different outcomes decrease with trivial ($V_{2\text{-}4\text{mmol/l}}$ and MAS) and small (VO_{2max} and IE). Match

1073 performance may vary during the season. At the MCP the observed alterations are considered of

1074 trivial magnitude. However, it seems that at the end ECP increments in total distance (small; TD)

1075 and High (HSR; moderate) and Very-high speed running (VHSR; small) and sprint (moderate) are

1076   of substantial magnitude compared the BCP. From the middle to the ECP, the observed increments

1077   are of small (TD, VHSR and sprint) and moderate magnitude (HSR). Although, the variability

1078   between studies is clear for TD, VHSR and sprint, all the studies observed substantial increments

1079   in HSR between the two previous time points. Different training methods or combination of

1080   methods may improve (pre-season) and assist in the maintenance or further improvement (in-

1081   season) of physiological determinants and endurance performance during the season.

1082

1083   **7. What are the challenges?**

1084

1085   *7.1. Research*

1086   Research in soccer uncovers the complexity of interactions established between the different

1087   performance dimensions and the factors that are intrinsic to each player and team. However, the

1088   paucity of in-season data on specific anaerobic/neuromuscular qualities (e.g., anaerobic power,

1089   relative force, rate force development, maximal speed) and physiological and endurance-related

1090   parameters (e.g., RE, VO_2 kinetics, cardiac autonomic adaptations; short heart-rate recovery) that

1091   may be relevant in improving running capacity, should be investigated to allow for a better

1092   understanding of seasonal variations in physical fitness, more robustly, through the in-season

1093   phases. As example, overall systematic analyses of the data revealed better scores in multi-joint,

1094   power-based, dynamic efforts during in-season periods. In part, these observations may lead to the

1095   following proposals: (i) neuromuscular adaptations affecting SSC mechanisms (phase analysis)

1096   may occur throughout the in-season period; and (ii) a composite score of power-based efforts may

1097   be more relevant for tracking the training status of professional players than a single measure, per

1098   se. Future research should also aim to understand seasonal changes in force capabilities during

1099   various velocities conditions and during specific motor tasks (jumping and sprinting) (Morin

1100 2019); efforts are already being developed in this direction (Haugen 2018; Jimenez-Reyes et al.

1101 2022). Moreover, studies aiming in improve the understanding of acute and chronic neuromuscular

1102 and endurance adaptations of professional players triggered by different in-season concurrent

1103 training modes (e.g., two instead of one: build power and endurance at the same time) is necessary.

1104 Research examining the effect of match exposure throughout the season on the performance

1105 adaptation kinetics of professional players is warranted; match-playing time may influence

1106 adaptations of specific and non-specific endurance and neuromuscular parameters during the

1107 season (Hader et al. 2019; Morgans et al. 2017; Silva et al. 2011; Sporis et al. 2011). Furthermore,

1108 understand how the distinct internal and external load parameters (Level 1, 2 and 3 metrics)

1109 experienced by each individual player during the optimization of the distinct performance

1110 dimensions (e.g, tactical) impact players fitness status will be key for optimize the full spectrum

1111 of the physical potential of the players (mechanical and metabolic). Studies characterizing the

1112 periodization of training loads (overall) during the pre-season and in-season periods of

1113 professional players are necessary. Moreover, considering the off-season detraining effects, a

1114 "reorganization" of the periodization during the transition period is necessary (Silva et al. 2016).

1115 In fact, these findings could lead one to question what the usefulness of such a loss of individual

1116 (collective) performance potential during off-season? We recently, made a call to action to

1117 understand how the prescription of off-season individualized training programs may influence

1118 seasonal performance (Silva et al. 2016). We highlighted that this period should be viewed as a

1119 'window of opportunity' for players to recover and to 'rebuild' for the following season (Silva et

1120 al. 2016). 'Rebuild' for a more efficient and consistent in season performance.

1121 The perceptible increase in HSR towards the end-of-season period can be influenced, at least in

1122 part, by an improvement of pacing strategies in some form by professional players. As such, the

1123   development and improvement of conscious and/or sub-conscious pacing strategies (Carling &

1124   Bloomfield 2010; Edwards & Noakes 2009; Mugglestone et al. 2012) that seems to take place

1125   during matches cannot be excluded; there are contradictions regarding the concept of team sport

1126   players pacing their effort throughout the game (Aughey 2010). This fact seems consistent with

1127   the higher physical performance in games towards the end of the season (Mohr et al. 2003;

1128   Rampinini et al. 2007b; Silva et al. 2013b) and in other football codes (Aughey 2011), without

1129   improvements in the majority of physiological and functional parameters; evidence of increases in

1130   certain stress biomarkers have also been reported (Handziski et al. 2006; Heisterberg et al. 2012;

1131   Kraemer et al. 2004; Meyer & Meister 2011; Reinke et al. 2009; Silva et al. 2014; Suda et al.

1132   2012). However, the well know context of the final stage of the competitive season (e.g, definition

1133   of team rank and contract renewal) as obvious impact in players "motivation" to perform. In these

1134   specific periods there is no space to "error", and most likely "Mind will prevail over Muscle"

1135   (Marcora & Staiano 2010; Pessiglione et al. 2007). As so, caution is needed when estimating

1136   players "readiness" from overall match activity profile. Research on these factors is necessary.

1137   A better understanding of roles and tactics of team organization and an improvement in decision-

1138   making during season matches should be taken in account as central variables that may contribute

1139   to maintaining or increasing match performance throughout the season (Vigne et al. 2012).

1140   Interestingly, data on longitudinal changes in match activity throughout the season seem to suggest

1141   an increased match efficiency (ranging from 2.6-6%) during the in-season period (efficiency =

1142   percentage of the total distance performed in high-intensity categories) (Mohr et al. 2003;

1143   Rampinini et al. 2007b; Silva et al. 2013b). Another interesting factor is that high-level soccer

1144   players seem to exhibit superior anticipation capacity accompanied by more effective search

1145   behaviors and elaborative thought processes (Casanova et al. 2013). Nevertheless, the state of

1146   research regarding improvements in perceptual-cognitive processes in highly trained players and

1147   the influence of pacing and match activity remains very scarce. Curiously, elite players with long-

1148   term careers, parallelly to a annual gradual decrease in match-related physical output (0.56%-1.8%

1149   by year) improve technical–tactical skills with increasing age (Rey et al. 2022). 'Integrated'

1150   approachs that contextualizes physical demands in relation to key tactical activities for each

1151   position and collectively for the team are warranted; understanding the physical performance in

1152   relation to the tactical roles (Bradley & Ade 2018). In fact, is not the match running performance

1153   alone that is important for achieving success, but rather its relation to technical/tactical skills

1154   (Hoppe et al. 2015). Finally, the causative factors of the observed long-term changes (evolutionary

1155   trends) are not known and can be related, among others, with processes of players selection (e.g.,

1156   towards more "highly impulsive" players), improvements in facilities and equipment's (e.g., grass

1157   conditions) and training-related processes (e.g., better physical conditioning, training

1158   monitorization and players nutrition and recovery support). Research into the previous components

1159   is necessary.

1160   *7.2. Training*

1161   Although one normally expects than within the season (from BCP to MCP or MCP to ECP) the

1162   consistent training of the physical, tactical, and technical dimensions of performance and as well

1163   the stimulus provided by competitive matches, could lead to a further optimization of players

1164   performance, more robustly concerning the start of competition phase (e.g, BCP to MCP).

1165   However, within these periods there are by average observed changes of trivial magnitude.

1166   Specifically, substantial alterations where evident only for IE (decreased) and sub-maximal

1167   exercise performance (improved). From MCP to ECP all the examined parameters tend to decrease

1168   with a trivial magnitude and substantial negative alterations been observed for VO_{2max} and IE. This

1169   undesirable dynamic in certain physiological determinants and endurance-related performance

1170   measures could be explained by the tight in-season schedule, with most of the time dedicate to

1171   recover from the previous match and prepare the strategy for the next opponent. In this regard, if

1172   a "window of opportunity" occur (e.g, player ban as result of a red card and players not selected

1173   for national team breaks) further in-season improvements in aerobic and anaerobic qualities

1174   determinant for the running capacity and sub-maximal and maximal soccer-running performances

1175   than can be achieved through normal training routines may be obtained by incorporation of short

1176   duration HIT blocks (Christensen et al. 2011; Wahl et al. 2014). As an example, although positive

1177   adaptations in RE have mainly been reported and investigated during the pre-season, there are

1178   recent reports of increased RE (75% of MAS) in players after performing 2 weeks of intense HIT

1179   executed just after the competitive season ended (Christensen et al. 2011); this result suggests that

1180   players still have significant physiological and performance adaptation potential to be explored.

1181   Nevertheless, caution is needed when extrapolating these findings for professional players as these

1182   experimental studies were performed by amateur and semi-professional players (Christensen et al.

1183   2011; Wahl et al. 2014). Nonetheless, it seems that special attention should be given to

1184   neuromuscular involvement during HIT (Bogdanis et al. 2009; Bogdanis et al. 2011) and to the

1185   concurrent effect of HIT (McGawley & Andersson 2013), as it may be a determinant of the gains

1186   in running capacity during a short in-season intervention period. Nevertheless, being a very

1187   sensible process, these intervention periods require individualized management of the

1188   training/match load (Silva & Rebelo 2019). In fact, within the same team a player may

1189   "underperform" as result of an over exposure while other player could be "underperforming"

1190   because of a detraining-related condition (Silva & Rebelo 2019). Finally, the observations of a

1191   long-term persistent trend towards faster players and increased game speed (shorter and more

1192   "explosive" sprints and higher maximal running speeds) as well specific technical variables (e.g.,

1193   passing rates) should be reflected not only on players selection but also in the training organization

1194   (e.g., physical conditioning). Regarding the latter, training should "feed" the players ability to

1195   perform maximal neuromuscular efforts and to repeat them over time; with the level of perceptual-

1196   cognitive demands varying according to each individual player needs.

1197

1198   *7.3 Monitoring*

1199   Notwithstanding some techniques applied in research settings provide valuable information (valid,

1200   reliable), its utilization in routine operations within the club setting is limited (Silva & Rebelo

1201   2019). The imposed physical demands (e.g. maximal tests) and the invasive nature may explain at

1202   least in part the scarce applicability of several techniques in the real-world scenario (Carling et al.

1203   2018). How motivated a player is for performing an end of season maximal testing session? This

1204   has obviously implications in the analyzed performance measures derived from testing sessions

1205   and match analysis, more influential through ECP assessments. Training may represent the perfect

1206   ecological setup to use as a 'lab' and shed some light as to the training status of the player (Silva

1207   & Rebelo 2019). To this aim, a more action-oriented approach is needed; information derived from

1208   training sessions with tools that allow the simultaneous, instantaneous and non-invasive capture

1209   of multiple sources of information (Carling et al. 2018; Morin et al. 2021). As example, there are

1210   specific periods such as the warm-up and/or the main part of the training session (during gym or

1211   field sessions) that can be used to collect more precise information (neuromuscular and

1212   cardiorespiratory) regarding the players training status (Silva & Rebelo 2019). As example, Morin

1213   et al., (2021) recently investigate an in-situ approach to directly assess individual acceleration-

1214   speed profile. Moreover, standardized drills with planned (e.g., sub-maximal running drill and or

1215   passing drills) (Buchheit et al. 2013) and unplanned (e.g., small sided-games) external load

1216   (precise and imprecise behaviors, respectively) can be applied within those parts of training

1217   practice to gain insight on players training status (Brink et al. 2012; Morin et al. 2021; Rago et al.

1218   2017; Rago et al. 2018; Rowell et al. 2018b). As example, given the clear disconnection between

1219   RE assessment methodology and soccer-specific activity during training and matches, there is

1220   some evidence that soccer-specific work economy may somewhat improve during the season; the

1221   relevant gains may not be detectable by conventional treadmill testing (Helgerud et al. 2001;

1222   McMillan et al. 2005). Nevertheless, although this monitoring strategy is not applicable without

1223   the coach's approval, it builds an avenue for increased player "buy in" (Silva & Rebelo 2019). A

1224   wide range of information can be collected during a standardized warm-up (Buchheit et al. 2013)

1225   that can inform on the training status of the athlete (Halson 2014). As an example, the examination

1226   of physiological (HR) and perceptual (RPE) indicators of load in sub-maximal running exercise

1227   can provide valuable information on players cardiorespiratory fitness and fatigue level (Halson

1228   2014). Additionally, information on neuromuscular training status can be collected within this

1229   training stage and other periods (e.g, standardized small-sided game) by means of GPS and

1230   accelerometer-derived metricsto (e.g, load per minute, load triaxial contributions) (Cormack et al.

1231   2013; Morin et al. 2021; Rowell et al. 2018b). This latter monitoring strategy when applied during

1232   specific moments of the microcycle offers a great ecological and valid option for monitoring

1233   training status (Rago et al. 2017; Rago et al. 2018; Rowell et al. 2018b). In fact, this has been

1234   recently investigated in order to overcome the limitations (e.g. time for testing, isolated tests) of

1235   assessing elite players when using more traditional moments and tools (Rago et al. 2017; Rago et

1236   al. 2018; Rowell et al. 2018a). Nevertheless, when using standardized small-sided games, well-

1237 known factors that affect players exercise intensity need to be regarded (e.g. space, duration and

1238 team structure), but alsoteam constitution should be maintained stable (if possible the same players

1239 in each team) (Silva & Rebelo 2019).

1240

1241 **8. Limitations**

1242 It is important to highlight some limitations inherent to this work. In this review, we aggregate

1243 teams from distinct soccer leagues (e.g., European, and Asian). Although we included adults (>19

1244 yrs) soccer players described has professional or elite player, given that there is no common

1245 perspective or terminology to characterize the caliber and training status of an individual or cohort,

1246 we need to consider that a considerable variation in training load and training history may exist

1247 between the included teams (McKay et al. 2022). Secondly, the time length between the different

1248 season moments may vary between studies. As example, in some studies the preparation period

1249 could last four weeks and in others height weeks. Furthermore, season organization may diverge.

1250 In some studies players could had an extended mid-season break (e.g., 2 weeks) due to the winter

1251 environmental conditions (e.g, Romanian League, and German Bundesliga), while in others just a

1252 short number of days for Christmas festivities (e.g, Portuguese, or Spanish leagues) or even this

1253 period being one of the most congested periods of the competition (e.g, English premier league).

1254

1255 **9. Conclusion**

1256

1257 Both short- and long-term detraining during the off-season period seem to have negative effects

1258 on body composition with alterations of small magnitude in body mass, body fat and decrements

1259 of moderate magnitude in lean body mass. The transition period also results in deteriorations of

1260 small to moderate magnitude in jump ability (Non-CMJ and CMJ_{Based}) and linear and

1261 multidirectional speed (acceleration and maximal velocity phase). Furthermore, a large magnitude

1262 in physiological determinants and endurance performance measures (large for VO_{2max} and time to

1263 exhaustion and moderate and very large for intense intermittent exercise) have also been reported.

1264 These detraining effects may influence how players prepare during the pre-season and in-season

1265 and, in a certain way, affect their performance levels, especially in the first matches of the

1266 competitive season (Kraemer et al. 2004).

1267 During the preparation phase players "recover" competitive capacity. The different investigations

1268 suggest that no unique and specific pattern of variation in body composition profile occur during

1269 the pre-season and in-season periods. Nevertheless, the general picture suggests that professional

1270 players may maintain their BM after the start of the training period through improvements of small

1271 magnitude in LBM and BF and with no substantial alterations within the in-season moments. These

1272 biometric alterations signify that chronic exposure of professional players to training and

1273 competition results in improved muscular and adiposity profiles and therefore a better overall body

1274 composition. Neuromuscular adaptations have been observed throughout absolute and relative

1275 measures of force production (1RM and relative force) as well as through jump, sprint, and COD

1276 tests. Specifically, by average, improvements of small magnitude in non-CMJ and CMJ_{Based} jumps,

1277 and the acceleration and maximal velocity phase of the sprint are observed when preparing to

1278 competition phase. In the middle of the competition period, they are observed small (CMJ_{Based} and

1279 ACC_{Phase}), and moderate (non-CMJ and MV_{Phase}) improvements compared to the start of the

1280 preseason phase. However, alterations towards the end of season (ECP) seem to be force-velocity

1281 dependent; CMJ_{Based} and maximal speed improve to a small extent with non-CMJ and sprint

1282 acceleration phase revealing moderate performance increments compared to PPS. A general

1283   analysis suggest that trivial alterations occur withing the in-season (BCP to MCP and MCP to

1284   ECP) in these performance parameters. However, these is the result of the variability observed

1285   between studies; more evident when monitoring the CMJ performance.

1286   Improvements of moderate magnitude in the velocity at fixed blood lactate concentrations ($V_{2\text{-}}$

1287 $_{4mmol/l}$) and of large magnitude in VO_{2max}, MAS and IE are by average observed after preseason.

1288   During in-season, in the MCP, are observed generally better scores when compared to the PPS; by

1289   average, improvements of moderate magnitude in VO_{2max} and submaximal intensity exercise and

1290   large in MAS and IE. At the ECP, the increases in the abovementioned parameters are of moderate

1291   magnitude in all the examined outcomes. Although more scarcely investigated, from BCP to MCP,

1292   there are observed by average alterations of trivial magnitude in MAS (decrease) and VO_{2max}

1293   (increase) and changes of small magnitude in IE (decrease) and sub-maximal intermittent exercise

1294   (increase). From the MCP to ECP, the different outcomes decrease by average with trivial ($V_{2\text{-}}$

1295 $_{4mmol/l}$ and MAS) and small magnitudes (VO_{2max} and IE). Match performance may vary during the

1296   season. At the MCP the observed alterations are by average considered of trivial magnitude.

1297   However, it seems that at the end ECP increments in total distance (small; TD) and distance

1298   performed in High (HSR; moderate) and Very-high speed running (VHSR; small) and sprint

1299   (moderate) speed zones are of substantial magnitude compared the BCP. From the middle to the

1300   ECP, the observed increments are by average of small (total distance, VHSR and sprint) and

1301   moderate magnitude (HSR). Although, the variability between studies is clear for TD, VHSR and

1302   sprint, all the studies observed substantial increments in HSR between the two previous time

1303   points. Finally, studies examining evolutionary trends by means of exercise and competition

1304   performance measures suggests of a heightened importance of neuromuscular factors in soccer.

1305 In conclusion, although an extraordinary growth in the number of scientific investigations

1306 concerning soccer has been observed in the 3ʳᵈ millennium, there is still much to elucidate

1307 regarding the complexity of interactions established between the different performance dimensions

1308 and the factors that are intrinsic to each player and team. Notwithstanding the fundamental role of

1309 the most-up-to date evidence-based training practices and monitoring tools for assure an efficient

1310 a proficient training process, high-level teams' success, and players excellence achievement, will

1311 be always closely dependent of the *specificity* of the training stimulus provided (e.g., nature of the

1312 content) and *sensibility* of the technical staff (e.g., mastery of coach managing players

1313 match/training load) on *driving* the training process.

1314

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Figure 1

Seasonal variations in body composition (average weighted effect sizes).

BM- body mass; BF- absolute and relative body fat; LBM- lean body mass; PPS- prior preseason phase; BCP- beginning competition phase; MCP – middle competition phase; ECP – end of competition phase.

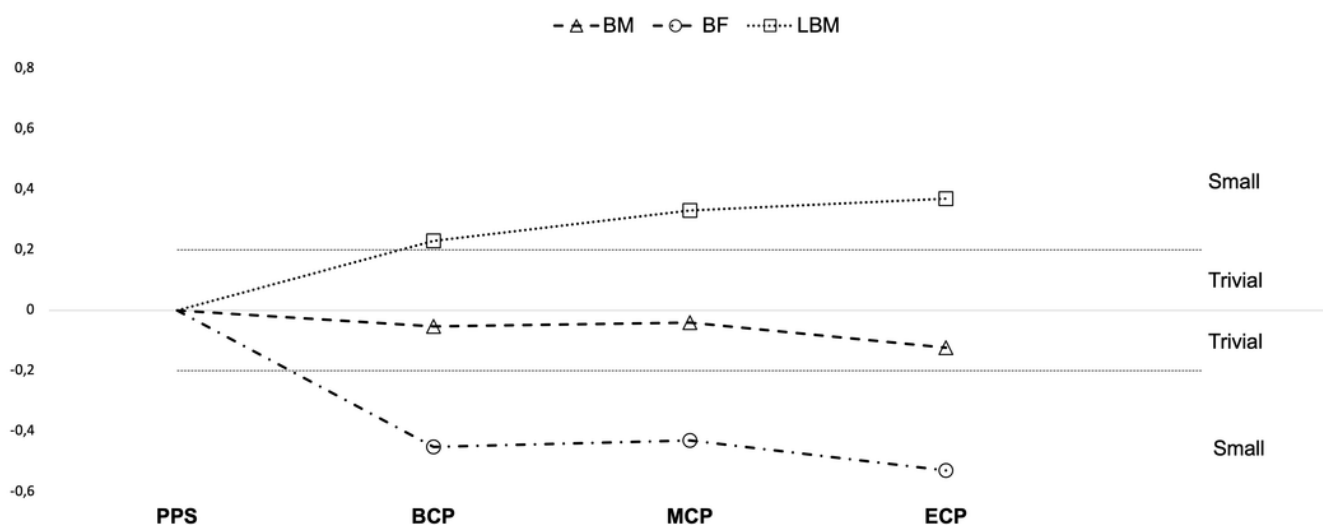



Figure 2

Seasonal variations in absolute and relative body fat (weighted effect sizes).

PPS- prior preseason phase; **BCP-** beginning competition phase; **MCP –** middle competition phase; **ECP –** end of competition phase; Dashed line represents average values

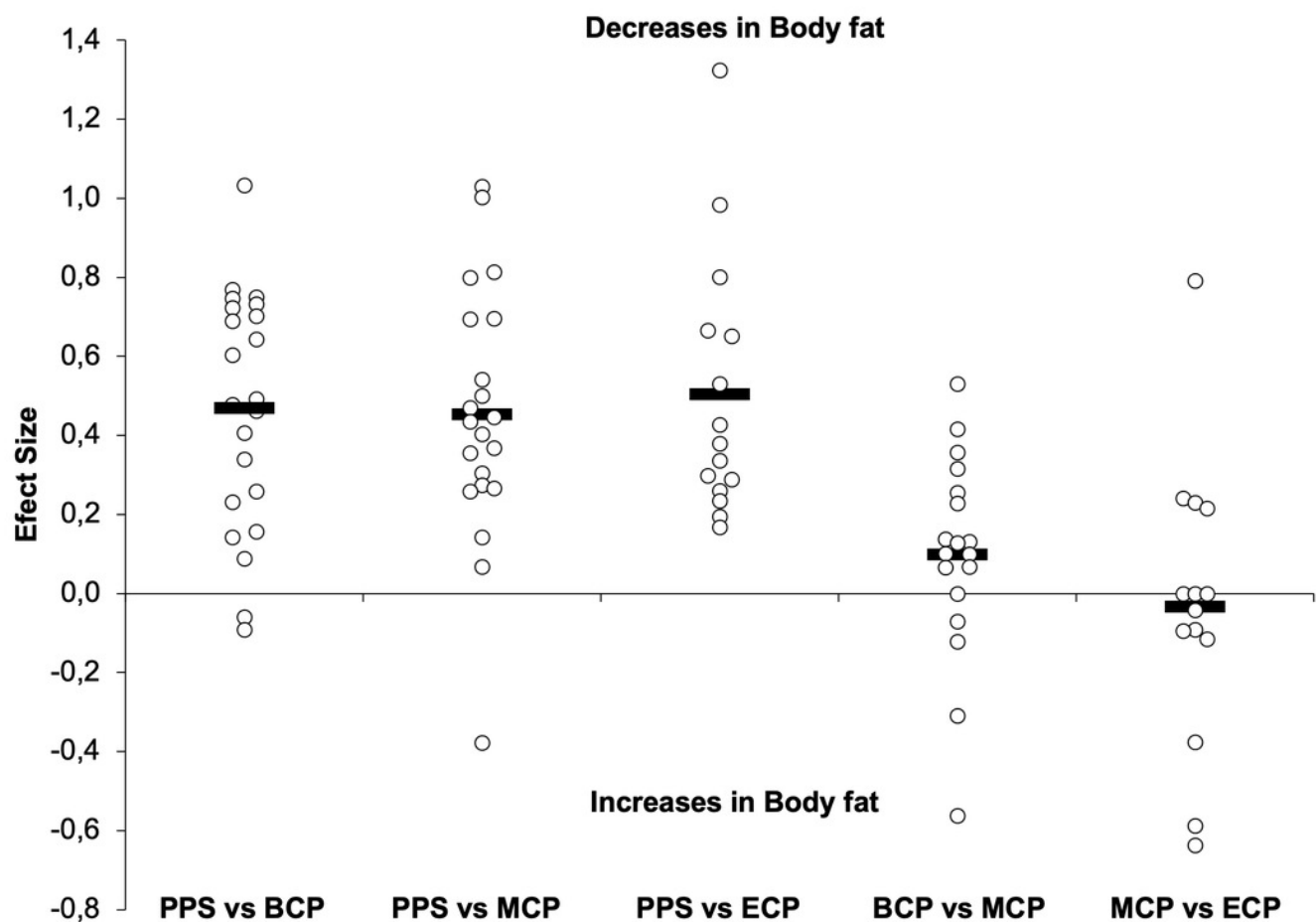



Figure 3

Seasonal variations in Lean Body mass (weighted effect sizes)

PPS- prior preseason phase; BCP- beginning competition phase; MCP – middle competition phase; ECP – end of competition phase; Dashed line represents average values.

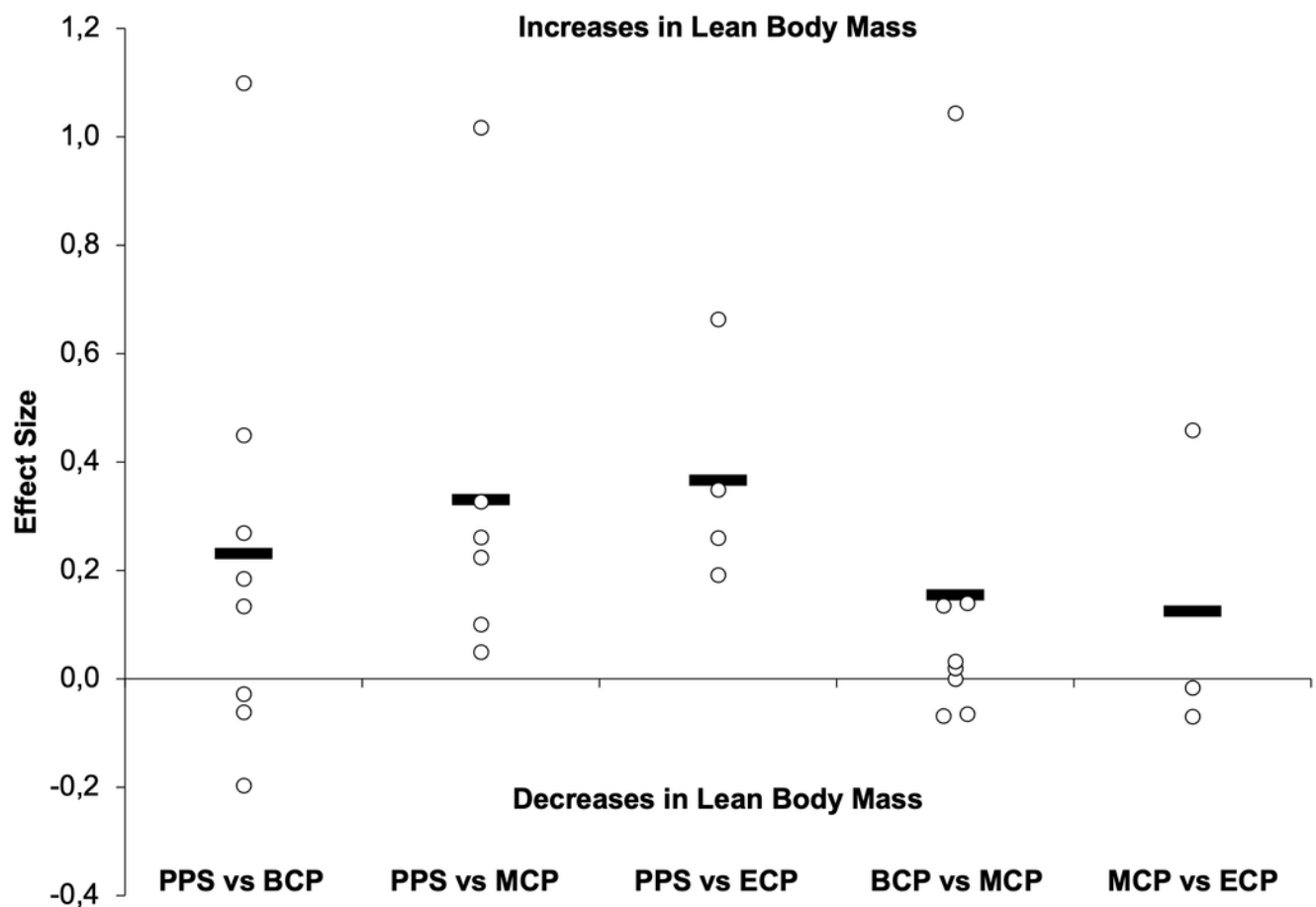



Figure 4

Seasonal variations in neuromuscular performance (average weighted effect sizes).

CMJ$_{Based}$ - single actions including countermovement (countermovement jump with and without arm swing); Non-CMJ - single actions not including a countermovement (squat jump with and without arm swing); ACC$_{Phase}$ - acceleration phase (5-10-15 and 20 meters distances); MV$_{Phase}$ - maximal velocity phase (30 and 50 meters distances); PPS- prior preseason phase; BCP- beginning competition phase; MCP – middle competition phase; ECP – end of competition phase; Dashed line represents average values

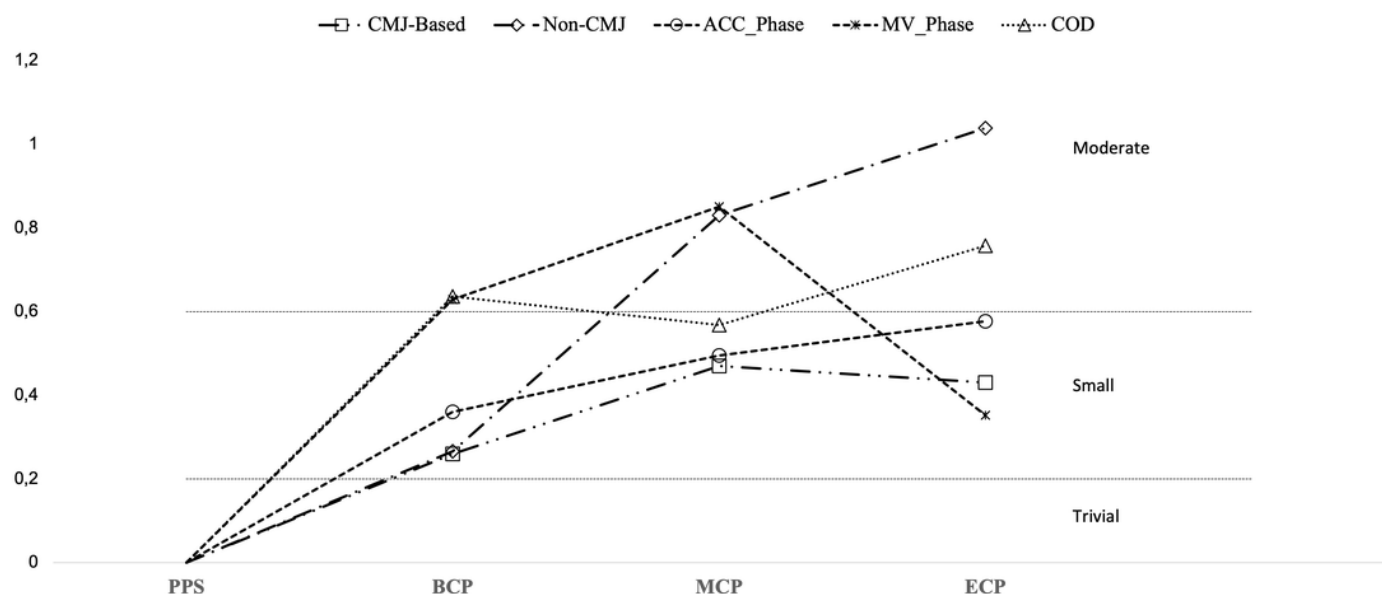



Figure 5

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

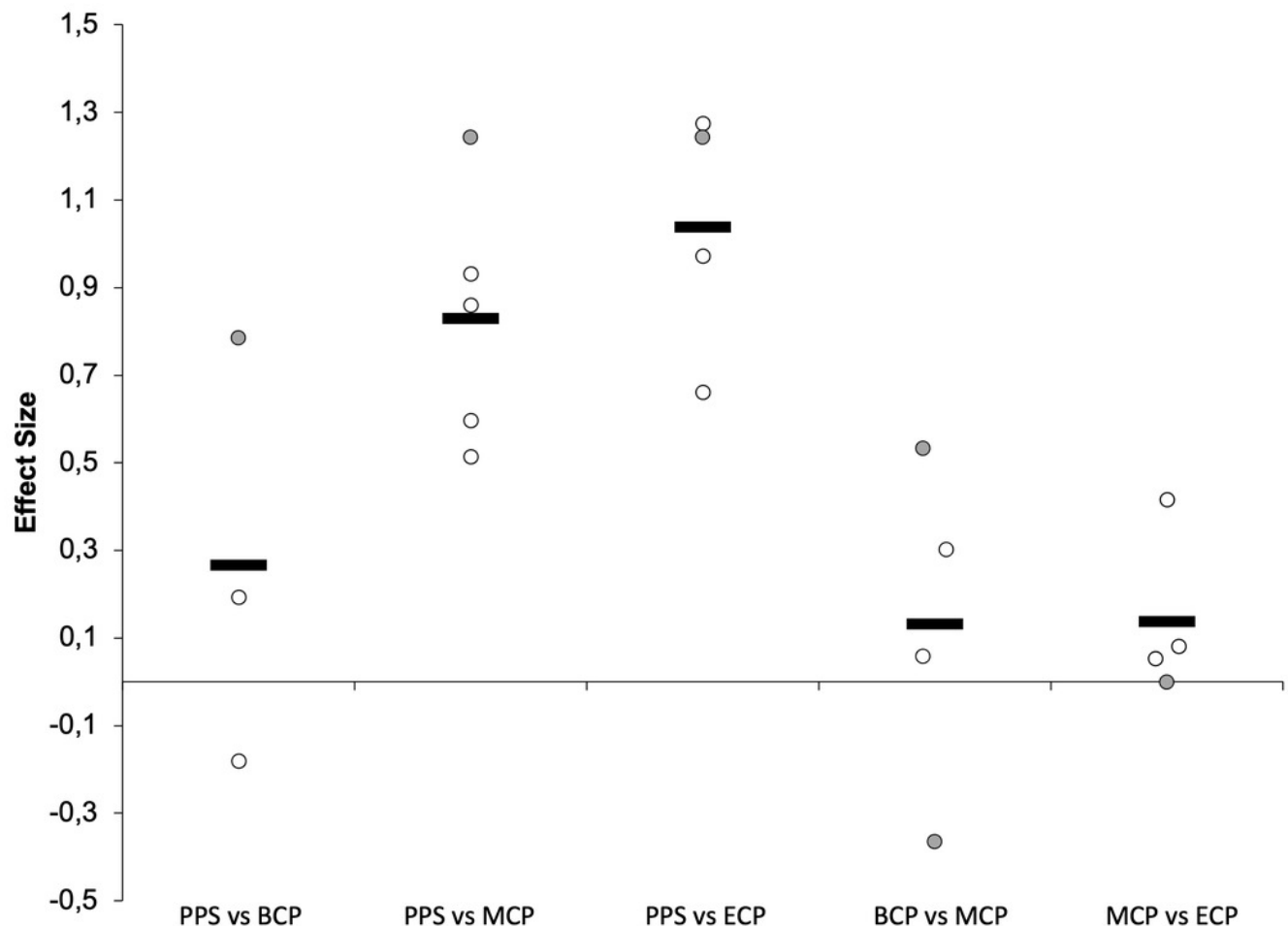



Figure 6

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

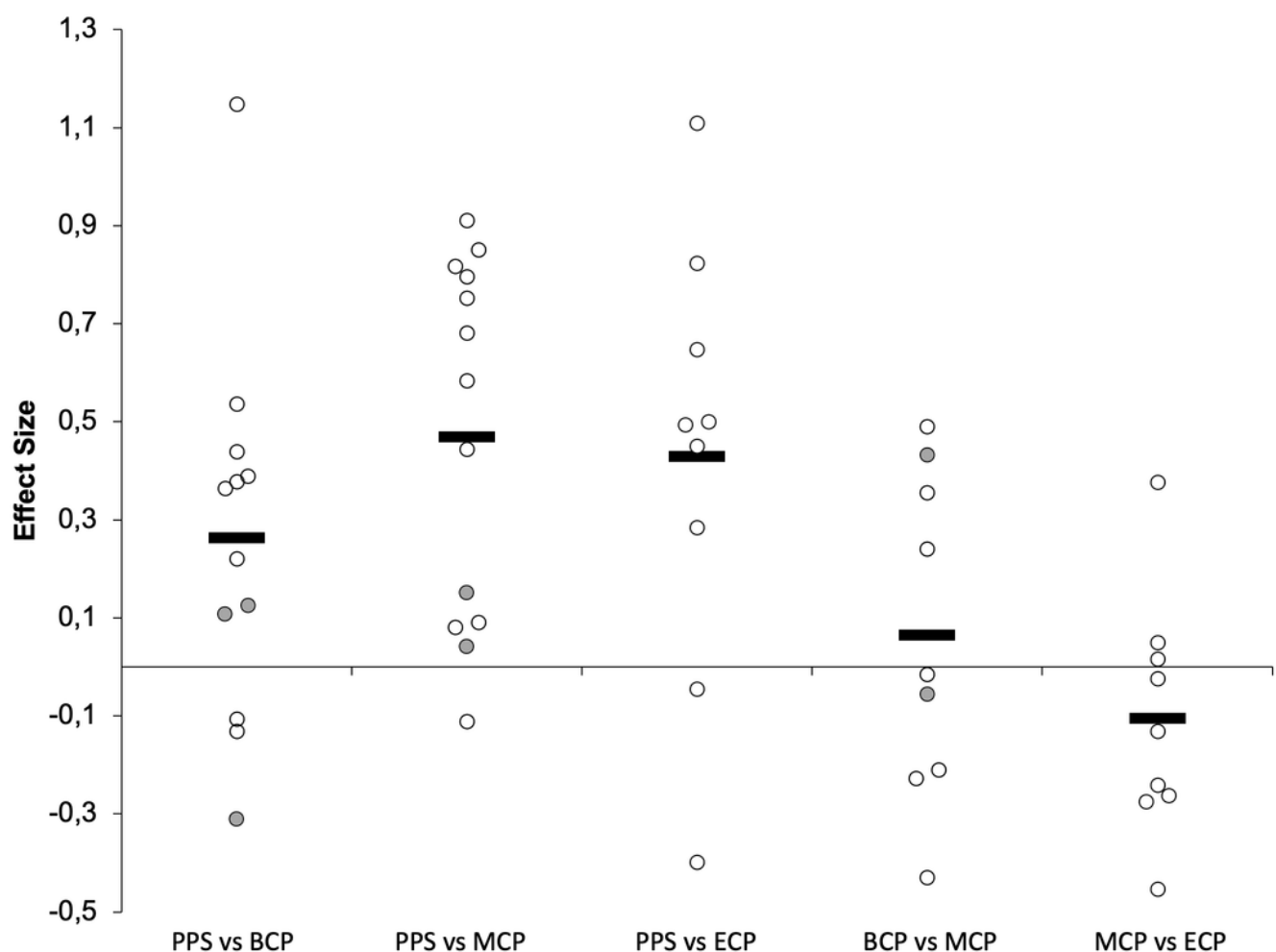



Figure 7

Seasonal variations in the acceleration phase of the sprint (weighted effect sizes)

PPS- prior preseason phase; BCP- beginning competition phase; MCP – middle competition phase; ECP – end of competition phase; Dashed line represents average values

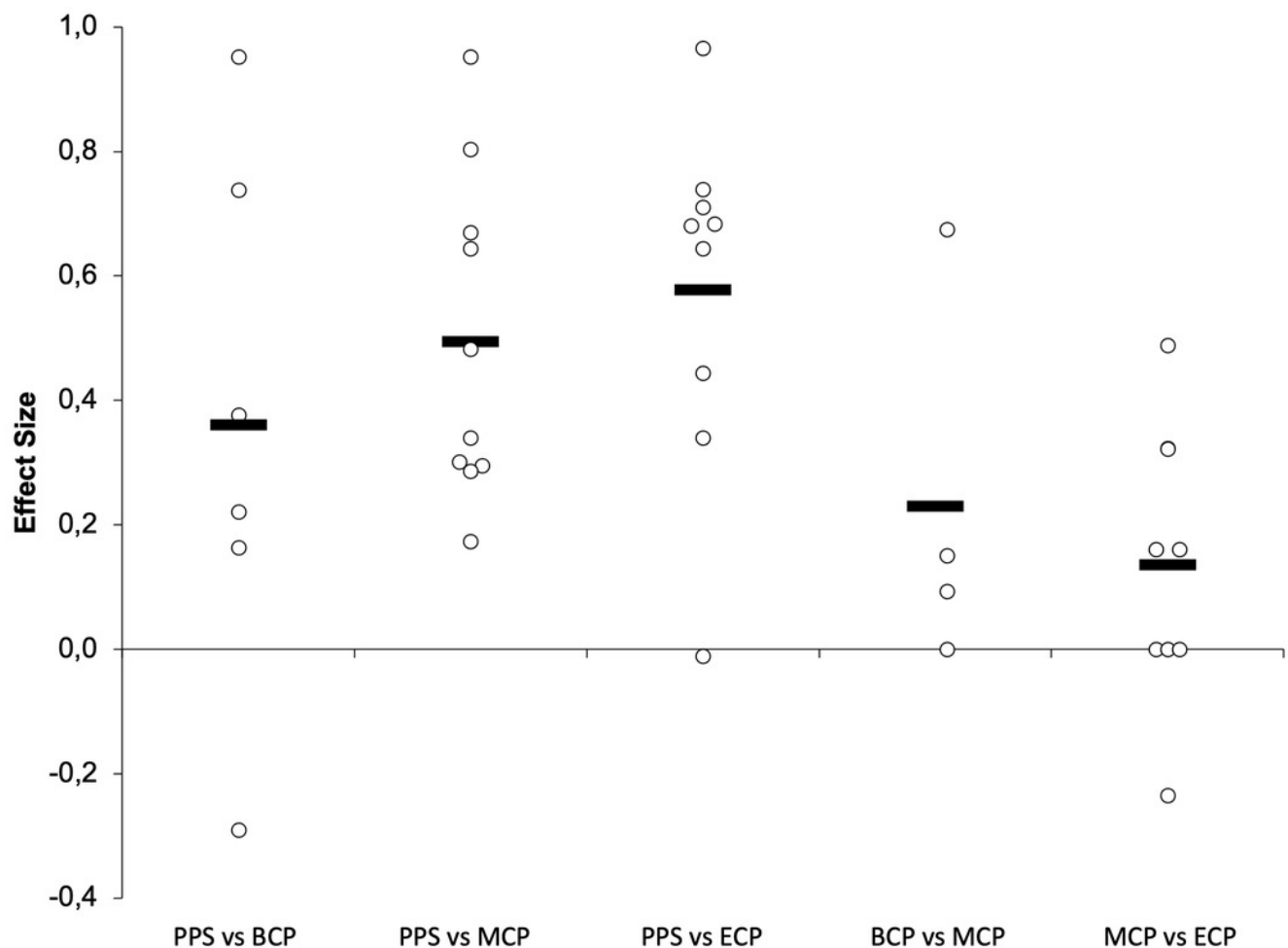



Figure 8

Seasonal variations in the maximal velocity phase of the sprint (weighted effect sizes)

PPS- prior preseason phase; BCP- beginning competition phase; MCP – middle competition phase; ECP – end of competition phase; Dashed line represents average values

Scatter plot with y-axis labeled "Effect Size" ranging from -0,6 to 2,0. X-axis categories: PPS vs BCP, PPS vs MCP, PPS vs ECP, BCP vs MCP, MCP vs ECP.

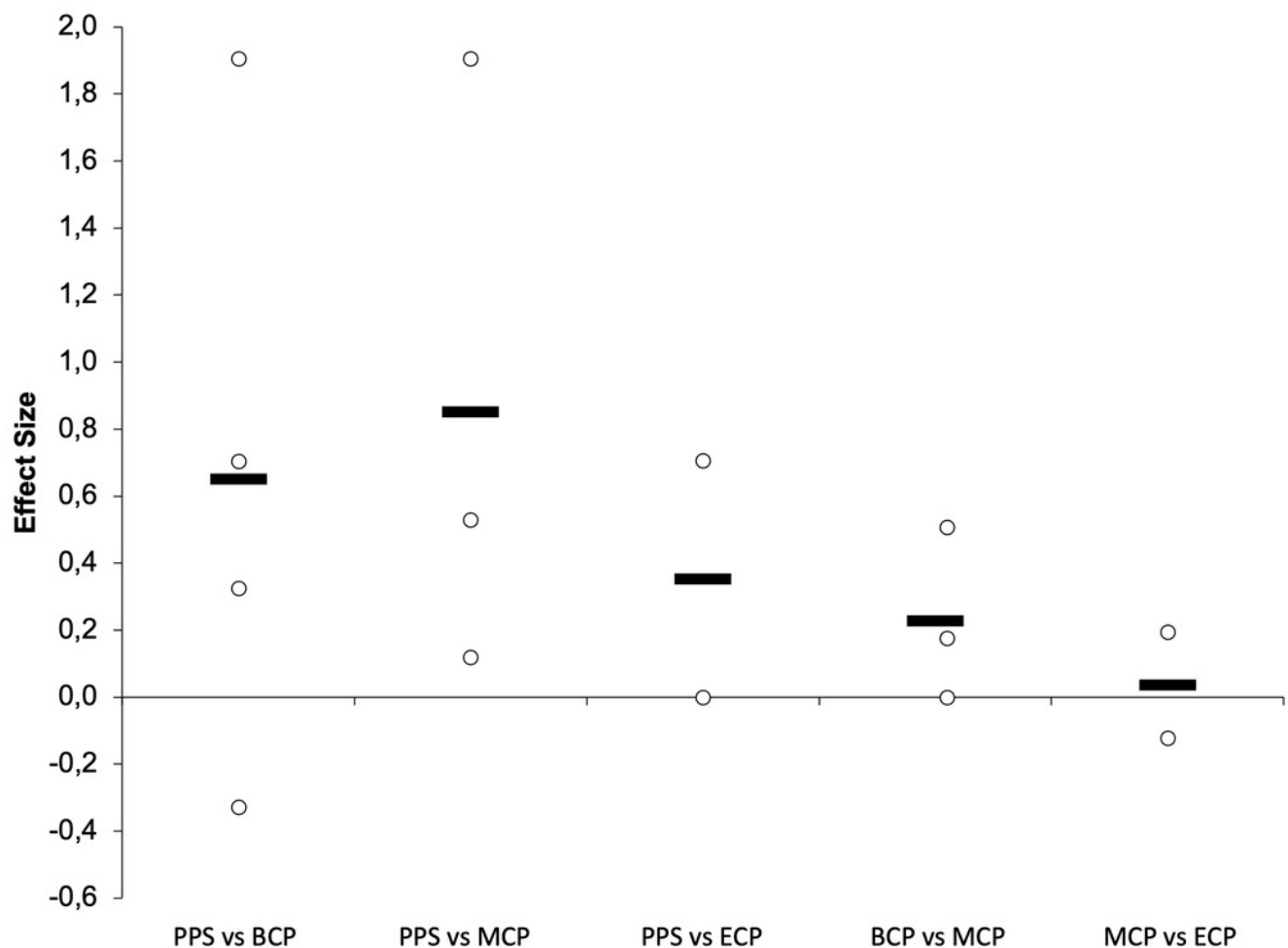



Figure 9

Seasonal variations in physiological determinants and endurance performance (average weighted effect sizes)

VO_{2Max}- maximal oxygen consumption; Speed at sub-maximal intensities- speed recorded at

blood lactate concentrations of 2 and 4 $mmol^{-1}$; MAS- maximal aerobic speed; IE- high-

intensity intermittent exercise (30-15 and YO-YO tests); PPS- prior preseason phase; BCP-

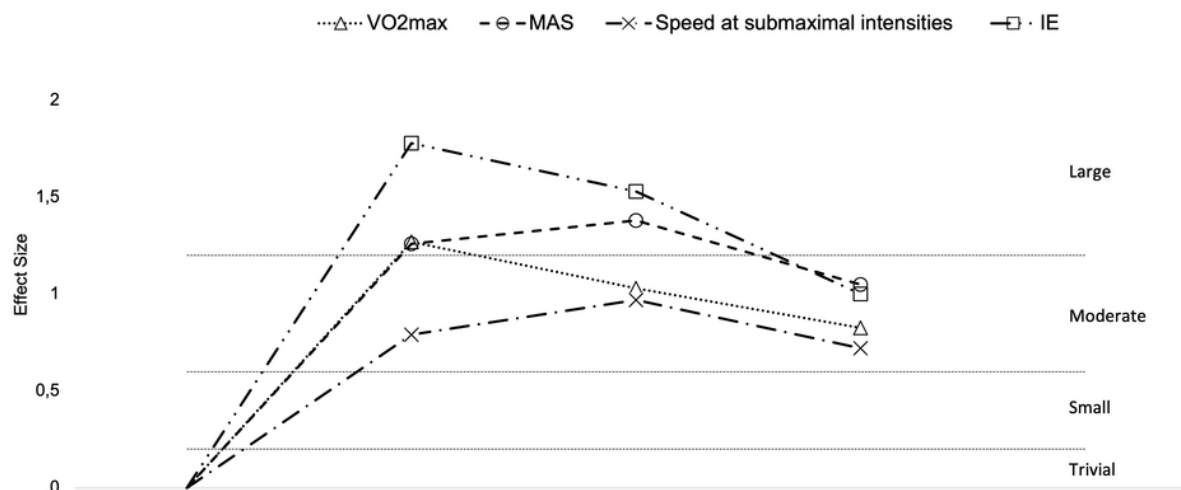
beginning competition phase; MCP – middle competition phase; ECP – end of competition

phase.

Figure 10

Seasonal variations in VO$_{2Max}$ (weighted effect sizes);

PPS- prior preseason phase; BCP- beginning competition phase; MCP – middle competition phase; ECP – end of competition phase; Dashed line represents average values

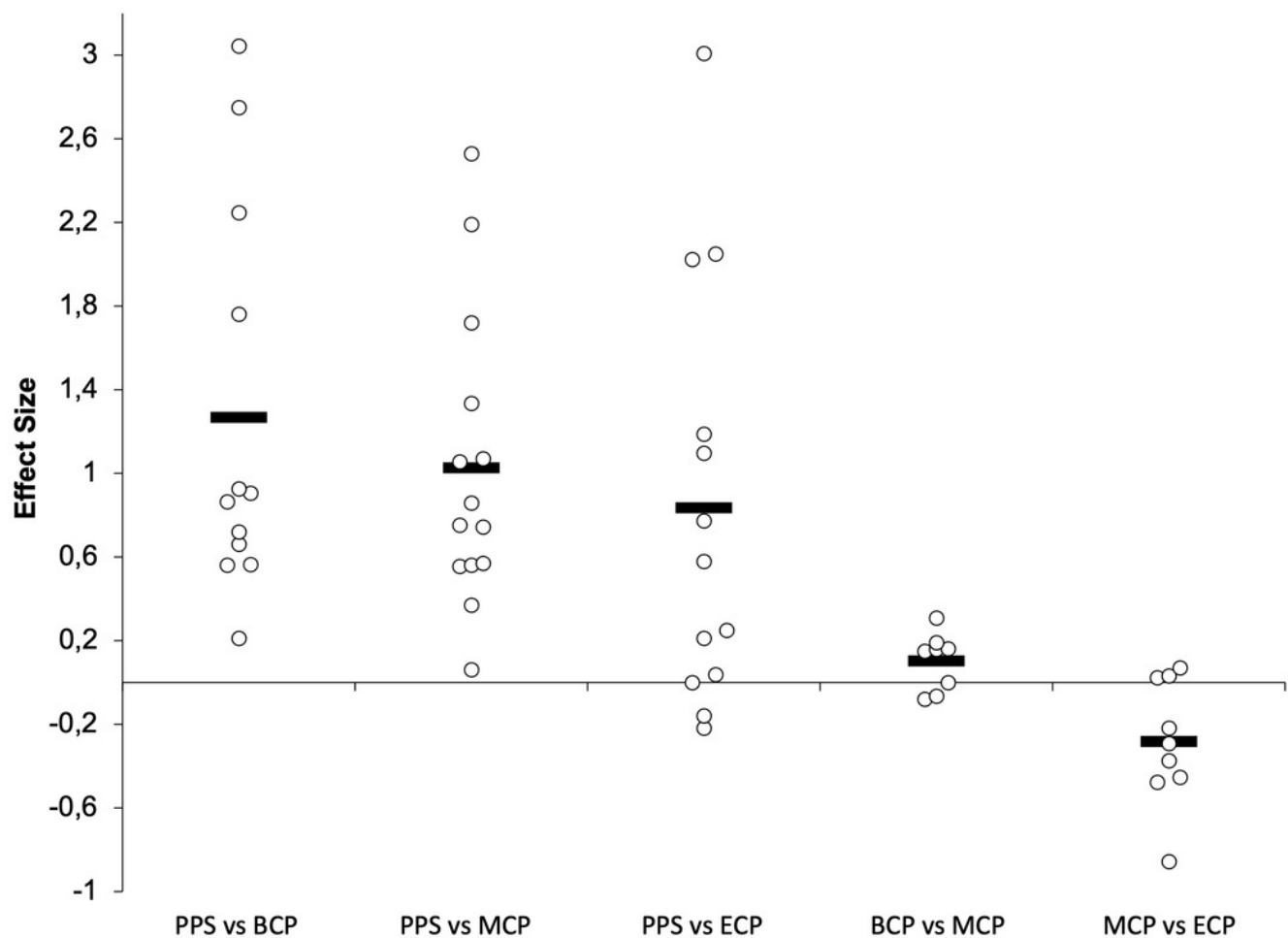



Figure 11

Seasonal variations in maximal aerobic speed (weighted effect sizes)

PPS- prior preseason phase; BCP- beginning competition phase; MCP – middle competition phase; ECP – end of competition phase; Dashed line represents average values

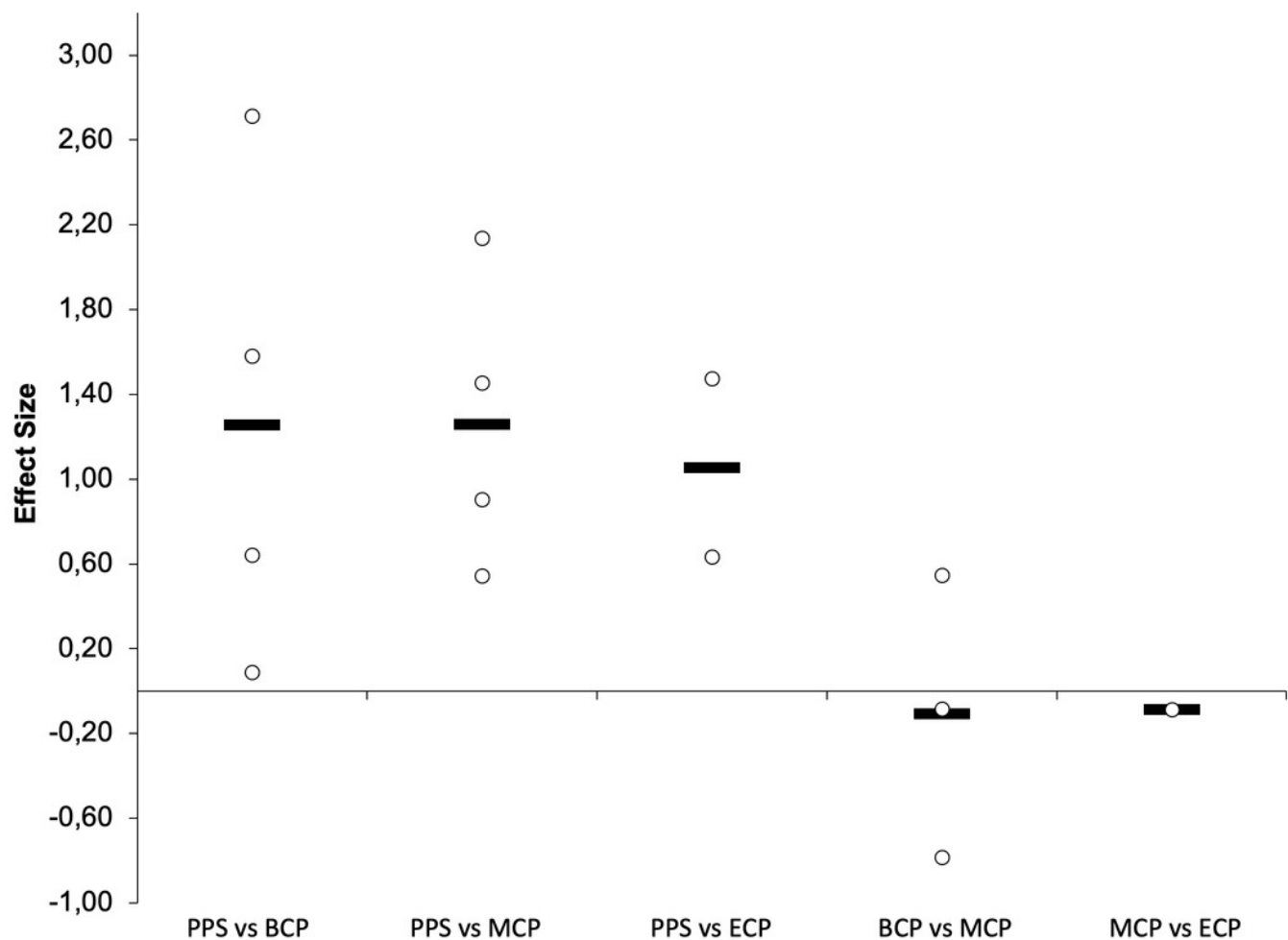



Figure 12

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

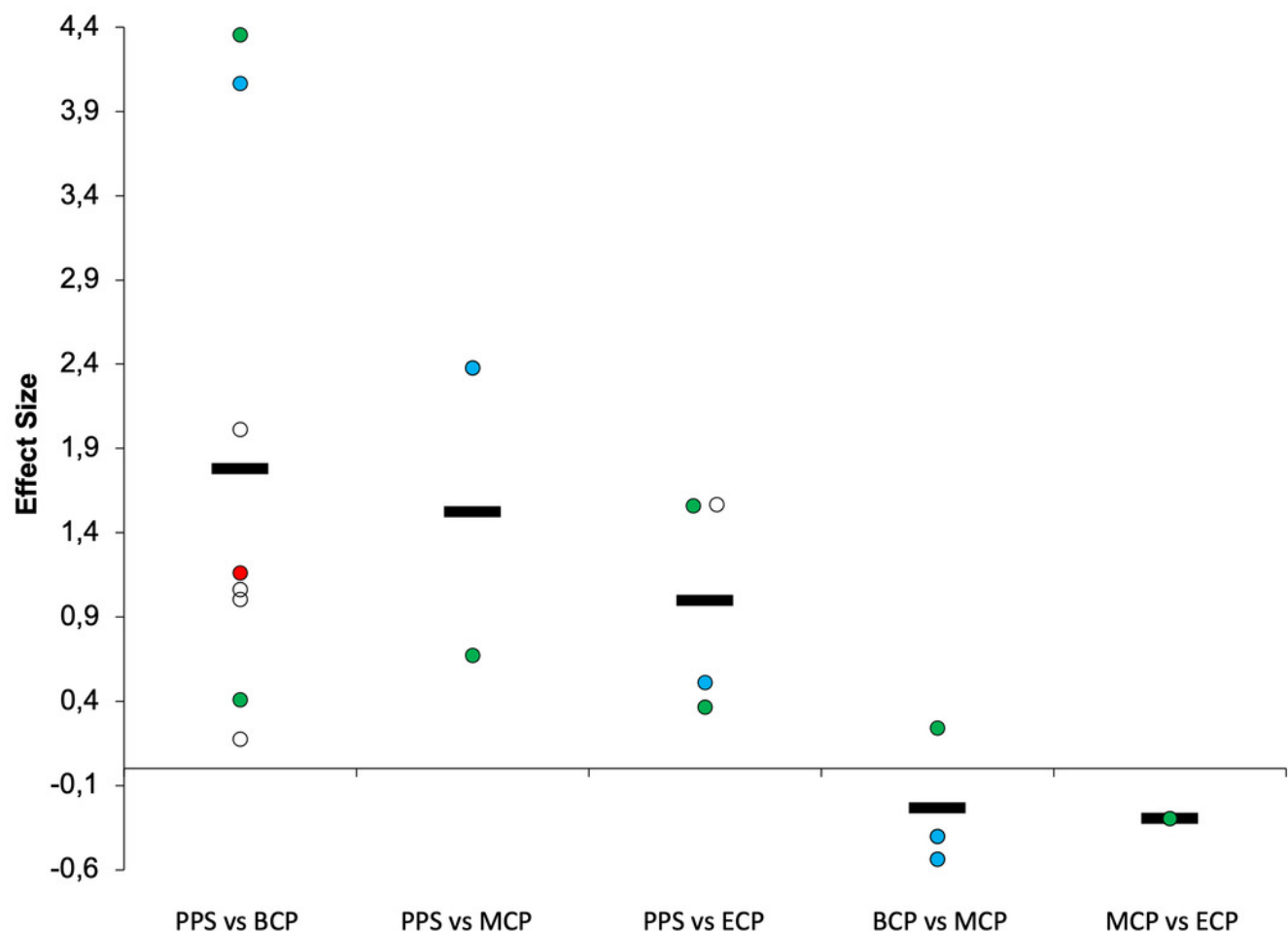



Figure 13

Seasonal variations in game-related physical parameters (average weighted effect sizes)

TD – total distance covered; HSR – high-speed running distance; VHSR – very-high-speed running distance; Sprint- sprint distance. BCP- beginning competition phase; MCP – middle competition phase; ECP – end of competition phase.

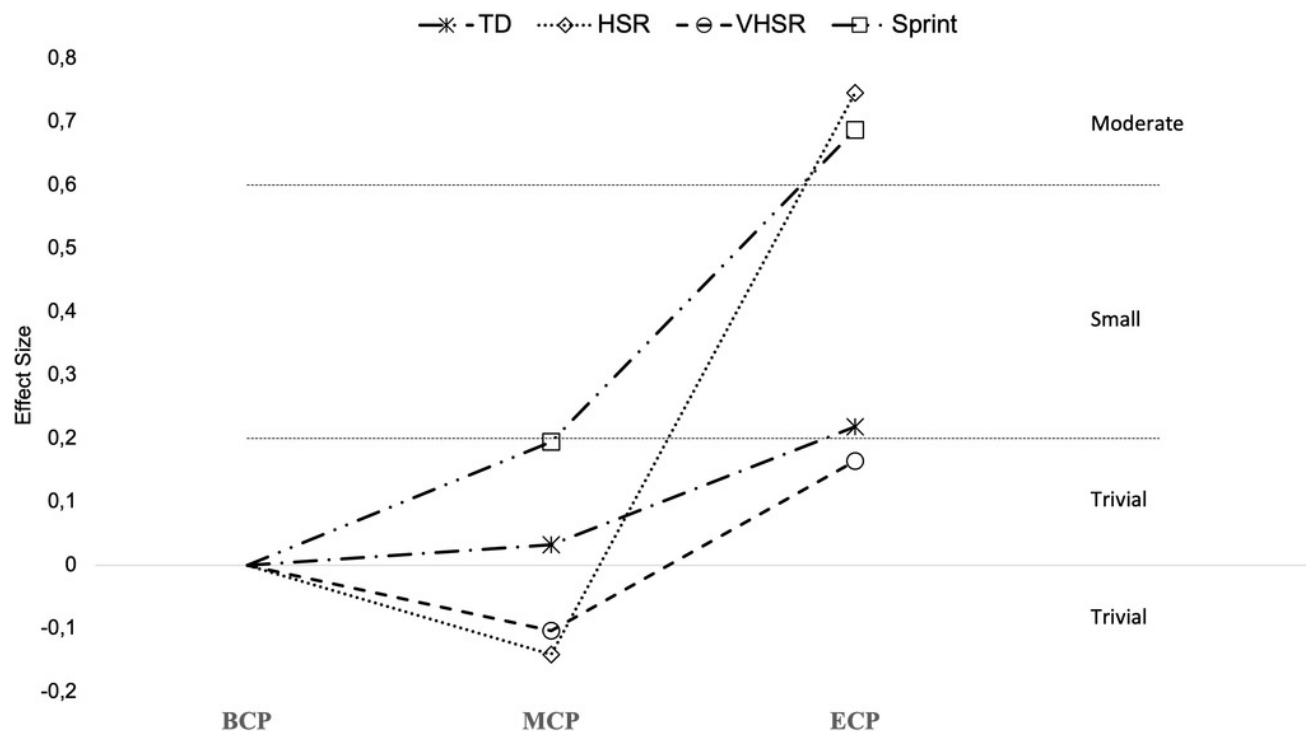



Figure 14

Seasonal variations in total distance covered (weighted effect sizes)

BCP- beginning competition phase; MCP – middle competition phase; ECP – end of competition phase; Dashed line represents average values

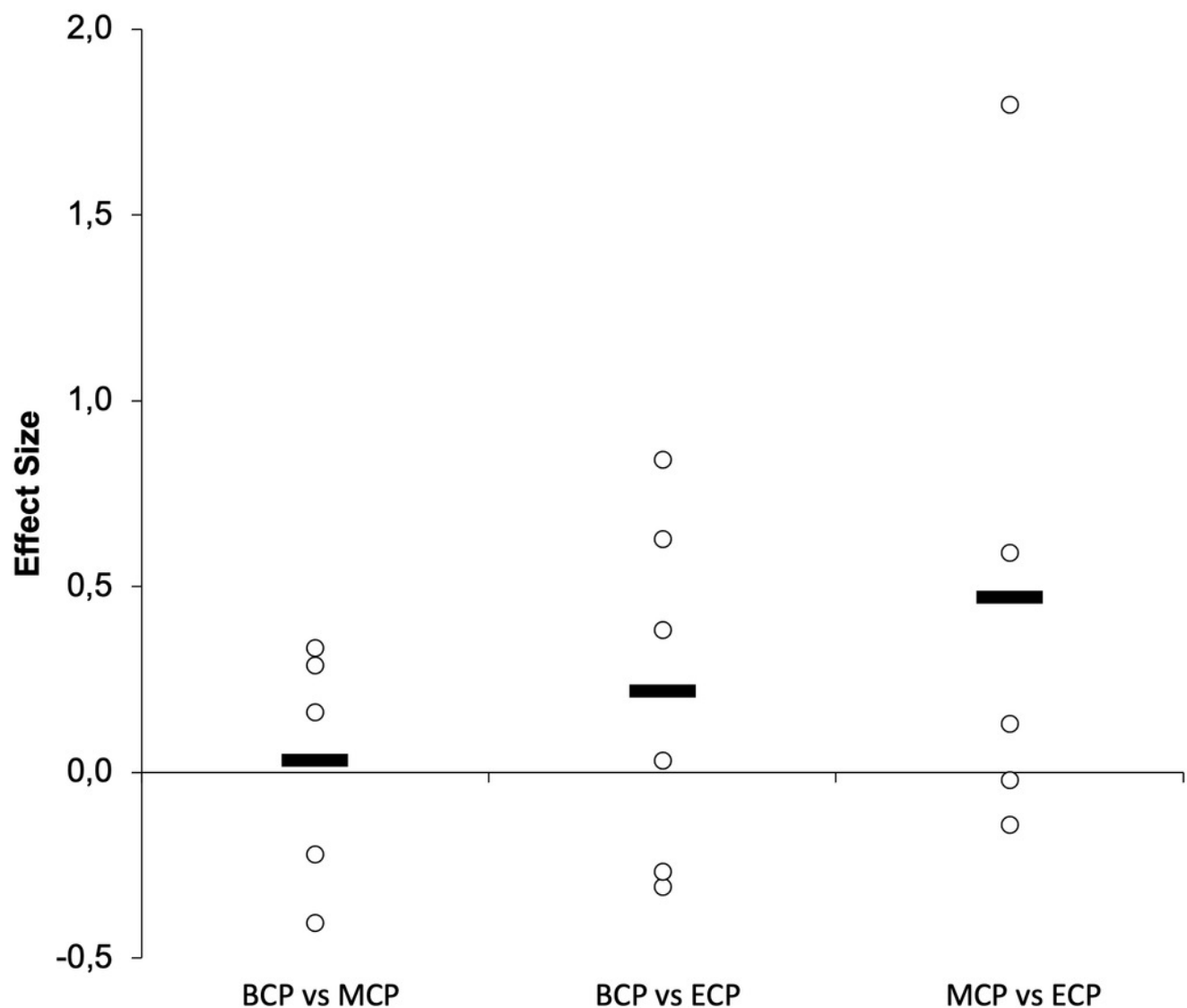
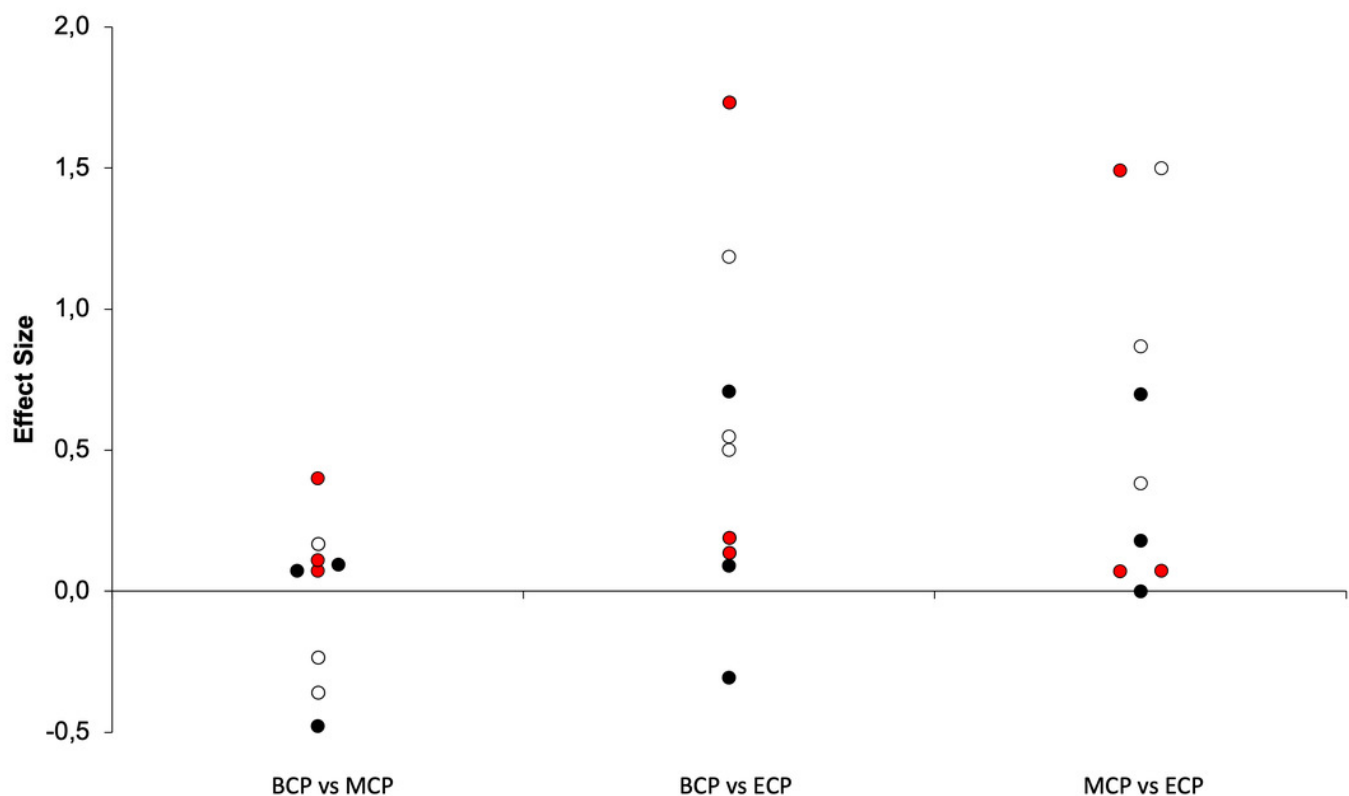



Figure 15

Seasonal variations in high-intensity speed zones (weighted effect sizes)

BCP- beginning competition phase; MCP – middle competition phase; ECP – end of competition phase; white filled circles (HSR); Black filled circles (VHSR); red filled circles (Sprint).

Studies included in the quantitative description of seasonal variations in physical fitness

N – sample size**; PPS -** prior pre-season; **BCP –** beginning competition phase; **MCP –** middle competition phase; **ECP-** end competition phase;

Study	Sample	N (Age)	PPS	BCP	MCP	ECP	Study	Sample	N (Age)	PPS	BCP	MCP	ECP
(Aziz et al. 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-Peñas et al. 2013)	Professional Spain	42 (25)	X	X	X	
(Boullosa et al. 2013)	Elite Spain	12 (24)	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		
	Elite England	15 (U19)	X	X	X	X	(Malliou et al. 2003)	Professional Greece	19 (27.2)	X	X		
(Bunc et al. 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			(Meckel 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			(Michalczyk et al. 2008)	Professional Poland	19 (26.1)	X	X		
(Castagna et al. 2013)	Elite Italy	18 (28.6)	X	X			(Mohr et al. 2003)	Professional Denamark	10 (26.4)		X	X	X
(Clark et al. 2008)	Elite England	10-22 (25)	X		X	X	(Mohr et al. 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'Ascenzi et al. 2013)	Professional Italy	23 (26.6)	X	X	X	X	(Ostojic 2003)	Elite Serbia	30 (23.5)	X	X	X	X
(Devlin et al. 2017)	Elite Australia	18 (25.5)	X	X	X	X	(Ostojic et al. 2009)	Elite Serbia	12 (25.8)	X	X		
(Dunbar 2002)	Professional England	11 (NS-adults)	X	X	X	X	(Owen et al. 2018)	Elite European	22 (24)	X	X		
(Edwards et al. 2003)	Professional England	12 (26.2)	X			X	(Padron-Cabo et al. 2018)	Professional Spain	519 (adult)		X	X	X
(Eliakim et al. 2018)	Professional Israel	31(NS-adults)	X	X			(Papadakis et al. 2015)	Professional Greece	10 (23.6)	X	X	X	X
(Eniseler et al. 2012)	Elite Turkey	14 (25.8)	X			X	(Rampinini et al. 2007)	Professional Italy	20 (26.4)		X	X	X
(Fessi et al. 2016)	Professional Qatarl	17 (23.7)	X	X	X		(Reinke et al. 2009)	Professional Germany	10 (20-36)	X	X		X
(Haritodinis et al. 2004)	Elite Greece	12 (25)	X	X		X	(Requena et al. 2017)	Professional Spain	19 (26.2)	X		X	X
(Iaia et al. 2009)	Professional Denmark	12 (22.4)	X	X	X		(Silva et al. 2013)	Professional Portugal	13 (25.7)		X	X	X
(Iga et al. 2014)	Professional England	35 (20.4)	X	X	X	X	(Silva et al. 2011)	Professional Portugal	18 (25.7)	X	X	X	X
(Kalapotharakos et al. 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							

N – sample size; **PPS -** prior pre-season; **BCP** – beginning competition phase; **MCP** – middle competition phase; **ECP-** end competition phase;

Studies included in the quantitative description of seasonal variations by outcome

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$_{Based}$ –** jumps involving a countermovement jump; **ACC$_{Phase}$** - sprint acceleration phase; **MV$_{Phase}$ –** maximal velocity phase; **COD -** change of direction ability; **VO$_{2max}$ –** maximal oxygen consumption; **MAS –** maximal aerobic speed; **SM –** submaximal intensity exercise**; IE –** intense intermittent exercise; **GPP –** game physical parameters**; CMJ-** countermovement jump; **CMJ$_{WAS}$-** countermovement jump with arm swing; **SJ-** squat jump; **SJ$_{WAS}$-** squat jump with arm swing; **E-** estimated; **D-** direct measurement; **YYIR1-** yo-yo intermittent recovery test level1; **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$_{Speed/HR/VO2}$ –** Speed/Heart rate/ oxygen consumption at ventilatory threshold; **V$_{@2-4mmol/l}$ –** speed at a blood lactate concentration of 2, 3 and 4 mmol/l; **LT$_{Speed}$ –** speed at lactate threshold; **LT$_{VO2}$ –** oxygen consumption at lactate threshold; **HR$_{10-14-18\ km/h}$ –** heart rate at speed of 10 14 and 18 km/h; **%VO$_{2max@4mmol}$ -** percentage of VO$_{2max}$ at a blood lactate concentration of 4 mmol/l; **HR$_{max@4mmol}$ -** percentage of maximal heart rate at a blood lactate concentration of 4 mmol/l; **AT$_{\%VO2max}$ –** percentage of VO2max at the anaerobic threshold;

Study	Body Composition	Strength	Jump Ability		Sprint Ability			VO_{2max}	Endurance			GPP
			Non-CMJ	CMJ_{Based}	ACC_{Phase}	MV_{Phase}	COD		MAS	SM	IE	
(Aziz et al. 2005)	BM; BF		SJ_{WAS}		5-20-m			E				
(Bonuccelli et al. 2012)	BF; LBM											
(Boullosa et al. 2013)									Gacon Test		YYIR1	
(Bradley et al. 2011)											YYIE2	
(Bunc et al. 2015)	BM; BF; LBM							D	Vpeak			
(Campos-Vazquez et al. 2016)											30-15	
(Casajus 2001)	BM; BF; LBM		SJ; SJ_{WAS}	CMJ; CMJ_{15s}				D		VT_{Speed}; VT_{HR}; VT_{VO2}		
(Castagna et al. 2011)										$V_{@2mmol/l}$		
(Castagna et al. 2013)								D		$V_{@2-4mmol/l}$	YYIR1	
(Clark et al. 2008)				CMJ; CMJ_{20s}				D		$AT_{\%VO2max}$		
(Clemente et al. 2021)	BM; BF											
(D'Ascenzi et al. 2013)	BM; BF; LBM											
(Devlin et al. 2017)	BF; LBM											
(Dunbar 2002)										$V_{2-3mmol/l}$		
(Edwards et al. 2003)	BM							D		VT_{VO2}; LT_{VO2}		
(Eliakim et al. 2018)				CMJ				D				
(Eniseler et al. 2012)		KE; KF										
(Fessi et al. 2016)	BM; BF			CMJ; CMJ_{WAS}	10-m	30-m			Vam-Eval			
(Haritodinis et al. 2004)								D				
(Iaia et al. 2009)											YYIR2	
(Iga et al. 2014)	BF											
(Kalapotharakos et al. 2011)	BM; BF							D	vVO_{2max}	$\%VO_{2max}$ & HR_{max} & $V_{@4mmol/l}$		
(Koundourakis et al. 2014)	BM; BF		SJ	CMJ	10-20-m			D				
(Krustrup et al. 2003)											YYIR1	
(Krustrup et al. 2006)											YYIR2	
(Lago-Peñas et al. 2013)	BM; BF		SJ	CMJ; CMJ_{WAS}				D	Vam-Eval			
(Link & de Lorenzo 2016)												TD
(Los Arcos et al. 2015)	BM; BF			CMJ; CMJ_{WAS}	5-15-m					$V_{@3mmol/l}$		

Study	Body Composition	Strength	Jump Ability		Sprint Ability			VO$_{2max}$	Endurance			GPP
			Non-CMJ	CMJ$_{Based}$	ACC$_{Phase}$	MV$_{Phase}$	COD		MAS	SM	IE	
(Malliou et al. 2003)		KE	SJ	CMJ								
(Manzi et al. 2013)								D		V$_{@4mmol/l}$; VT$_{VO2}$	YYIR1	
(Meckel et al. 2018)	BM; BF			CMJ			4x10-m	D		VT$_{Speed}$		
(Metaxas et al. 2006)	BM; BF; LBM							D				
(Michalczyk et al. 2008)	BM							D				
(Mohr et al. 2003)								D				TD; HSR
(Mohr et al. 2002)										HR$_{10-14-18 \, km/h}$		
(Morgans et al. 2014)												TD; VHSR; Sprint
(Ostojic 2003)	BM; BF; LBM					50-m						
(Ostojic et al. 2009)	BM; BF			CMJ								
(Owen et al. 2018)	BF; LBM											
(Padron-Cabo et al. 2018)												TD; VHSR; Sprint
(Papadakis et al. 2015)	BF			CMJ						V$_{@2-4mmol/l}$		
(Rampinini et al. 2007)												TD; HSR VHSR
(Reinke et al. 2009)	BM; BF											
(Requena et al. 2017)	BM; BF; LBM			CMJ	15-m				Vam-Eval			
(Silva et al. 2013)												TD; HSR; Sprint
(Silva et al. 2011)	BM; BF	KE; KF		CMJ	5-m	30-m	T-test				YYIE2	
(Suda et al. 2012)	BM; BF; LBM											
(Zoppi et al. 2006)						30-m				LT$_{Speed}$		

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$_{Based}$** – jumps involving a countermovement jump; **ACC$_{Phase}$** - sprint acceleration phase; **MV$_{Phase}$** – maximal velocity phase; **COD** - change of direction ability; **VO$_{2max}$** – maximal oxygen consumption; **MAS** – maximal aerobic speed; **SM** – submaximal intensity exercise; **IE** – intense intermittent exercise; **GPP** – game physical parameters; **CMJ-** countermovement jump; **CMJ$_{WAS}$-** countermovement jump with arm swing; **SJ-** squat jump; **SJ$_{WAS}$-** squat jump with arm swing; **E-** estimated; **D-** direct measurement; **YYIR1-** yo-yo intermittent recovery test level1; **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$_{Speed/HR/VO2}$** – Speed/Heart rate/ oxygen consumption at ventilatory threshold; **V$_{@2-4mmol/l}$** – speed at a blood lactate concentration of 2, 3 and 4 mmol/l; **LT$_{Speed}$** – speed at lactate threshold; **LT$_{VO2}$** – oxygen consumption at lactate threshold; **HR$_{10-14-18 \, km/h}$** – heart rate at speed of 10 14 and 18 km/h; **%VO$_{2max@4mmol}$** - percentage of VO$_{2max}$ at a blood lactate concentration of 4 mmol/l; **HR$_{max@4mmol}$** - percentage of maximal heart rate at a blood lactate concentration of 4 mmol/l; **AT$_{\%VO2max}$** – percentage of VO2max at the anaerobic threshold;