Adaptability of performance to different contextual constraints as a predictor of development and success in competitive football: A systematic review

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2 development and success in competitive football: A systematic review

3

4 Abstract

5 This systematic review organizes the literature regarding the influence of contextual

6 constraints on football match action profiles, in order to inform better practice when

7 utilized a data-informed approach towards identifying and predicting high performing

8 football players. Furthermore, the validity of examining 'on-ball' match actions in

9 competitive matches as an indicator of performance was also investigated. Based on the

10 studies reviewed, task and environmental constraints were highlighted to be significantly

11 influential on match actions performed, which suggests that recruitment strategies may be

12 more successful if there were a greater emphasis on identifying players that best fit the

13 constraints unique to the team, rather than recruiting the 'best' player in the position.

14 Additionally, the ability to adapt and successfully produce goal-directed behaviour in a

15 variety of contexts may therefore be indicative of future high performance. Results from

16 existing studies suggest that match actions performed in competitive matches can

17 significantly distinguish between higher and lower performing teams or individuals.

18 However, given the largely retrospective study designs of existing studies, a shift towards

19 prospective study designs utilizing machine learning or statistical modelling is proposed to

20 increase the practical applicability of theoretical findings.

21 *Keywords*: ecological dynamics, match actions, adaptability, performance environment,

22 performance analysis

23

24   Abstract

25   L'évaluation des performances dans le football reste un défi auquel sont souvent

26   confrontés les chercheurs et les praticiens du football, spécifiquement compte tenu de

27   l'évolution constante des contraintes rencontrées dans le jeu à la fois au niveau individuel

28   mais également au niveau collectif. Dans l'objectif de rendre l'analyse la plus objective et

29   la plus complète possible, principalement lors de l'identification et la prédiction de la

30   performance, l'utilisation des données de match se doit d'être basée sur des fondements

31   théoriques de la performance sportive. La présente revue systématique se propose ainsi

32   d'organiser la littérature qui s'intéresse à l'identification et la prédiction de la performance

33   en football en fonction des diverses contraintes de tâches ou d'environnement qui les

34   influencent. Plus précisément, l'utilité des données de match comme indicateur de

35   performance est discutée. A partir des études identifiées dans la littérature, les contraintes

36   de tâches et d'environnement qui influencent significativement le jeu sont discutées,

37   suggérant que les stratégies de recrutement pourraient s'optimiser par l'identification des

38   joueurs qui seraient les « plus adaptés » aux contraintes spécifiques d'une équipe plutôt que

39   de recruter le « meilleurs » joueur de son poste. De plus, outre la production idéale d'un

40   seul comportement précis, la capacité de s'adapter et de produire avec succès un large panel

41   de comportements qui sont spécifiquement efficaces dans un contexte donné, autrement dit

42   la capacité de montrer un haut niveau de flexibilité dans le jeu, peut s'avérer être révélatrice

43   de performances élevées futures. Les résultats des études existantes suggèrent que les

44   actions de match en compétition permettent effectivement de distinguer les joueurs les plus

45   performants des joueurs moins performants. Cependant, les conceptions de ces études étant

46   largement rétrospectives, le développement d'étude prospectives utilisant des modélisations

3

47   statistiques est proposé afin d'accroître l'utilisabilité des résultats observés dans ce domaine

48   de recherche de la prédiction de la performance.

49

50   *Keywords*: dynamique écologique, actions de match, adaptabilité, environnement de

51   performance, analyse de performance

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4

53   Highlights

54   • Task and environmental constraints critically influence the match actions demanded

55   of football players, therefore data-informed systems of talent identification or

56   recruitment should seek to identify the best-fitting player instead of seeking to

57   identify the 'best' player in the position.

58   • Due to the significant influence of task and environmental constraints that are

59   constantly changing, existing evidence suggests that a player's ability to adapt to a

60   variety of contexts may potentially be a crucial indicator of performance.

61   • Match actions performed in competitive football matches are strong indicators of

62   performance, but future research should utilize more prospective-oriented or

63   predictive study designs in order to increase the practical implications of theoretical

64   findings in this area of research.

65

66

67   **Introduction**

68   In the modern era of association football, the exponential increase in financial

69   returns associated with succeeding at the highest performance level, has spurred football

70   organizations to incorporate a more quantifiable, data-informed approach to guide strategic

71   operations (Schildkamp & Kuiper, 2010). To increase their potential for success, football

72   organizations seek to statistically evaluate, compare or predict the level of individual or

73   team performance more proficiently than their competitors. In doing so, these organisations

74   seek to gain advantages, especially in performance analytics-driven talent identification and

75   recruitment. However, the process of scientifically comparing or predicting performance

76   quality in football is less straightforward compared to sports with more stable performance

77   environments, such as archery, weightlifting or long jumping. In these sports, formal

78   definitions of quality are more easily identified (i.e., arrow placement accuracy, weight

79   lifted, or distance jumped respectively) and a relational order between performances can be

80   readily determined (Pappalardo et al., 2019).

81   Traditionally, to explain and evaluate performance, researchers tended to

82   operationalise a set of 'objective and universal' indicators of performance quality by

83   deconstructing evaluation procedures into isolated, sport-specific performance measures

84   such as general agility, speed endurance and sprinting power that are assessed outside of

85   competitive matches (Höner et al., 2015; Lago-Peñas et al., 2014; Rommers et al., 2019).

86   Other such evaluations have focused on frequency analyses of sport specific actions such as

87   dribbling, shooting at goal and number of completed passes (Höner et al., 2015; Rommers

88   et al., 2019). However, such action-oriented approaches have shown limited accuracy in

89   discriminating and predicting future competitive football performance, possibly because

90   frequency analyses based on recording "context-free" actions do not consider performance

91   in the highly dynamic and interactive demands of the competitive environment, as they

92   only arise with the introduction of teammates, opposition and a competitive match setting

93   (Correia et al., 2013; Travassos et al., 2013). In response to limitations of this de-

94   contextualised, behaviouristic approach, an ecological dynamics rationale postulates that

95   'context is everything' in analysis and evaluation (Rothwell et al., 2020). A contextualised

96   approach to performance analytics implies that a more precise evaluation of football

97   performance is one that involves the continuous interactions that emerge between the

98   performer(s) and their environment. In ecological dynamics, such an approach is required

99   because of the deep interconnectedness between intentions, perceptions, and actions of

100   sport performers needed when interacting with the emerging performance contexts (Davids

101   et al., 2013; Travassos et al., 2013).

102   Building on the shift towards using theoretical principles of ecological dynamics as

103   a framework for performance analytics, researchers in recent years have examined actions

104   during competition to assess competitive performance (Gama et al., 2020; Sarmento et al.,

105   2018). Data on competitive match performance, have sought to describe and explain 'on-

106   ball' actions emerging from players during competitive matches (e.g., opportunities

107   (affordances) for performing penetrative passes, shots, tackles, interceptions). Such data

108   have been proposed as more reliable measures of footballing performance because they are

109   emergent from a performer's interactions with competitive contextual constraints, and are

110   shaped by the key constraints of a sport context (Den Hartigh et al., 2018; Koopmann et al.,

111   2020).

112   **Ecological dynamics and performance analytics: Context is everything!**

113   An ecological dynamics rationale suggests that, to meaningfully utilize frequency

114   data on match actions as a valid performance measure, due consideration of contextual

115   constraints is important (Den Hartigh et al., 2018). This proposition has been corroborated

116   by previous research highlighting the importance of task and environmental constraints,

117   such as the type of competition in which match actions were performed (Fernandez-

118   Navarro et al., 2016) and/or effects of opposition quality (Castellano et al., 2013), and their

119   significant influence on player behaviours and match actions.

120   With this theoretical backdrop, this systematic review seeks to organize existing

121   literature using a data-informed approach for identifying and predicting high performers in

122   football at present. To achieve our aim, we used an ecological dynamics framework to

123   identify and theoretically organize the literature on: (1) the various environmental and task

124   constraints found to significantly influence match action profiles, and (2), football match

125   action data in relation to performance by profiling the purpose and key findings of the

126   studies. We also identified common research methodologies and highlighted potential

127   directions of future work. The following research questions were examined:

128   1. What are the environmental or task constraints that significantly influence the

129   frequency of specific match actions and what is the direction and magnitude of their

130   influence?

131   2. Are the technical actions observed during competitive football matches a significant

132   indicator or predictor of performance?

133   In relation to these two research questions, considering the ecological dynamics

134   theoretical framework highlighted in the introduction, we hypothesized that (1)

135   environmental and task constraints significant influence the frequency of match actions,

136 and that (2) future performance can be significantly classified or predicted by examining

137 actions performed during actual football matches.

<div align="center">**Methods**</div>

Search and selection

140   Studies examined in this systematic review were gathered according to the Preferred

141 Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines (Page et

142 al., 2021) by searching through three electronic databases, namely SPORTDiscus, ProQuest

143 Sport Medicine & Education Index, and Web of Science. The following combinations of

144 keywords were entered for each database: (a) football, OR soccer; AND (b) match actions,

145 OR match analysis, OR game specific skills, OR technical skills, OR event data, OR game

146 analysis, OR notational analysis, OR performance analysis.

147   The initial search was performed in June 2020, and a total of 31,819 articles were

148 identified. The articles were screened, based on three inclusion criteria. First, the sport

149 examined in the study must be association football, limited to studies of the full-sized 11-a-

150 side format, when performed by males at the age group, amateur or professional level. This

151 was done to limit the influence of match setup or player gender on resultant match actions.

152 As age-related differences on match action profiles were meaningful for the intended

153 purpose of the systematic review, studies that examined competitive performance data in

154 age-group football up to adult, professional football, were included in the analysis. Second,

155 the relationships between: (a) match actions and football performance, or (b),

156 environmental or task constraints and match actions must have been explicitly investigated.

157 Last, the studies must have been quantitative in nature, explicitly examining match action

158 data as the primary variable of analysis.

159   ***Figure 1 somewhere here***

160   After the automated screening for duplicate and ineligible articles filtered by topic

161   and keywords, 1,861 articles remained for the initial screening. The title and abstracts of

162   these articles were then screened based on the inclusion criteria by one review author for a

163   subsequent review of the full text. Altogether, 201 articles were selected for further

164   examination of full texts. At this stage, articles that raised ambiguity in inclusion were

165   highlighted for a review of the full text and discussed with two other reviewers. Where

166   necessary, the eventual inclusion or exclusion of articles were determined through

167   consensus. Finally, 45 articles were selected for analysis, based on their relevance in

168   addressing our two main research questions. The references of the selected articles were

169   subsequently screened to identify potentially relevant articles not identified by the original

170   search, which yielded a further two studies meeting the inclusion criteria. The process for

171   article collection, screening and selection is detailed in Figure 1. After a comprehensive

172   analysis of the selected articles, it was determined that the most appropriate way to classify

173   the articles would be to utilize a modified version of the classification system proposed by

174   Sarmento et al., (2014). The articles were classified on two levels of analysis (Figure 2): by

175   type of analysis utilized in the article (comparative or predictive); and by type of

176   performance being measured (individual or team level of performance).

177   ***Figure 2 somewhere here***

178   **Results**

179   *What are the environmental or task constraints that significantly influence the frequency of*

180   *these match actions and what is the direction and magnitude of influence?*

181   Based on the assumption that there are pronounced differences in the task demands

182   on players in different playing positions, resulting in disparate match action profiles, 24%

183   of the studies conducted separate analyses for each major position or sub-roles within each

184   playing position. Studies in this category of analysis primarily examined how different

185   environmental and task constraints varied in their influence on match action profiles and

186   examined differences in direction and magnitude of their influence between playing

187   positions. A summary of the study findings is provided in Table 1.

188   ***Table 1 somewhere here***

189   ***Playing position***

190   Several studies examined effects of playing position (with respect to area of the

191   field: e.g., *central* or *wide*) on match action profiles in isolation, regardless of interactions

192   with other environmental and task constraints. For instance, researchers identified that

193   differences in match action profiles were greatest between central defenders and forwards

194   in the UEFA Champions League (UCL), with forwards performing more offensive match

195   actions such as shots, shots on target, and key passes (Yi et al., 2018). Match actions also

196   differed between the sub-roles within major playing positions. For example, *central*

197   midfielders in the UCL performed more shots and shots on target compared to *wide*

198   midfielders (Yi et al., 2018). Sub-role differences in match action profiles were not league-

199   specific and were evident in many competitions. For instance, central defenders in the

200   Asian Cup performed fewer ground duels in comparison to wide defenders, while central

201   midfielders performed more passes and successful passes than wide midfielders (Ermidis et

202   al., 2019).

203   ***Team and Opposition Strength***

204   Across multiple studies, match action profiles varied depending on the strength of

205   the opposition – which were determined through their eventual position (i.e. placing) in the

206   league (Liu, Yi, et al., 2015) or club ranking point systems such as the UEFA season club

207   coefficient (Liu, Gómez, et al., 2016). These studies examined changes in match action

208   profiles while only considering the strength of the opposition (Liu, Yi, et al., 2015) or while

209   considering the strength of one's own team in relation to the opposition (Liu, Gómez, et al.,

210   2016). In both cases, significant variations in attacking match actions were highlighted. For

211   example, match actions such as assists, total number of shots, shots on target, touches on

212   the ball, through balls, key passes, fouls drawn, aerial duels won and number of offsides

213   varied more widely when teams played against stronger opposition in the Spanish La Liga

214   (Liu, Yi, et al., 2015). Similarly, when accounting for strength of both teams, teams in the

215   UCL varied significantly in frequency of shots, shots on target, shots from open play,

216   passes, ball possession, aerial duels and fouls conceded (Liu, Gómez, et al., 2016).

217   ***Seasons***

218   Frequency of certain match actions varied significantly across different seasons of

219   the Chinese Super League (Zhou et al., 2020), English Premier League (EPL) (Bush et al.,

220   2015) and La Liga (Serrano et al., 2019). These changes were primarily specific to playing

221   position – with the total number of passes and passing accuracy percentage of central

222   defenders and midfielders increasing in the 2012-13 season of the EPL compared to 2006-

223   07 (Bush et al., 2015). Conversely, goalkeepers in La Liga exhibited a lower number of

224   total saves in the 2016-17 season compared to 2011-12 (Serrano et al., 2019). These

225   changes were also observed at the team level, with teams performing more crosses, shots,

226   and offensive match actions leading to entry into the opposing penalty area in the 2017

227   season compared to the 2012 season of the Chinese Super League (Zhou et al., 2020).

228   *League type*

229   Differences in match action profiles between different leagues were highlighted

230   when comparing between leagues in similar (Dellal et al., 2011) or different tiers of

231   competition (Elyakim et al., 2020). In particular, the number of aerial duels occurring, and

232   number of ball touches taken during La Liga and EPL matches were significantly different,

233   with players in La Liga competing in more aerial duels but having fewer touches on the ball

234   per possession period compared to players in the EPL (Dellal et al., 2011). This observation

235   suggests that, although teams may compete in similar competitive tiers (both compete for

236   qualification into the UCL), there may be league-specific differences which contextualise

237   playing styles, which then influence emergent match action profiles. Significant differences

238   were also found between leagues of different competitive tiers, primarily in offensive

239   match actions. For instance, teams in the Italian Serie A demonstrated greater frequency of

240   passes into the penalty box, key passes, total shots, and offensive match actions leading to

241   entry into the opposing penalty area compared to teams in a lower competitive tier such as

242   the Israeli Premier League (Elyakim et al., 2020).

243   *Age group*

244   Evidence from the studies examined suggests that frequencies of certain match

245   actions significantly differed across matches played in different age groups. Specifically,

246   frequency of passes, ball touches, involvements with the ball, and successful pass

247   percentage were positively associated with age, with elite U18 Japanese players performing

248   significantly more of such actions compared to those at the U13 level (Goto & Saward,

249   2020). Similarly, Brazilian players in older age groups (U15) demonstrated greater pass

250   accuracy, greater frequency of passes, ball touches, and ball touches per involvement,

251   compared to their younger counterparts (U13 or U11) (Palucci Vieira et al., 2019).

252   ***Team playing style***

253   Differing playing styles were also highlighted as a significant influence on match

254   actions collectively performed by teams. Specifically, teams competing in the FIFA World

255   Cup 2018 were found to exhibit either a possession- or direct-play oriented playing style

256   (Yi et al., 2019). Possession-oriented teams executed more goal scoring, offensive and

257   passing related match actions compared to direct-play teams. Similarly, in the Chinese

258   Super League there were four distinct playing styles (e.g., focus on possession, set piece

259   attacks, counterattacking, or transitional play) characterized by significantly different match

260   action profiles (Lago-Peñas et al., 2017).

261   Additionally, defensive playing styles utilized by the opposition also significantly

262   influenced the match actions performed. For instance, against a well-organized defensive

263   playing style (i.e., where the defending team has a coordinated and balanced structure, with

264   players in their specific positions), attacking teams in the UCL were more reliant on crosses

265   as the penultimate match action in offensive sequences leading to goals (González-Ródenas

266   et al., 2019). In contrast, against a disorganized defensive playing style (i.e., certain players

267   are not in their specific positions, and the defending team seeks to urgently stop their

268   numerical or positional disadvantage), attacking teams relied more frequently on dribbling

269   as the penultimate action before scoring.

270   ***Team formation***

271   Evidence from the studies examined also highlight playing formation of the team

272   and that of the opponent as a significant influence on the frequency of match actions

273   performed. Specifically, teams that played in a 4-4-2 (i.e., four defenders, four midfielders,

274   and two forwards) or 4-3-3 formation played a significantly higher number of passes

275   compared to those playing in a 4-5-1 formation (Bradley et al., 2011). However, the

276   formation that the opposition team utilized also played a crucial role, as teams performed a

277   significantly greater number of passes when facing a 4-4-2 formation as compared to when

278   they faced a 4-2-3-1 formation (Carling, 2011).

279   ***Period of match***

280   Certain match actions also varied in their frequency across different time periods

281   within matches. For example, passing frequency and number of involvements by players in

282   the English Championship dropped significantly in the second half of matches compared to

283   the first (Russell et al., 2013). In the same study, frequency of ball involvements also

284   dropped significantly in the last 15 minutes compared to the first 15 minutes of each match.

285   Similarly, players in the Italian Serie A also experienced significantly fewer ball

286   involvements, total short passes and successful short passes in the second half compared to

287   the first (Rampinini et al., 2009).

288   ***Nationality***

289   In the modern globalized era of football, there is a significantly larger talent pool

290   bolstered by foreign players that teams can recruit from to improve their squad. In the

291   Chinese Super League, these foreign players demonstrated significantly different match

292   action profiles compared to their domestic counterparts (Yang et al., 2018). Specifically,

293   foreign-born central defenders performed more aerial duels, ground duels and fewer crosses

294   while foreign-born wide defenders performed more passes compared to their domestic

295   counterparts. Significant differences were also found in offensive positions, for instance,

296   foreign-born forwards performed significantly more shots and demonstrated greater shot

297   accuracy.

298   ***Match score***

299   The current match score, which is indicative of whether a team was currently in a

300   favourable or non-favourable position, emerged as a significant influence on match action

301   profiles. Specifically, when their team was not in the lead during the match, players

302   competing in the UEFA European Championships 2016 had more possession and

303   performed more passes, short passes, and crosses when trying to tie the match or gain the

304   lead (Konefał et al., 2018).

305

306   *Are the technical actions observed during competitive football matches a significant*

307   *indicator or predictor of performance?*

308   There were multiple approaches undertaken to construct a measure of football

309   performance across the selected studies, which suggests that interpretation of high

310   performance in football needs theoretical guidance. At the team level, indicators of high

311   performance included successful match outcomes, team ranking derived from points earned

312   at the end of season, or qualification for later stages of a competition. Conversely, high

313   performers at the individual level were categorized based on membership of higher

314   performing teams (e.g., representing teams in higher competitive tiers, higher ranked teams

315   in the same tier or qualification into later stages of competition) or individual ranking

316   indexes. A summary of the studies examined at the comparative level of analysis and

317   predictive level of analysis is provided in Table 2 and Table 3 respectively. Studies were

318   classified as comparative if the primary purpose was to examine the differences between

319   high and low performers. Conversely, studies were classified as predictive if the primary

320   purpose was to highlight the match actions associated with level of performance achieved.

321   *Table 2 somewhere here*

322   *Team level - Comparative*

323   Offensive match actions related to a greater quantity, higher quality (location of

324   shot, type of shot) and efficiency of shooting (shots on target, goals to shots ratio), were

325   consistently revealed as indicators of higher team ranking or more positive match outcomes

326   (Del Coso et al., 2020; Delgado-Bordonau et al., 2013; Evangelos et al., 2014; Konefał et

327   al., 2018; Liu, Yi, et al., 2015; Liu, Gómez, et al., 2016; Rampinini et al., 2009; Varley et

328   al., 2017; Yue et al., 2014). Furthermore, greater quantity of passes and successful passing

329   percentage were also consistently indicative of higher performance (Evangelos et al., 2014;

330   Liu, Yi, et al., 2015; Liu, Gómez, et al., 2016; Rampinini et al., 2009; Yi et al., 2019).

331   Similarly, passes that created goal scoring opportunities in the offensive third of the pitch

332   or the opposition penalty area, significantly differentiate between teams of different

333   performance levels (Yang et al., 2018). Conversely, defensive match actions, such as the

334   number of successful 50-50 challenges (situation where both players have an equal chance

335   of winning the ball) (Yang et al., 2018), aerial and ground duels (Evangelos et al., 2014),

336   also significantly differed between teams of varying performance levels.

337   The variance of these actions performed across matches also differentiated between

338   teams of differing performance levels. Lower performing teams exhibited match action

339   profiles with less variability in frequency of defensive match actions observed, such as

340   interceptions and defensive clearances. In contrast, higher performing teams showed less

341   variability in offensive match actions such as assists, shots, shots on target, ball touches,

342   passes, through balls, key passes, successful dribbles and pass accuracy (Liu, Yi, et al.,

343   2015).

344   ***Individual level - Comparative***

345   Here, we sought to identify differences in match actions performed between

346   individuals of differing performance levels. Studies in this category of analysis exclusively

347   examined players in the goalkeeper position. Evidence from these studies suggested that

348   individual players with distinct levels of performance differed significantly in their match

349   action profiles. Goalkeepers competing in different competitive tiers significantly differed

350   in the type of distribution method chosen, intended area of distribution, and distribution

351   success (Seaton & Campos, 2011). High performance goalkeepers competing in the first

352   division of La Liga, for example, distributed the ball more frequently into areas that

353   provided a greater tactical advantage for the team when attacking (e.g., central zone of the

354   attacking third), compared to goalkeepers from the second division, third division or under-

355   19 years old youth teams. Furthermore, goalkeepers that represented lower ranked teams

356   within La Liga performed more passes and were also required to perform more saves

357   (Serrano et al., 2019)

358   ***Table 3 somewhere here***

359   ***Team level - Predictive***

360   The studies in this category sought to highlight match actions significantly

361   associated with level of performance achieved. Similar to the results of the comparative

362   research articles, a greater quantity, higher quality (location of shot, type of shot) or

363 efficiency of shots (shots on target, goals to shots ratio) were identified as significant

364 predictors of positive match outcome. Additionally, greater amount of time in possession

365 was identified to be significantly correlated with positive match outcomes (Elyakim et al.,

366 2020; Liu, Gómez, et al., 2015; Liu, Hopkins, et al., 2016). Also, more shots and ball

367 recoveries, combined with greater shot accuracy and fewer shots allowed, were positively

368 associated with points earned in the season (Brito Souza et al., 2019).

369 Interestingly, although successfully executed offensive pass-related actions (such as

370 accurate passes, crosses, and key passes) were positively associated with match outcomes,

371 the absolute quantity of match action frequencies did not have the same association with

372 match outcomes. For instance, a high number of passes, crosses or dribbles attempted

373 (Harrop & Nevill, 2014; Liu, Gómez, et al., 2015) were not significantly associated with

374 team performance and were sometimes associated with negative match outcomes.

375 Similarly, although a greater frequency of tackles (Liu, Gómez, et al., 2015; Mao et al.,

376 2016) and aerial duels won (Liu, Gómez, et al., 2015) were positively associated with

377 match outcomes, a greater frequency of shots blocked (Liu, Gómez, et al., 2015), fouls

378 conceded (Moura et al., 2014; Pappalardo & Cintia, 2017), clearances and goalkeeper

379 interventions (Pappalardo & Cintia, 2017) were negatively associated with match

380 outcomes.

381 *Individual level - Predictive*

382 The articles within this level of predictive analysis primarily examined match

383 actions crucial in predicting individual performance. To quantify individual performance, a

384 top-down approach was commonly utilized whereby researchers pre-classified individuals

385 into different levels of performance based on a proprietary performance index (Oberstone,

386   2010); membership of teams (1) that finished in the top or bottom half of the same league

387   (Adams et al., 2013), (2) in leagues of different competitive tiers (Barron et al., 2020), or

388   (3) in football academies of different competitive tiers (Waldron & Worsfold, 2010). After

389   which, researchers examined individual match action profiles to derive the match actions

390   significantly associated with level of individual performance.

391   Across the major outfield playing positions, higher frequency in offensive match

392   actions, such as successfully executed passes, was significantly associated with

393   membership of higher performing teams (Adams et al., 2013; Barron et al., 2020). Akin to

394   earlier sections, successful shooting was significantly associated with greater individual

395   performance. Specifically, individuals that executed more successful shooting attempts

396   were likelier to compete in a league of higher competitive tier in the following season, such

397   as progressing from the English Championship to the EPL (Barron et al., 2020). Similarly,

398   successful shooting was significantly associated with likelihood of recruitment into an elite

399   EPL academy (Waldron & Worsfold, 2010). For goalkeepers, shots conceded in and

400   outside the box, punches, short passes, clean sheets, and goals allowed were significantly

401   associated with individual performance indicated by scores on the Opta Index (a

402   consolidated performance metric built from the weighted frequencies of different key

403   match actions for each playing position) (Oberstone, 2010).

404   In contrast to this top-down approach, one study utilized a bottom-up approach

405   which involved first identifying the critical match actions for each playing position

406   (Pappalardo et al., 2019). This was achieved by using a machine learning approach to

407   identify match actions that best contributed to a positive performance outcome. Individual

408   performance level was then constructed by combining the frequency and derived

409   importance of these critical match actions. Using this approach, the match actions

410   highlighted to be critical in predicting individual performance were assists, key passes (i.e.,

411   pass leading to shooting opportunity, but no goal scored), and shot accuracy. Interestingly,

412   the critical match actions identified from the bottom-up approach were similar to those

413   identified from the top-down approach.

414   **Discussion**

415   Building on an ecological dynamics approach, this systematic review sought to

416   highlight the environmental and task constraints of significant influence in contextualising

417   competitive performance in football (Araújo et al., 2021). We sought to identify the

418   direction and magnitude of their influence, and to establish the processes in which

419   quantitative indicators of football performance can be meaningfully interpreted.

420   Furthermore, existing evidence on the validity of frequency of match actions as a

421   performance indicator in football was also examined.

422   **High performance as best fit rather than best player**

423   The significant influence of the multitude of key constraints on emergent match

424   action profiles highlighted in this systematic review presents several contributions to the

425   assessment of performance in football. Most notably, these results highlight the importance

426   of contextualizing performance and accounting for key constraints when assessing

427   performance in football. More specifically, because the key constraints acting on each

428   individual are unique, even between players in similar positions, indicators of high

429   performance cannot be universal. They largely depend on the unique task and

430   environmental constraints demanded of the individual in particular environments. For

431   instance, forward players from lower ranked teams were required to perform more

432   defensive actions (e.g., aerial duels, clearances) while those from higher performing teams

433   executed more possession and offensive actions (e.g., ball touches, passes, shots on targets

434   and assists) (Liu, Gómez, et al., 2016). Therefore, during recruitment, teams should closely

435   consider the unique constraints that would be exacted on their potential recruit (and

436   consequently, the match actions that they would be required to perform regularly) as part of

437   their selection process. From a practical perspective, this may be exemplified by lower

438   ranked teams understanding that they would not have the bulk of possession during

439   matches, and therefore looking to recruit forward players that 'fit' their team constraints

440   (e.g., proficiency in winning aerial duels, defensive awareness) rather than those with

441   traditionally-valued abilities (e.g., dribbling proficiency)

442   Building on this concept of the 'best-fit' player, the current approach of

443   approximating level of individual performance based on membership of high or low

444   performing teams (Adams et al., 2013; Barron et al., 2020; Waldron & Worsfold, 2010)

445   may have limited validity as it disregards the contexts of competitive performances. To

446   illustrate, defenders with low capabilities in defensive match actions may not have their

447   weaknesses highlighted if they represent high performing teams, as they are rarely required

448   to perform these actions (Liu, Gómez, et al., 2016; Yi et al., 2019). Conversely, defenders

449   with high capabilities in both offensive and defensive match actions may not be identified

450   as a high performer if they represent lower performing teams, due to the lack of

451   opportunities to demonstrate offensive match actions.

452   Accordingly, future research should consider building on the bottom-up approach

453   proposed by (Pappalardo et al., 2019) that was described in the earlier section. For example,

454   by first identifying the match actions critical for competing successfully under specific

455   local constraints, lower resourced or lower performing teams can build a prediction model

456   to identify candidate high performers. Conversely, higher resourced or higher performing

457   teams could identify candidate high performers using a disparate model accounting for their

458   own specific constraints. In this way, a more contextualized measure of individual

459   performance may be developed, whereby individual performance is defined as the

460   likelihood of improving match outcomes based on unique task and environmental

461   constraints experienced by the team, instead of the performer biased approach of recruiting

462   the best player in the position. Such a system might be instrumental in reducing likelihood

463   of false positives (i.e., low performers getting by in high performing teams) or false

464   negatives (i.e., high performers not recognized due to representation of low performing

465   teams) in assessing individual player performance.

466   To this end, it is important to consider that contextual demands faced by the players

467   are constantly changing. For example, professional football teams face different opponents

468   every week, in a variety of settings (e.g., type of competition, match location) and these

469   demands significantly alter task and environmental constraints at the individual and team

470   level. Therefore, from an ecological perspective, the ability to successfully adapt to

471   perennial changes in contextual constraints could be most indicative of high performance

472   (Davids et al., 2005, 2015). The importance of this performer adaptability in skill

473   acquisition has been widely highlighted in sports coaching and practice design (Woods et

474   al., 2019). Taken together with the results of the current study, it is justifiable to

475   hypothesize that adaptability may be a crucial indicator of athletic performance or

476   imperative to athlete development. In this case, a hallmark of an elite performer amongst

477   professional players could be 'behavioural flexibility', or the ability to repeatedly adapt

478   one's match actions to dynamically changing contextual constraints (Ranganathan et al.,

479   2020). Therefore, more than assessing which match actions are linked to higher

480   performance, a potentially crucial question relates to if the ability to generate a variety of

481   necessitated goal-directed behaviour is indicative of high performance. Indeed, a key

482   consideration from an ecological dynamics approach is whether multiple sets of match

483   actions can lead to a similar outcome within a similar context, also known as *degeneracy*

484   (Seifert et al., 2016). In this perspective, a higher level of degeneracy (i.e., possessing a

485   greater number of coordinative patterns or behavioural responses to achieve similar goal-

486   directed outcomes) is a key signature of individual and collective expertise. Diversity of

487   match actions both within a similar context and between different contexts therefore may

488   provide information on expertise level of players and teams.

489   **Match actions as an indicator of performance in football**

490   The results of the present review suggest that frequency data on match actions,

491   performed by individuals or collectively as a team, have some value in differentiating

492   between individuals or teams of contrasting levels of performance. However, the present

493   findings also reveal the need for advances in current theoretical approaches to improve the

494   practical viability of utilizing match actions frequency data as a performance indicator in

495   football.

496   *Shift towards prospective study designs*

497   Across the studies examined, all the studies utilized a retrospective study design

498   with the exceptions of Pappalardo et al., (2019) and Serrano et al., (2019). These

499   retrospective study designs focused solely on examining key differences between

500   individuals or teams of high or low performance in a certain context. Most crucially, the

501   retrospective approach does not apply its findings towards a set of participants outside of

502   the sample from which the findings were derived. Therefore, it remains unknown whether

503   findings from these studies are limited to the participants studied or if they remain true

504   when applied to other samples or different contexts. Furthermore, these studies may be

505   limited in their practical value as football organizations are more likely to edge out their

506   competition if they can predict the likelihood that a player would be a high performer

507   instead of merely knowing the characteristics of previously high performing players.

508   In response, a prospective-oriented approach that seeks to shift the focus towards

509   forecasting likelihood of high performance in the future, could provide more value to

510   practitioners. Such an approach should closely examine knowledge from existing

511   retrospective studies, to guide the construction of prediction models using machine learning

512   and statistical modelling techniques. Moreover, to further bolster the validity of these

513   models, the prospective approach should be grounded in the ecological dynamics

514   framework and should account for task and environmental constraints unique to the context

515   of the team or individual (Araújo et al., 2021). Specifically, prediction models in this

516   prospective approach should seek to forecast likelihood of high performance in a specific

517   context (i.e., in a certain team with specific task and contextual constraints, see earlier

518   section on high performance as best fit). Such an approach would provide greater practical

519   value for football organizations as they serve as an empirical, data-informed means of

520   player evaluation grounded by existing knowledge. Consequently, such an approach also

521   allows for the forecasting of future performance in different potential environments.

522   Specifically, players who show high potential in adapting to multiple and varied contexts

523   could, therefore, be considered more valuable than players with limited adaptability.

Limitations

524

525   As briefly discussed in previous sections, the inconsistency in operational

526 definitions of performance (e.g., team performance was categorized as ranking within the

527 league, match outcome, or qualification towards next stage of competition) and match

528 actions (multiple definitions between sports data companies, and hand notations done by

529 researchers) make it difficult to conduct a meta-analysis or use another systematic statistical

530 approach in the current systematic review. Therefore, although evidence from the reviewed

531 studies suggest that 'on-ball' match actions are a significant indicator and predictor of

532 performance, we are unable to statistically conclude the strength or extent to which they

533 can be used to differentiate and predict performance. It is possible that other indicators,

534 such as match actions that occur 'off-the-ball' (e.g., ball recovery actions, compactness of

535 team shape) may also need to be considered in order to more comprehensively assess

536 performance (Memmert et al., 2017). Future research may consider addressing this

537 inconsistency in operational definitions by conducting meta-analyses only using studies

538 from a single sports data company with consistent operational definitions.

Conclusion

539

540   Given the dynamic nature of the sport, researchers and practitioners in football have

541 long struggled with establishing an objective, universal definition of footballing

542 performance. And perhaps more importantly, establishing processes in which performances

543 can be meaningfully analysed to generate practical insights and inform decision-making.

544 The results of this review further reinforce the need to transition towards an ecological

545 dynamics approach when utilizing a data-informed approach towards identifying and

546 predicting high performing football players. Specifically, use of match action data as a

547 performance indicator, which more closely accounts for interactions between a performer

548 and contextual constraints, certainly appears to be a more reliable performance indicator

549 compared to those measured in abstract, "context-free" environments. In addition, the

550 significant influence of environmental and task constraints on the match actions performed

551 suggest that behavioural flexibility and adaptability to varied contexts should be considered

552 as a key factor for expert performance, at both the individual and team level.

553   Pertaining to study designs in this area of research, there is an overwhelming use of

554 a retrospective, top-down approach to classify performance. Given the potential

555 applications of this performance analysis oriented, data-informed approach in player

556 recruitment, performance forecasting and contract decisions, it seems reasonable to propose

557 that future work should transition towards a prospective research design that places greater

558 emphasis on utilizing the knowledge derived from retrospective studies towards forecasting

559 future performance. Lastly, future research should examine the prospective power of

560 critical match actions in the short- and long-term using mathematical modelling and

561 simulation techniques and explore the influence of multiple environmental and task

562 constraints on the likelihood of future high performance. This approach would, therefore,

563 emphasize the need to consider behavioural flexibility and adaptability as key indicators to

564 be considered in talent identification.

565

566 **Declaration of interest statement**

567

568 **Conflicts of interest/Competing interests:**

569 The authors declare no conflicts of interest or competing interests

570 **Availability of data and material:**

571 Not applicable – Paper is a Systematic Review

572 **Code availability:**

573 Not applicable – Paper is a Systematic Review

574 **Ethics approval:**

575 Not applicable – Paper is a Systematic Review

576 **Consent to participate:**

577 Not applicable – Paper is a Systematic Review

578 **Consent for publication:**

579 Not applicable – Paper is a Systematic Review

583

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