Effects of congested match periods on acceleration and deceleration profiles in professional soccer

AUTHORS: Léo Djaoui1, Adam Owen1,2, Matt Newton3, Pantelis Theodoros Nikolaidis4, Alexandre Dellal1,2, Karim Chamari5

1 Inter-university Laboratory of Human Movement Biology, University Claude Bernard Lyon 1, University of Lyon, Lyon, France
2 Seattle Sounders FC, Seattle, Washington, USA
3 Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, United Kingdom
4 School of Health and Caring Sciences, University of West Attica, Athens, Greece.
5 FIFA Medical Centre of Excellence, Centre orthopédique Santy, Sport Science and Research Department, Lyon, France.
6 ASPETAR, Qatar Orthopaedic and Sports Medicine Hospital, Doha, Qatar

ABSTRACT: The aim of the present study was to analyse the influence of congested periods of matches on the acceleration (Acc) and deceleration (Dec) profiles of elite soccer players. Twenty-three elite male professional soccer players participated in the study across 31 official matches. Assessed periods included: (i) congested periods (three to four days between games), and (ii) non-congested periods (more than four days between games). Physical activity during matches was recorded during games using a 10Hz global positioning system device, coupled with a 100 Hz accelerometer, and was analysed according to the periods. Maximal Acc (73.2 ± 20.3 vs. 84.918.5 m), high Acc (244.0 ± 49.5 vs. 267.0 ± 37.8 m), maximal Dec (139.0 ± 44.8 vs. 152.039.3 m) and the total decelerating-distance (5132 ± 690 vs. 5245 ± 552 m) were lower in congested than in non-congested periods (p < 0.05, effect size 0.31–0.70). Neither a main effect of playing position nor a period*playing position interaction on Acc and Dec were observed (p > 0.05). It was concluded that Acc and Dec match activities were significantly affected during congested periods compared to non-congested highlighting a possible fatigue accumulation being responsible for the observed decrement in physical activity. Monitoring Acc and Dec metrics throughout particular periods of congested fixtures amongst professional soccer teams is advised and may be a way to assess physical and fatigue status.

CITATION: Djaoui L, Owen A, Newton M et al. Effects of congested match periods on acceleration and deceleration profiles in professional soccer. Biol Sport. 2022;39(2):307–317.

INTRODUCTION

Competitive soccer match-play at the very elite level involves a high physical demand imposed on players to perform continued, explosive changes of direction (COD) coupled with a large amount of repeated high-speed actions [1]. Daily assessment and monitoring of player training and match demands have received much attention in recent times with global positioning systems (GPS) being one of the most common approaches of quantifying players’ physical load. Total distance covered (TDC) and time spent at different speeds thresholds monitored via GPS are two of the most common reported metrics [2, 3]. As a result of this, limiting the reported analysis to speed-based thresholds, and minimal reports surrounding few key movements involving high muscular and power demands (but with minimal or reduced speed involvement), are not taken into consideration.

According to research, the energy cost related to high-speed running (HSR) distance is underestimated based on the lack of soccer-specific movements continually performed in either training or competitive match play such as accelerations (Acc), decelerations (Dec) and COD [4, 5]. For the reader, Acc and Dec are defined as changes in speed velocity, often measured in meters per second; Acc are positive changes in speed (e.g. speed up motions) and Dec are negative changes in speed (e.g. slow down motions). During Acc, Dec and COD, both concentric and eccentric muscle contractions result in increased potential of muscle damage [6, 7, 8, 9]. This process also leads to an increase in the anaerobic contribution and physiological stress [10, 11, 12]. Also, it has been reported the notion that Acc and Dec actions within soccer specific environments can assist in the strengthening of the lower limb muscles [9]. Furthermore, increasing durations of acceleration movements combined with the number of acceleration movements induces increased peak heart rates, in conjunction with a greater blood lactate and perceived
exertion [13]. It has also been shown that Acc and Dec activity was moderately correlated with HSR distances during elite soccer matches [14]. Utilising this information and suggested recommendations from the literature, the need to monitor soccer players’ physical activity combining both speed and Acc/Dec indicators is of paramount importance [15].

Competitive and training demands imposed on elite level players is continually increasing based on the need to fulfil increased domestic, European and International fixtures. Such busy schedules impose short recovery bouts between matches. Literature suggests that during congested fixture periods, elite players can reproduce distances covered during fixtures through increasing match distance covered at low intensity [16, 17], but without significantly changing the moderate-, high- and maximal-speed running activity [18]. Recently, it was also reported that congested fixture period increased the physiological stress and fatigue, especially increasing blood levels of C-reactive proteins, white-blood cells and creatine kinase (CK) [19]. Creatine kinase, as a marker of muscular damage, was the only indicator in this particular investigation that was significantly affected by a shorter recovery between matches [19]. Moreover, the CK increase observed 24hrs and 48hrs post-game has been related to a neuromuscular COD test impairment [20]. Further reports in this area highlighted how excessive competitive fixtures as a result of combined domestic and continental participation may induce significant end of season-accumulated haemolysis [21]. In particular, Owen et al. [21] revealed how relationships exist between lower mean cell volumes, mean cell haemoglobin, red-blood cell count and haematocrit values, highlighting the accumulative effects of seasonal training and congested match-play demands.

From the current literature, it might be hypothesised that the increased muscle damage marker observed during congested matches was a resultative of repetitive Acc and Dec movements performed during match-play, in accordance with a lack of sufficient between match recovery. Related to this, Arruda et al. [22] found that the number of Acc per minute (Acc/min) was significantly impacted by a very congested game schedule among youth soccer players. Furthermore, Acc/min were especially reduced during the 2nd and the 5th matches of a three-day tournament. Nevertheless, to date, and to the best of the authors’ knowledge, no study has examined the effect of a congested calendar on Acc and Dec during official matches in professional senior soccer players. However, it should be taken into account that players perform different Acc and Dec profiles according to their positional role on the field [23]. As a result of the literature surrounding this topic, the aim of the present investigation was to examine the physical activity of professional players during congested and non-congested matches, with specific reference to the Acc and Dec profiles, in terms of both distance covered and time spent. It was hypothesised that Acc and Dec scores would be negatively impacted across a congested fixture period and that this outcome would vary according to the playing positions.

MATERIALS AND METHODS

Experimental Approach to the Problem

To analyse the effect of a congested fixture period on Acc/Dec profiles, 32 official competitive matches were analysed across two consecutive seasons between March and May 2016 (n = 13 matches) and between July and December 2016 (n = 19 matches). Across the analysis, a total of seven matches (n = 7) were played in a congested period and twenty-five (n = 25) were played in a non-congested period. Three to four days between games separated the “congested matches”, with the “non-congested matches” being characterized by at least five days between games. All the official matches included 30 competitive matches from a professional European country league, and 2 competitive match data sets taken from the Football Association’s National cup competition.

Subjects

Twenty-four elite male professional soccer players (age: 23 ± 4.5 years – range between 19,5 and 28,5; height: 178 ± 6.1 cm; weight: 73 ± 8.2 kg) from the same Swiss team participated to the study. Thirteen of the players were part of their respective national team with team being a high calibre successful domestic club playing in their respective national Premier League. Players were split into five playing positions: central backs (CB, n = 5), full backs (FB, n = 5), central midfielders (CM, n = 6), wide forwards (WF, n = 4) and central forwards (CF, n = 4). The players who participated to at least 70 min in every match were included in the analysis. From a total number of 406 individual matches (n = 67 CB, n = 77 FB, n = 120 CM, n = 75 WF and n = 67 CF) recorded, only 270 individual matches met with the inclusion criteria and were therefore analysed (n = 58 CB, n = 65 FB, n = 72 CM, n = 36 WF and n = 39 CF). During the congested periods of matches, only players who played the previous match, three or four days before, were included in the analysis. None of the players participated to all of the 32 analysed matches of the analysed periods. Throughout the procedure, players were informed to maintain usual nutritional and recovery protocols usually used in the club. All participants provided written consent before the beginning of the investigation. The present study was approved by the involved sport science department of the soccer club and by the local university ethics committee before the beginning of the assessments. The present study conforms with the ethical standards for research recommendation of the Helsinki Declaration.

Procedure

Throughout all matches, players’ physical activity was assessed using a 10 Hz GPS coupled with a 100 Hz accelerometer (Viper, Statsport, Ireland) which has been reported as a valid and reliable GPS unit, especially when tracking team sport movements and accelerations [24, 25]. The TDC and relative TDC per minute (RTDC) were measured. The distance covered and time spent at different speed thresholds were also measured and expressed in absolute distance over the game and relative distance over one minute:
Positional match profiles during fixture congestion

| TABLE 1. Distance covered and time spent at different speed threshold during congested and non-congested professional soccer matches. |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                    | Central Backs | Full Backs | Central Midfielders | Wide Forwards | Central Forwards | All players |
|                                                                                                    |              |           |                   |               |                 |             |
|                                                                                                    | Congested   | Non-Congested | Congested | Non-Congested | Congested | Non-Congested | Congested   | Non-Congested | Congested   | Non-Congested | Congested | Non-Congested |
|                                                                                                    | Total       | ± 712     | ± 810 | ± 719 | ± 700 | ± 2034 | ± 1003 | ± 653 | ± 1561 | ± 1274 | ± 1253 | ± 1344 | ± 1082 |
|          | Total /min         | 9703        | ± 6096       | ± 488 | ± 302 | ± 360 | ± 1190 | ± 573 | ± 245 | ± 941 | ± 615 | ± 621 | ± 753 | ± 604 |
|          | Non-Congested     | 10076       | 6213       | 2082 | 3381 | 3348 | 3491 | 3519 | 3766 | 3505 | 3531 | 2796 | 2899 | 3275 |
|          | Congested         | 10477       | 6377       | 436 | 352 | 37.1 | 38.5 | 41.4 | 37.6 | 40.7 | 32.0 | 32.9 | 35.7 | 37.9* |
|          | Non-Congested     | 10501       | 6223       | ± 36.4 | ± 3.37 | ± 3.33 | ± 10.9 | ± 3.98 | ± 2.08 | ± 8.48 | ± 4.44 | ± 4.08 | ± 64.9 | ± 47.0 |
|          | Congested         | 9969        | 5909       | ± 33.2 | ± 35.2 | ± 37.1 | ± 11.0 | ± 8.34 | ± 6.25 | ± 8.04 | ± 7.85 | ± 8.97 | ± 7.66 | ± 7.67 |
|          | Non-Congested     | 10311       | 6396       | ± 4.12 | ± 4.71 | ± 4.15 | ± 11.0 | ± 8.34 | ± 6.25 | ± 8.04 | ± 7.85 | ± 8.97 | ± 7.66 | ± 7.67 |
|          | Congested         | 10668       | 6396       | ± 4.38 | ± 4.10 | ± 6.61 | ± 4.79 | ± 5.14 | ± 6.34 | ± 7.97 | ± 6.56 | ± 7.18 | 5.45 | 5.96 |
|          | Non-Congested     | 10160       | 470        | ± 0.65 | ± 0.93 | ± 1.34 | ± 1.66 | ± 1.36 | ± 1.49 | ± 1.56 | ± 1.94 | ± 1.27 | ± 1.38 | ± 1.47 |
|          | Congested         | 9233        | 590        | 1.23 | 1.00 | 1.80 | 1.75 | 1.15 | 1.11 | 1.91 | 2.07 | 1.99 | 2.31 | 1.53 |
|          | Non-Congested     | 9410        | 688        | ± 0.65 | ± 0.62 | ± 0.73 | ± 0.68 | ± 0.62 | ± 0.72 | ± 0.80 | ± 0.63 | ± 0.91 | ± 1.02 | ± 0.78 | ± 0.88 |

**Distance Covered (m)**

**TIME SPENT (s)**

TDC: total distance covered; LSR: low-speed-running (0–10.8 km.h⁻¹); ISR: intermediate-speed running (> 10.8–19.8 km.h⁻¹); HSR: high-speed running (> 19.8–25.2 km.h⁻¹); Sprint (> 25.2 km.h⁻¹); NA: non-assessed; * Significantly different from congested matches (p < 0.05).
low-speed running (LSR, 0 to 10.8 km·h⁻¹), RLSR, intermediate-speed running (ISR, > 10.8 to < 19.8 km·h⁻¹), RISR, HSR, sprint (> 25.2 km·h⁻¹), and Rsprint, as inspired from previous studies [26, 27].

Acceleration profiles were determined using the following eight categorisations: Decelerations – maximal (MDec; < -3 m·s⁻²), high (HDec; from -3 to < -2 m·s⁻²), intermediate (IDec; from -2 to < -1 m·s⁻²) and low deceleration (LDec; from -1 to < 0 m·s⁻²); and Accelerations – low (LAcc; from > 0 to 1 m·s⁻²), intermediate (IAcc; from > 1 to 2 m·s⁻²), high (HAcc; from > 2 to 3 m·s⁻²) and maximal acceleration (MAcc; > 3 m·s⁻²) as proposed by Osgnach et al. [28]. The Total distance accelerating and decelerating (TAcc and TDec, respectively) were also assessed. For each of these categories, distance and time were measured and quantified.

**Statistical analyses**

Normality was first checked with the Shapiro-Wilk test. When a variable was not normally distributed, as it was the case for the absolute distance covered, differences between playing positions in physical activity profiles in professional soccer players during official matches.

| Distance covered | Differences between playing positions (p < 0.005) | Effect size | Time spent | Differences between playing positions (p < 0.005) | Effect size |
|------------------|-----------------------------------------------|-------------|------------|-----------------------------------------------|-------------|
| Total            | FB > CB, CF and CM > CF                       | 0.59–0.99   | Total      | NA                                            | NA          |
| LSR              | CB, FB > CF and FB > CM                       | 0.49–0.93   | LSR        | NA                                            | NA          |
| ISR              | (CM > CB), FB, WF > CF                        | 0.50–0.95   | ISR        | (CM > CB), FB, WF > CF                        | 0.46–0.98   |
| HSR              | FB, CF, WF > CM                               | 0.51–1.76   | HSR        | FB, CF, WF > CM                               | 0.53–1.74   |
| Sprint           | FB, CF, WF > CB, CM                           | 0.89–1.22   | Sprint     | FB, CF, WF > CB, CM                           | 0.90–1.25   |
| Total /min       | FB, CM, WF > CB and FB > CF                   | 0.48–0.78   | Total /min | NA                                            | NA          |
| LSR /min         | -                                             | -           | LSR /min   | NA                                            | NA          |
| ISR /min         | CM, WF > CB, CF and CM > FB > CF              | 0.55–0.84   | ISR /min   | CM, WF > CB, CF and CM > FB > CF              | 0.58–0.88   |
| HSR /min         | FB, WF, CF > CM                               | 0.62–1.76   | HSR /min   | FB, WF, CF > CM                               | 0.64–1.75   |
| Sprint /min      | FB, WF, CF > CB, CM                           | 0.85–1.35   | Sprint /min| FB, WF, CF > CB, CM                           | 0.87–1.37   |
| TAcc              | FB > CB, CM                                  | 0.86–0.98   | TAcc        | FB > WF                                       | 0.57–0.72   |
| MAcc             | (CF > FB), CM, WF > CB                       | 0.57–1.04   | MAcc        | CF, CM > FB                                   | 0.63–0.68   |
| HAcc             | FB, CM, WF, CF > CB                          | 0.70–0.95   | HAcc        | FB, CM > CB, CF                              | 0.48–0.56   |
| IAcc              | FB, CM, WF > CB and FB > CF                   | 0.68–1.33   | IAcc        | FB > CB, WF and CF > FB > CM                  | 0.63–1.30   |
| LAcc              | FB > CF                                      | 0.87        | LAcc        | CB, FB > WF                                   | 0.63–0.67   |
| TAcc /min        | FB, CM, WF > CB                              | 0.60–1.08   | TAcc /min   | -                                             | -           |
| MAcc /min        | (CM, CF > FB), WF > CM                       | 0.50–1.27   | MAcc /min   | CM, CF > FB and CM, CM, CF > FB               | 0.58–0.94   |
| HAcc /min        | (FB, WF > CF), CM > CB                       | 0.61–1.27   | HAcc /min   | FB, CM, WF > CB                              | 0.58–0.80   |
| IAcc /min        | FB, CM, WF, CF > CB                          | 0.73–1.36   | IAcc /min   | FB, CM, WF > CB and FB > CF                   | 0.54–1.30   |
| LAcc /min        | FB, WF > CB                                  | 0.58–0.68   | LAcc /min   | -                                             | -           |
| TDec             | CB, FB, CM, WF > CF                          | 0.64–1.03   | TDec        | CB, FB > WF, CF                              | 0.66–1.00   |
| MDec             | (CF > CM), FB, WF > CB                       | 0.77–1.61   | MDec        | FB, CM, WF, CF > CB                          | 1.21–1.71   |
| HDec             | FB, CM, WF, CF > CB and CF > CM              | 0.60–1.64   | HDec        | FB, CM, WF > CB                              | 0.60–1.57   |
| IDec              | FB, CM > CB, CF                              | 0.49–0.91   | IDec        | FB > (CB > CF), CM, WF                       | 0.75–1.25   |
| LDec              | CB, FB, CM, WF > CF                          | 0.78–1.12   | LDec        | CB > CM, WF and FB > WF, CF                   | 0.59–1.01   |
| TDec /min        | CB > WF and CM, WF > CF                      | 0.52–0.77   | TDec /min   | CB, FB > CF                                  | 0.61_0.69   |
| MDec /min        | CF > FB, CM, WF > CB                         | 0.66–1.70   | MDec /min   | (CF > FB, CM), WF > CB                       | 0.66–1.62   |
| HDec /min        | CF > FB, CM, WF > CB                         | 0.68–1.62   | HDec /min   | FB, CM, WF > CF                              | 1.09–1.55   |
| IDec /min        | FB, CM, WF > CB                              | 0.75–0.89   | IDec /min   | FB, CM, WF > CB                              | 0.52–0.91   |
| LDec /min        | CB, CM, WF > CB                              | 0.68–0.93   | LDec /min   | CB > CF                                       | 0.82        |

TDC: total distance covered; LSR: low-speed-running; ISR: intermediate-speed running; HSR: high-speed running; Sprint: T, M, H, I and LAcc: total, maximal, high, intermediate and low accelerations, respectively; T, M, H, I and LDec: total, maximal, high, intermediate and low decelerations, respectively; NA: non-assessed; CB: central backs; FB: full backs; CM: central midfielders; WF: wide forwards; CF: central forwards. Effect size: small < 0.50, moderate: 0.50 to 0.80, or large: > 0.80
### TABLE 3. Distance covered accelerating and decelerating during congested and non-congested periods of matches in professional soccer players.

|                | CB                  | FB                  | CM                  | WF                  | CF                  | All players       |
|----------------|---------------------|---------------------|---------------------|---------------------|---------------------|-------------------|
|                | Congested           | Non-congested       | Congested           | Non-congested       | Congested           | Non-congested     | Congested           | Non-congested       | Congested           | Non-congested       |
| TAcc /min      | ±334 ±394 ±381 ±356 | ±1039 ±511 ±374 ±791 | ±5237 ±4923 ±4576 ±4679 | ±4883 ±4922 ±546   |
| HAcc /min      | ±155 ±13.8 ±19.5 ±15.3 | ±21.8 ±16.4 ±11.6 ±18.1 | ±23.3 ±22.9 ±20.3 ±18.5 | ±35.9 ±21.4 ±47.5 ±51.1 | ±30.2 ±49.5 ±37.8 |
| IAcc /min      | ±48.5 ±85.7 ±112.6 ±102 | ±228 ±117 ±115 ±181 | ±181 ±139 ±167 ±133 | ±911 ±932 ±3896 ±5322 | ±35.9 ±21.4 ±47.5 ±51.1 | ±30.2 ±49.5 ±37.8 |
| LAcc /min      | ±280 ±316 ±324 ±280 | ±769 ±411 ±296 ±582 | ±500 ±526 ±519 ±423 | ±500 ±526 ±519 ±423 | ±500 ±526 ±519 ±423 | ±500 ±526 ±519 ±423 |
| TDec /min      | ±3.14 ±3.70 ±4.01 ±3.20 | ±9.61 ±4.93 ±5.40 ±7.63 | ±5.40 ±6.58 ±6.35 ±5.42 | ±5.40 ±6.58 ±6.35 ±5.42 | ±5.40 ±6.58 ±6.35 ±5.42 | ±5.40 ±6.58 ±6.35 ±5.42 |
| HDec /min      | ±0.30 ±0.30 ±0.30 ±0.30 | ±0.30 ±0.30 ±0.30 ±0.30 | ±0.30 ±0.30 ±0.30 ±0.30 | ±0.30 ±0.30 ±0.30 ±0.30 | ±0.30 ±0.30 ±0.30 ±0.30 | ±0.30 ±0.30 ±0.30 ±0.30 |
| IDec /min      | ±0.88 ±0.83 ±1.18 ±1.04 | ±2.20 ±1.18 ±1.56 ±1.90 | ±1.66 ±1.76 ±1.64 ±1.48 | ±1.66 ±1.76 ±1.64 ±1.48 | ±1.66 ±1.76 ±1.64 ±1.48 | ±1.66 ±1.76 ±1.64 ±1.48 |
| LDec /min      | ±2.80 ±3.04 ±3.41 ±2.47 | ±7.07 ±4.01 ±4.06 ±5.43 | ±3.83 ±5.07 ±4.73 ±4.03 | ±3.83 ±5.07 ±4.73 ±4.03 | ±3.83 ±5.07 ±4.73 ±4.03 | ±3.83 ±5.07 ±4.73 ±4.03 |
| MDec /min      | ±21.9 ±22.4 ±31.5 | ±47.6 ±33.1 ±24.3 ±36.4 | ±45.7 ±32.4 ±44.8 ±39.3 | ±45.7 ±32.4 ±44.8 ±39.3 | ±45.7 ±32.4 ±44.8 ±39.3 | ±45.7 ±32.4 ±44.8 ±39.3 |
| HDec /min      | ±32.6 ±34.9 ±31.8 ±38.9 | ±75.2 ±36.6 ±58.0 ±56.1 | ±42.5 ±59.1 ±43.2 ±48.6 | ±42.5 ±59.1 ±43.2 ±48.6 | ±42.5 ±59.1 ±43.2 ±48.6 | ±42.5 ±59.1 ±43.2 ±48.6 |
| IDec /min      | ±111 ±11.2 | ±112 ±61.3 ±153 | ±167 ±140 ±15.9 ±12.4 | ±167 ±140 ±15.9 ±12.4 | ±167 ±140 ±15.9 ±12.4 | ±167 ±140 ±15.9 ±12.4 |
| MDec /min      | ±380 ±362 ±368 ±1000 | ±507 ±288 ±777 ±678 | ±610 ±668 ±552 | ±610 ±668 ±552 | ±610 ±668 ±552 | ±610 ±668 ±552 |
| TDec /min      | ±528 ±529 ±534 ±538 | ±500 ±500 ±500 ±500 | ±500 ±500 ±500 ±500 | ±500 ±500 ±500 ±500 | ±500 ±500 ±500 ±500 | ±500 ±500 ±500 ±500 |
| LAcc /min      | ±38.1 ±38.4 ±40.1 ±40.2 | ±39.9 ±40.1 ±42.0 ±41.2 | ±38.7 ±38.6 ±39.7 | ±38.7 ±38.6 ±39.7 | ±38.7 ±38.6 ±39.7 | ±38.7 ±38.6 ±39.7 |

T, M, H, I and LAcc: total, maximal, high, intermediate and low accelerations, respectively; T, M, H, I and LDec: total, maximal, high, intermediate and low decelerations, respectively. * Higher during non-congested vs. congested, for the same measure and the same playing position (p<0.05).
### TABLE 4. Time spent accelerating and decelerating during congested and non-congested periods of matches in professional soccer players.

| (s)   | Central Backs | Full-Backs | Central Midfielders | Wide Forwards | Central Forwards | All players |
|-------|---------------|------------|---------------------|---------------|------------------|-------------|
|       | Congested     | Non-congested | Congested     | Non-congested | Congested     | Non-congested | Congested     | Non-congested | Congested     | Non-congested | Congested     | Non-congested |
| TAcc  | ± 621         | ± 832       | ± 306             | ± 518         | ± 878          | ± 434        | ± 944         | ± 629         | ± 870         | ± 526         | ± 629         | ± 870         |
| MAcc  | ± 29.7        | ± 34.0      | ± 38.4            | ± 42.9        | ± 38.2         | ± 37.6       | ± 35.6        | ± 41.3        | ± 33.7        | ± 39.4*       | ± 33.7        | ± 39.4*       |
| HAcc  | ± 6.66        | ± 7.15      | ± 6.45            | ± 7.25        | ± 5.92         | ± 0.79       | ± 8.23        | ± 9.36        | ± 8.20        | ± 7.68        | ± 8.20        | ± 7.68        |
| IAcc  | ± 93.7        | ± 105       | ± 111             | ± 99.2        | ± 115          | ± 110        | ± 97.0        | ± 104         | ± 100         | ± 110*        | ± 100         | ± 110*        |
| LAcc  | ± 37.5        | ± 389       | ± 434             | ± 390         | ± 407          | ± 394        | ± 363         | ± 362         | ± 397         | ± 401         | ± 362         | ± 397         |
| TDec  | ± 39.8        | ± 47.2      | ± 36.5            | ± 88.4        | ± 34.7         | ± 19.6       | ± 69.2        | ± 47.7        | ± 67.5        | ± 51.1        | ± 69.2        | ± 47.7        |
| MDec  | ± 4.04        | ± 4.11      | ± 4.65            | ± 4.26        | ± 4.46         | ± 4.49       | ± 4.17        | ± 4.10        | ± 4.30        | ± 4.37        | ± 4.17        | ± 4.30        |
| HDec  | ± 0.39        | ± 0.29      | ± 0.50            | ± 0.84        | ± 0.39         | ± 0.44       | ± 0.62        | ± 0.63        | ± 0.50        | ± 0.50        | ± 0.62        | ± 0.63        |
| IDec  | ± 44.0        | ± 39.3      | ± 43.3            | ± 40.7        | ± 38.7         | ± 41.6       | ± 40.4        | ± 42.1*       | ± 38.9        | ± 40.4        | ± 42.1*       | ± 38.9        |
| LDec  | ± 10.1        | ± 4.29      | ± 9.21            | ± 4.47        | ± 8.56         | ± 4.65       | ± 9.03        | ± 5.10        | ± 8.83        | ± 4.92        | ± 9.03        | ± 5.10        |
| TDec /min | ± 2969       | ± 3106      | ± 3023            | ± 3070        | ± 2844         | ± 2957       | ± 2941        | ± 2780        | ± 2717        | ± 2909        | ± 2909        |
| MDec /min | ± 30.4       | ± 45.0      | ± 49.1            | ± 41.3        | ± 47.4         | ± 46.4       | ± 47.1        | ± 51.9        | ± 41.4        | ± 45.3*       | ± 41.4        | ± 45.3*       |
| HDec /min | ± 79.9       | ± 85.2      | ± 104             | ± 94.9        | ± 103          | ± 93.5       | ± 102         | ± 95.8        | ± 97.3        | ± 12.2        | ± 12.2        | ± 14.8        |
| IDec /min | ± 362        | ± 382       | ± 411             | ± 408         | ± 373          | ± 397        | ± 387         | ± 368         | ± 342         | ± 378         | ± 342         | ± 378         |
| LDec /min | ± 2496       | ± 2604      | ± 2462            | ± 2510        | ± 2335         | ± 2410       | ± 2408        | ± 2273        | ± 2226        | ± 2281        | ± 2281        | ± 2436        |
| TDec /min | ± 31.8       | ± 32.9      | ± 32.1            | ± 31.3        | ± 31.4         | ± 31.3       | ± 31.3        | ± 31.3        | ± 31.3        | ± 31.3        | ± 31.3        | ± 31.3        |
| MDec /min | ± 0.33       | ± 0.36      | ± 0.48            | ± 0.52        | ± 0.50         | ± 0.53       | ± 0.55        | ± 0.58        | ± 0.45        | ± 0.50*       | ± 0.58        | ± 0.45*       |
| HDec /min | ± 0.86       | ± 0.90      | ± 1.09            | ± 1.04        | ± 1.12         | ± 1.07       | ± 1.18        | ± 1.15        | ± 1.04        | ± 1.05        | ± 1.05        | ± 1.05        |
| IDec /min | ± 3.89       | ± 4.04      | ± 4.33            | ± 4.08        | ± 4.35         | ± 4.23       | ± 3.94        | ± 4.09        | ± 4.20        | ± 3.89        | ± 4.09        | ± 4.20        |
| LDec /min | ± 26.8       | ± 27.6      | ± 25.9            | ± 26.7        | ± 25.5         | ± 26.4       | ± 25.7        | ± 26.1        | ± 25.6        | ± 25.6        | ± 25.6        | ± 25.6        |

T, M, H, I and LAcc: total, maximal, high, intermediate and low accelerations, respectively; T, M, H, I and LDec: total, maximal, high, intermediate and low decelerations, respectively. * Higher during non-congested vs. congested (p<0.05); † Higher during congested vs. non-congested (p<0.05).
Positional match profiles during fixture congestion

**FIG. 1.** Distance covered and time spent accelerating and decelerating during congested and non-congested period of professional soccer matches.

TAcc, MAcc, HAcc, IAcc, LAcc: total, maximal, high, intermediate and low accelerations, respectively; TDec, MDec, HDec, IDec, LDec: total, maximal, high, intermediate and low decelerations, respectively.

* Higher during non-congested vs. congested, for the same measure (p < 0.05); $ Higher during congested vs. non-congested, for the same measure (p < 0.05).
and the relative measures of MAcc (as a time and a distance) and MDec (as a distance), the Kruskal-Wallis non-parametric test was carried out. When a variable was normally distributed, a two-way ANOVA was used to test the effect of condition (congested periods vs. non-congested periods), positions and the interaction these two factors on the variable. A difference was considered as significant when \( p < 0.05 \). When significant, t-tests or Wilcoxon tests were used to point the differences and Bonferroni’s correction was applied for the playing positions analysis. Therefore, differences between playing positions were considered significant when \( p < 0.005 \). Measures reliability was calculated with Cronbach’s alpha and with coefficients of variation (CV) that were calculated from the ratio standard deviation (sd)/mean. The effect sizes (ES) were calculated for every significant difference and interpreted as small: < 0.50, moderate: 0.50 to 0.80, or large: > 0.80, as described by Cohen [29]. All the data are presented as mean ± sd.

RESULTS

Physical activity in terms of speed threshold
Across the period analysed, it was observed a condition (congested vs. non-congested) effect for ISR distance per minute (F(1,269) = 4.42, CV: 20–22%, ES: 0.31, p = 0.03). However, no condition effect was observed for absolute and relative TDC (F(1,269) = 1.09 & 2.22 respectively, \( p > 0.05 \), CV: 10–13%), LSR (F(1,269) = 0.39 & 0.26 respectively, \( p > 0.05 \), CV: 7–12%), HSR (F(1,269) = 3.07 & 3.63, \( p > 0.05 \), CV: 27–34%) and sprint (F(1,269) = 0.02 & 0.01 respectively, \( p > 0.05 \), CV: 48–57%) measures (Table 1). The playing position effect for every analysed variables was presented in Table 2. No interaction effect was observed for the TDC, LSR, ISR, HSR and sprints in terms of both distance and time (F(4,260) = 0.12 to 1.36, \( p > 0.05 \)).

Physical activity in terms of acceleration and deceleration
A condition effect was verified for the distances covered at MAcc (F(1,269) = 19.8, \( p < 0.0001 \), ES: 0.60) and HAcc (F(1,269) = 14.6, ES: 0.56, \( p = 0.0002 \), RMAcc (F(1,269) = 22.2, ES: 0.33, \( p < 0.0001 \), RHAcc (F(1,269) = 16.9, ES: 0.57, \( p < 0.0001 \), RMDec (F(1,269) = 7.56, ES: 0.34, \( p = 0.006 \) and RIdDec (F(1,269) = 4.02, ES: 0.29, \( p = 0.046 \)) (Table 2). A condition effect was also verified for the time spent in TAcc (F(1,269) = 10.1, ES: 0.49, \( p = 0.002 \), MAcc (F(1,269) = 27.1, ES: 0.70, \( p < 0.0001 \), HAcc (F(1,269) = 18.4, ES: 0.61, \( p < 0.0001 \), LAcc (F(1,269) = 12.1, ES: 0.53, \( p = 0.0006 \) and MDec (F(1,269) = 8.93, ES: 0.36, \( p = 0.003 \), and RTamAcc (F(1,269) = 10.4, ES: 0.50, \( p = 0.001 \), RMAcc (F(1,269) = 30.1, ES: 0.68, \( p < 0.0001 \), RHAcc (F(1,269) = 21.7, ES: 0.64, \( p < 0.0001 \), RTDec (F(1,269) = 4.71, ES: 0.31, \( p = 0.03 \) and RMDec (F(1,269) = 10.6, ES: 0.42, \( p = 0.001 \)) (Table 3, Table 4, Figure 1). No interaction effects were observed for all the acceleration and deceleration variables (\( p > 0.05 \)). CV obtained in Acc and Dec profiles ranged from 8 to 32% and Cronbach’s alpha was 0.95.

DISCUSSION

The aim of the present study was to analyse the effects of acceleration and deceleration profiles of professional soccer players during official games across congested fixture periods in terms of distance covered and time spent in each Acc and Dec. The results highlighted the fact that both Acc and Dec profiles were significantly affected by congested periods of matches. It was observed that (i) the distance covered through maximal Acc, relative maximal Acc, high Acc, relative high Acc, relative maximal Dec and relative intermediate Dec during matches were lower in congested than in non-congested periods (ES: 0.33–0.60) (Figure 1A and 1B); (ii) the duration of MAcc, RMAcc, HAcc, RHAcc, MDec, RMDec and TDec were also lower in congested than in non-congested periods (ES: 0.36–0.70) (Figure 1C and 1D).

Arruda et al. [22] observed a decrease in the total number of Acc per min during a five-mini match tournament performed in three days (two matches the first two days and one last day) in youth soccer players. The number of Acc and Dec was not assessed in the present study, it is therefore difficult to compare them to our results. However, although the competitive context and the type of players were totally different, it might be considered that both studies were complementary by its findings.

It is interesting to notice that distances covered and time spent in MAcc and MDec, in all absolute and relative measures (except distance covered in MDec), were negatively affected by a congested calendar. It might be suggested that the players in the present study showed significant decreases in distance covered and time spent at different Acc and Dec thresholds during congested matches, especially in maximal acceleration profiles, as a consequence of cumulated general and peripheral (e.g. muscular) fatigue [30]. Current research highlighted an increase in the physiological stress and fatigue within congested periods, especially with a significant decrease in salivary testosterone, salivary immunoglobulin-A and an increase in muscle damage markers [19, 31, 32]. It is well known that COD, Acc and Dec, which are specific components of soccer player’s movements [1], require a strong muscular involvement with both concentric and eccentric muscle contractions [6, 7, 8], especially when starting from low-speed running that imply very high Acc to reach great speed in short time [28, 33].

No differences were specifically observed among playing positions for the effect of a congested calendar. Various authors observed that defensive players were negatively affected by a congested calendar, in terms of tactical synchronisation [34], defensive technical activity [31], and physical activity when comparing a microcycles of two matches within three-day vs. four-day [35]. Suggestions of why offensive players were less affected by the congested phases maybe due to fitness levels, potential benefits of more squad rotation aspects, or possible substitution strategies [34, 35]. Indeed, it was suggest-
Positional match profiles during fixture congestion

playing rotation and substitution strategies than defensive players. Interestingly, in the present investigation, 49% of the substitutions made by the team across the investigated periods were for WF and CF, while only 21% were for CB and FB, as reported by the data selection. Offensive players did not benefit from this substitution strategy to maintain the level of Acc and Dec during the congested periods. Anyway, no difference was made between the microcycles that includes two consecutive games within three to four days. It could therefore be interesting to analyse the differences between these two conditions in order to detect any position-related impact.

Duration spent within the TAcc and in the LAcc were increased during the congested match periods assessed. Since the present study was the first to analyse Acc profiles during congested periods of elite professional soccer match-play, comparisons with similar literature was not viable. However, similar positive effects of a congested fixture period have been found concerning the relative total distance covered, and the relative low-speed running (< 11 km·h⁻¹) bouts per minute of play amongst professional players [16]. Authors of this particular investigation suggested that these increased values may be linked to tactical factors such as team formation, playing style, specific physical and technical demands and different levels of opposition [16]. Increases in the absolute and relative TAcc and LAcc were accompanied by decreases in absolute and relative MAcc and HAcc, during the congested matches in the current study. Therefore, it can be suggested that the significant increase of TAcc and LAcc may be seen as an involuntary coping strategy that players perform subconsciously in order to compensate the reduction in MAcc and HAcc. Furthermore, these may be performed or caused by an accumulated fatigue across the congested periods, with the aim of trying to maintain performance levels. Faude et al. [36] have shown that soccer performance is more dependent on high speed runs and sprints than on low intensity efforts highlighting that soccer goals are very often preceded by high intensity straight sprints. Aerobic capacity is a key-factor to reproduce high and very high intensity running, accelerating and decelerating efforts over a long period of time like in a soccer game [1]. Moreover, developing aerobic capacity might be important to reduce injury risks and improve match performance [37].

The report from playing position differences (Table 2) showed that FB and WF had a similar overall physical activity, except in the time spent in TAcc and TDec, where FB reported higher values. These observations were in accordance with previous statement reporting that FB and WF work in synergy [38] with similar profiles and positional demand in term of attacking and defensive involvement [17, 39, 40]. The difference observed in the total time spent in Acc and Dec might be explained by the fact that FB is positioned deeper on the field, therefore FB would need more time to reach offensive zones when his team gains ball possession and, in the same way, to get back to his defensive position when his team has lost the ball. In the present study, FB and WF had the highest overall physical implication, which might be related to the playing system used by the investigated team, which might have highly involved the lateral players [41]. CB had the lowest overall activity, except in LSR, LAcc, TDec, LDec, RTDec and RLDec. These observations were in line with the current literature stating that CB is the playing position with the lowest physical demand, especially high intensity efforts [27, 42]. However, their tactical position on the field, facing the game, make them see and anticipate the moves, especially realising more backward and lateral runs that cost more energy than classical forward running [43].

The analysis of distance covered and time spent at different speed threshold showed that the congested calendar did not affect the overall physical activity, except for distance covered per minute at ISR, which were negatively affected during congested matches (35.5 ± 7.66 vs. 37.9 ± 7.67, ES: 0.31). This result was not in accordance with the current literature. Some authors found a positive impact of congested calendar in running distance covered at speeds inferior to 12 km·h⁻¹ [17] and distance per minute covered at speeds inferior to 11 km·h⁻¹ [16]. It is possible that the different inclusion criteria related to time of play induced differences within the studies, as Djouji et al. [17] included players who participated to the total duration of the match and only measured absolute distance covered, and Carling et al. [16] included every players including substitutes. We can also consider that if only data from players who participated in 100% of a match would have been retained for the present analysis, the results could have been different. Furthermore, players from the present study covered −66 m per min and players from comparable studies covered −69–73 m per min [16] and −7100–7400 m (which would be higher than 70m per min) [17], with similar differences in all speed categories, which might suggest a different physical involvement related to a different level of players. The potential different standard of play and physical fitness might therefore explain the different results observed. It might therefore be suggested that, even if they were professional soccer players, the potential lower physical fitness of players from the present study could have negatively impacted their physical activity in relative ISR distance per minute during the congested periods. However, the distance covered and the time spent at HSR and sprinting were unaffected by a congested calendar, which was in accordance with current literature on this topic [18]. It might also be suggested that reducing the physical activity at ISR would not have the same effect on overall match performance, since high and very high intensity actions are supposed to be the most decisive ones to succeed [36, 44, 45].

In the present study, physical activity was tracked using 10 Hz GPS units, which were reported to have a compromised accuracy when tracking Acc over 4 m·s⁻² [46]. Nevertheless, even if caution is needed when interpreting MAcc and MDec assessed in the present investigation, 10 Hz units are, for now, and to the best of the author's knowledge, the best tool available when tracking Acc and Dec in team sport athletes with GPS [25].

To conclude, the present study is unique in its inception based on its analysis of the acceleration profiles of professional soccer players.
players within congested periods of matches. Results have revealed that congested fixture periods negatively affected maximal acceleration and deceleration of professional players in addition with a reduction of the total distance covered and time spent performing maximal and high accelerations. Defensive players like CB, FB and CM were mostly impacted through decrements during congested periods, however furthermore, the maximal- and HSR activity remained stable across the period of analysis. Subsequently, it may therefore be suggested that the accumulated fatigue imposed as a result of congested game periods affected the acceleration activity of the players. As a result, the findings of the present study may not be generalised across level of play and other teams or players at the professional level due the data being obtained from one playing squad, which is the main limitation of the present study. Professional soccer teams should be advised to monitor acceleration and deceleration metrics throughout particular periods of congested fixtures, like those imposed by the COVID-19 pandemic delays in competitions, as a way of monitoring and assessing physical player status and possible recovery. However, additional research is required and requested to analyse key relationships between acceleration profile, subjective fatigue, physiological indicators and injury rates during periods of fixture congestion.

**PRACTICAL APPLICATION**

Based on the fact that elite players are continually exposed to greater number of fixtures year upon year with limited recovery periods between games, this novel investigation highlighting the effects of acceleration and deceleration profiles and the potential fatiguening effects of fixture congestion is of great practical relevance. The analysis in the present study highlights that professional soccer players’ acceleration and deceleration profiles were significantly affected across congested playing periods. It is therefore recommended that soccer teams pay particular attention to the individual-related fatigue while monitoring Acc and Dec. The use of individual strategies as such as squad rotation, timing of substitutions and/or recovery strategies utilised to potentially eradicate such decreased physical activity and maintain performance in congested periods is highly suggested.

**KEY POINTS**

- A reduction in high and maximal accelerations was observed during congested compared to non-congested periods.
- A reduction in high and maximal decelerations was observed during congested compared to non-congested periods.
- The role of congested period on accelerations and decelerations did not vary by playing position.

**Acknowledgement**

The authors would like to thank all the players for their implication throughout the investigation process and procedures, and all the staff involved to make this investigation possible.

**Conflict of Interest**

The authors identify no conflicts of interest in the conduct of the present study.

**REFERENCES**

1. Stalen T, Chamari K, Castagna C, Wisløff U. Physiology of soccer: an update. Sports Med. 2005; 35(6): 501–536.
2. Aughey RJ. Applications of GPS technologies to field sports. Int J Sports Physiol Perform. 2011; 6:295–310.
3. Swallow WE, Skidmore N, Page RM, Malone JJ. An examination of in-season external training load in semi-professional soccer players: considerations of one and two match weekly microcycles. Int J Sport Sci Coaching. 2020 [Epub ahead of print].
4. Bradley PS, Sheldon W, Wooster B, Olsen P, Boanas P, Krstrup P. High-intensity running in English FA Premier League soccer matches. J Sports Sci. 2009; 27:159–168.
5. Gaudino P, Iaia FM, Alberti G, Sturdwick AJ, Atkinson G, Gregson W. Monitoring training in elite soccer players: a systematic bias between running speed and metabolic power data. Int J Sports Med. 2013;34:963–968.
6. Raastad T, Owe SG, Paulsen G, Enns D, Overguard K, Cramer R, Kiil S, Belcastro A, Bergersen L, Hallen J. Changes in calpain activity, muscle structure, and function after eccentric exercise. J Med Sci Sports Exerc. 2010; 42(1):86–95.
7. Young WB, Hepner J, Robbins DW. Movement demands in Australian rules football as indicators of muscle damage. J Strength Cond Res. 2012; 26(2):492–496.
8. Silva JR, Rebelo A, Marques F. Biochemical impact of soccer: an analysis of hormonal, muscle damage, and redox markers during the season. Appl Physiol Nutr Metab. 2014;39(4):432–438.
9. Owen AL, Dunlop G, Rouissi M, Chitara M, Paul D, Zouhal H, Wong Del P. The relationship between lower-limb strength and match-related muscle damage in elite level professional European soccer players. J Sports Sci. 2015;33(20):1–6.
10. Della A, Keller D, Carling C, Chaouachi A, Wong del P, Chamari K. Physiologic effects of directional changes in intermittent exercise in soccer players. J Strength Cond Res. 2010; 24(12):3219–3226.
11. Buchheit M, Bishop D, Haydar B, Nakamura FY, Ahmad A. Physiological responses to shuttle repeated sprint running. Int J Sports Med. 2010; 31:402–409.
12. Chaouachi A, Manzi V, Chaalali A, Wong del P, Chamari K, Castagna C. Determinants analysis of change-of-direction ability in elite soccer players. J Strength Cond Res. 2012; 26(10):2667–2676.
13. Akenhead R, French D, Thompson KG, Hayes PR. The physiological consequences of acceleration during shuttle running. Int J Sports Med. 2015; 36:302–307.
14. Castagna C, Varley M, Povoas SCA, D’Ottavio S. Evaluation of the match external load in soccer: methods comparison. Int J Sports Physiol Perform. 2016;6:1–25.
15. Dalen T, Ingebrigsten J, Ettema G, Hjelde GH, Wisløff U. Player load, acceleration, and deceleration during forty-five competitive matches of elite soccer. J Strength Cond Res. 2016; 30(2):351–359.
16. Carling C, Le Gall F, Dupont G. Are physical performance and injury risk in a professional soccer team in match-play affected over a prolonged period of fixture congestion? Int J Sports Med. 2012;33:36–42.
Positional match profiles during fixture congestion

17. Djacoui L, Wong DP, Pialoux V, Hautier C, Da Silva CD, Chamari K, Delali A. Physical activity during a prolonged congested period in a top-class European football team. Asian J Sports Med. 2014; 5(1):47–53.

18. Jones RN, Greig M, Mawené Y, Barrow J, Page RM. The influence of short-term fixture congestion on position specific match running performance and external loading patterns in English professional soccer. J Sports Sci. 2019; 37(12):1338–1346.

19. Mohr M, Draganidis D, Chatzinkolalou A, Barbero-Alvarez JC, Castagna C, Douroudos I, Avlonitou A, Margeli A, Papassotiriou I, Flouris AD, Jamartas AZ, Kustrup P, Fatouros IG. Muscle damage, inflammatory, immune and performance responses to three games in 1 week in competitive male players. Eur J Appl Physiol. 2016; 116(1):179–193.

20. Silva JR, Ascensão A, Marques F, Seabra A, Rebelo A, Magalhães J. Neuromuscular function, hormonal and redox status and muscle damage of professional soccer players after a high-level competitive match. Eur J Appl Physiol. 2013;113:2193–2201.

21. Owen, AL, Cossio-Bolaños M, Dunlop G, Rouissi M, Chtara M, Bragazzi N, Chamari K. Stability in post-seasonal hematological profiles in response to high competitive match-play loads within elite top level European soccer players: implications from a pilot study. Open Access J Sports Med. 2018;9:157–166.

22. Arruda AFS, Carling C, Zanetti V, Aoki MS, Coutts AJ, Moreira A. Effects of a very congested match schedule on body-load impacts, accelerations, and running measures in youth soccer players. Int J Sports Physiol Perform. 2015;10:248–252.

23. Beato M, Drust B. Acceleration intensity is an important contributor to the external and internal training load demands of repeated sprint exercises in soccer players. Res Sports Med. 2020 [Epub ahead of print].

24. Varley MC, Fairweather IH, Aughey RJ. Validity and reliability of GPS for measuring instantaneous velocity during acceleration, deceleration, and constant motion. J Sports Sci. 2012; 30(2):121–127.

25. Beato M, de Keijzer KL. The inter-unit and inter-model reliability of GNSS STATSports Apex and Viper units in measuring peak speed over 5, 10, 15, 20 and 30 meters. Biol Sport. 2019;36(4):317–321.

26. Rampinini E, Bishop D, Marcosa S, Ferrari Bravo D, Sassi R, Impellizzeri F. Validity of simple field tests as indicators of match-related physical performance in top-level professional soccer players. Int J Sports Med. 2007; 28(3):228–235.

27. Di Salvo V, Gregson W, Atkinson G, Tordoff P, Drust B. Analysis of high intensity activity in premier league soccer. Int J Sports Med. 2009;30:205–212.

28. Osgnach C, Posen S, Bernardini R, Rinaldi R, di Prampero PE. Energy cost and metabolic power in elite soccer: A new match analysis approach. Med Sci Sports Exerc. 2010;42:170–178.

29. Cohen, J. Statistical Power Analysis for the Behavioural Sciences. 2nd ed. Hillsdale, NJ: Lawrence Erlbaum, 1988.

30. Andersson H, Raastad T, Nilsson J, Paulsen G, Garthe I, Kadi F. Neuromuscular fatigue and recovery in elite female soccer: effects of active recovery. Med Sci Sports Exerc. 2008; 40(2):372–380.

31. Moreira A, Bradley P, Carling C, ARrueda AF, Spigolon LM. Effect of a congested match schedule on immune-endocrine responses, technical performance and session-RPE in elite youth soccer players. J Sports Sci. 2016;34(24):2255–2261.

32. Morgans R, Orme P, Anderson L, Drust B, Morton JP. An intensive winter fixture schedule induces a transient fall in salivary IgA in English premier league soccer players. Res Sports Med. 2014; 22(4):346–354.

33. Varley MC, Aughey RJ. Acceleration profiles in elite Australian soccer. Int J Sports Med. 2013;34:34–39.

34. Folgado H, Duarte R, Marques P, Sampaio J. The effects of congested fixtures period on tactical and physical performance in elite football. J Sports Sci. 2015;33(12):1238–1247.

35. Penedo-Jamardo E, Rey E, Padron-Cabo A, Kalen A. The impact of different recovery times between matches on physical and technical performance according to playing positions. Int J Perform Anal Sport. 2017;17(3): 271–282.

36. Faude O, Koch T, Meyer T. Straight sprinting is the most frequent action in goal situations in professional football. J Sports Sci. 2012;30:625–631.

37. Malone S, Owen A, Mendes B, Hughes B, Collins K, Gabbett TJ. High-speed running and sprinting as an injury risk factor in soccer: can well-developed physical qualities reduce the risk? J Sci Med Sport. 2018;21(3):257–262.

38. Silva P, Chung D, Carvalho T, Cardoso T, Davids K, Araujo D, Garganta J. Practice effects on intra-team synergies in football team. Hum Mov Sci. 2016;46:39–51.

39. Mohr M, Kustrup P, Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. J Sports Sci. 2003;21:519–528.

40. Dellali A, Wong Del P, Moalla W, Chamari K. Physical and technical activity of soccer players in the French first league – with special reference to their playing formation. Int SportMed J. 2010;11(2):278–290.

41. Bradley PS, Carling C, Archer D, Roberts J, Dodds A, Di Mascio M, Paul D, Gomez Diaz A, Peart D, Kustrup P. The effect of playing formation in high-intensity running and technical profiles in English FA Premier League soccer matches. J Sports Sci. 2011; 29(8):821–830.

42. Di Salvo, V, Baron, R, Tscham, H, Calderon Montero, FJ, Bachl, N, Pigozzi, F. Performance characteristics according to playing position in elite soccer. Int J Sports Med. 2007; 28:222–227.

43. Bloomfield J, Polman R, O'Donoghue P. Physical demands of different positions in FA premier league soccer. J Sports Sci Med. 2007;6(1):63–70.

44. Arnason A, Sigurdsson SB, Gudmundsson A, Holme I, Engebretsen L, Bahr R. Physical fitness, injuries, and team performance in soccer. Med Sci Sports Exerc. 2004; 36(2):278–285.

45. Lago-Perlas C, Casais L, Dellali A, Rey E, Dominguez E. Anthropometric and physiological characteristics of young soccer players according to their playing positions: relevance for competition success. J Strength Cond Res. 2011; 25(12):3358–3367.

46. Akenhead R, French D, Thompson KG, Hayes PR. The acceleration dependent validity and reliability of 10 Hz GPS. J Sci Med Sport. 2014;17(5):562–566.