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

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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.

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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 resultant 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 special 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:

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
DISTANCE COVERED (m)												
Total	9703 ± 712	10076 ± 810	10477 ± 719	10501 ± 700	9969 ± 2034	10311 ± 1003	10668 ± 653	10160 ± 1561	9233 ± 1274	9510 ± 1253	10005 ± 1344	10167 ± 1082
LSR	6096 ± 488	6213 ± 400	6377 ± 320	6223 ± 360	5909 ± 1190	5973 ± 573	6396 ± 245	5760* ± 941	5762 ± 615	5769 ± 621	6097 ± 753	6023 ± 604
ISR	3082 ± 336	3381 ± 578	3348 ± 447	3491 ± 419	3519 ± 1083	3766 ± 699	3505 ± 503	3531 ± 739	2796 ± 796	2899 ± 779	3275 ± 747	3460 ± 687
HSR	410 ± 73.9	387 ± 88.0	580 ± 127	622 ± 159	435 ± 129	470 ± 142	590 ± 123	688 ± 158	569 ± 128	635 ± 115	501 ± 138	543 ± 174
Sprint	115 ± 62.9	94.9 ± 58.9	171 ± 69.5	165 ± 64.0	106 ± 60.0	101 ± 66.4	177 ± 67.3	181 ± 57.5	170 ± 74.2	207 ± 98.9	141 ± 70.9	142 ± 80.8
Total /min	104 ± 6.16	107 ± 7.48	110 ± 7.57	112 ± 6.34	109 ± 18.9	113 ± 9.85	114 ± 9.50	117 ± 15.2	106 ± 10.7	107 ± 12.6	108 ± 12.2	111 ± 10.7
LSR /min	65.5 ± 3.64	65.8 ± 3.65	67.1 ± 3.37	66.2 ± 3.33	64.5 ± 10.9	65.3 ± 3.98	68.4 ± 2.08	66.1 ± 8.48	66.4 ± 4.44	64.9 ± 4.08	66.0 ± 64.9	65.7 ± 47.0
ISR /min	33.2 ± 4.12	35.8 ± 5.84	35.2 ± 4.71	37.1 ± 4.15	38.5 ± 11.0	41.4 ± 8.34	37.6 ± 6.25	40.7 ± 8.04	32.0 ± 7.85	32.9 ± 8.97	35.5 ± 7.66	37.9* ± 7.67
HSR /min	4.38 ± 0.65	4.10 ± 0.93	6.11 ± 1.34	6.61 ± 1.66	4.79 ± 1.36	5.14 ± 1.49	6.34 ± 1.56	7.97 ± 1.94	6.56 ± 1.27	7.18 ± 1.38	5.45 ± 1.47	5.96 ± 2.00
Sprint /min	1.23 ± 0.65	1.00 ± 0.62	1.80 ± 0.73	1.75 ± 0.68	1.15 ± 0.62	1.11 ± 0.72	1.91 ± 0.80	2.07 ± 0.63	1.99 ± 0.91	2.31 ± 1.02	1.53 ± 0.78	1.55 ± 0.88
TIME SPENT (s)												
Total	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
LSR	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ISR	810 ± 83.2	887 ± 152	867 ± 114	902 ± 108	917 ± 278	975 ± 177	912 ± 137	913 ± 190	718 ± 211	743 ± 201	852 ± 193	897 ± 178
HSR	67.3 ± 11.9	63.9 ± 14.5	95.0 ± 20.7	102 ± 26.0	72.0 ± 21.4	77.7 ± 23.2	96.7 ± 19.8	113 ± 26.0	93.4 ± 21.4	104 ± 19.0	82.4 ± 22.6	89.3 ± 28.5
Sprint	15.3 ± 8.19	12.5 ± 7.51	22.7 ± 8.97	21.9 ± 8.33	13.9 ± 7.82	13.4 ± 8.67	23.1 ± 9.00	24.0 ± 7.42	22.3 ± 9.43	27.1 ± 12.6	18.6 ± 9.22	18.7 ± 10.5
Total /min	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
LSR /min	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ISR /min	8.74 ± 1.06	9.38 ± 1.54	9.13 ± 1.20	9.58 ± 1.06	10.0 ± 2.82	10.7 ± 2.10	9.78 ± 1.68	10.5 ± 2.06	8.22 ± 2.09	8.42 ± 2.31	9.23 ± 1.99	9.81 ± 1.97
HSR /min	0.72 ± 0.10	0.68 ± 0.15	1.00 ± 0.22	1.08 ± 0.27	0.79 ± 0.23	0.85 ± 0.24	1.04 ± 0.25	1.31 ± 0.32	1.08 ± 0.21	1.18 ± 0.23	0.90 ± 0.24	0.98 ± 0.33
Sprint /min	0.16 ± 0.08	0.13 ± 0.08	0.24 ± 0.09	0.23 ± 0.09	0.15 ± 0.08	0.15 ± 0.09	0.25 ± 0.11	0.27 ± 0.08	0.26 ± 0.12	0.30 ± 0.13	0.21 ± 0.10	0.20 ± 0.11

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 distance (> 19.8 to < 25.2 km·h^{-1}), RHSR, 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

TABLE 2. Playing positions differences 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 > CB	0.51–1.76	**HSR**	FB,CF,WF > CM > CB	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 WF > 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 > CB	0.62–1.76	**HSR /min**	FB,WF,CF > CM > CB	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**	CB,FB > WF	0.57–0.72
MAcc	(CF > FB),CM,WF > CB	0.57–1.04	**MAcc**	CF,CM > CB	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 > CB	0.50–1.27	**MAcc /min**	CM,WF,CF > CB and 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,CF > 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,CF,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 > CB	1.09–1.55
IDec /min	FB,CM,WF > CB	0.75–0.89	**IDec /min**	FB,CM > CB,CF	0.52–0.91
LDec /min	CB,FB,CM,WF > CF	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.

(m)	CB		FB		CM		WF		CF		All players	
	Congested	Non-congested	Congested	Non-congested	Congested	Non-congested	Congested	Non-congested	Congested	Non-congested	Congested	Non-congested
TAcc	4645 ± 334	4797 ± 394	5133 ± 381	5113 ± 356	4870 ± 1039	4989 ± 511	5237 ± 374	4923 ± 791	4576 ± 671	4679 ± 646	4883 ± 690	4922 ± 546
MAcc	61.3 ± 15.5	73.5 ± 13.8	74.0 ± 19.5	82.5 ± 15.3	72.7 ± 21.8	91.2 ± 16.4	86.0 ± 11.6	83.0 ± 18.1	82.9 ± 23.3	96.4 ± 22.9	73.2 ± 20.3	84.9* ± 18.5
HAcc	218 ± 33.1	241 ± 30.4	255 ± 32.5	268 ± 32.8	239 ± 68.8	277 ± 35.9	279 ± 21.4	278 ± 47.5	253 ± 51.1	274 ± 30.2	244 ± 49.5	267* ± 37.8
IAcc	822 ± 84.5	853 ± 85.7	993 ± 112.6	983 ± 102	910 ± 228	958 ± 117	951 ± 115	973 ± 181	873 ± 181	880 ± 139	911 ± 167	932 ± 133
LAcc	3544 ± 280	3630 ± 316	3811 ± 324	3779 ± 280	3647 ± 769	3662 ± 411	3922 ± 296	3589 ± 582	3367 ± 500	3429 ± 526	3653 ± 519	3638 ± 423
TAcc /min	49.9 ± 3.14	50.8 ± 3.70	54.0 ± 4.01	54.4 ± 3.20	53.2 ± 9.61	54.7 ± 4.93	56.1 ± 5.40	56.6 ± 7.63	52.7 ± 5.40	52.7 ± 6.58	52.9 ± 6.35	53.8 ± 5.42
MAcc /min	0.66 ± 0.15	0.78 ± 0.14	0.78 ± 0.21	0.88 ± 0.16	0.79 ± 0.22	1.00* ± 0.17	0.92 ± 0.11	0.96 ± 0.20	0.97 ± 0.31	1.08 ± 0.21	0.80 ± 0.23	0.93* ± 0.20
HAcc /min	2.34 ± 0.30	2.55 ± 0.30	2.68 ± 0.34	2.85 ± 0.35	2.61 ± 0.70	3.04* ± 0.37	2.98 ± 0.21	3.21 ± 0.55	2.93 ± 0.58	3.09 ± 0.39	2.65 ± 0.52	2.92* ± 0.45
IAcc /min	8.84 ± 0.88	9.03 ± 0.83	10.5 ± 1.18	10.5 ± 1.04	9.94 ± 2.20	10.5 ± 1.18	10.2 ± 1.56	11.2 ± 1.90	10.0 ± 1.66	10.0 ± 1.76	9.88 ± 1.64	10.2 ± 1.48
LAcc /min	38.1 ± 2.80	38.4 ± 3.04	40.1 ± 3.41	40.2 ± 2.47	39.9 ± 7.07	40.1 ± 4.01	42.0 ± 4.06	41.2 ± 5.43	38.7 ± 3.83	38.6 ± 5.07	39.6 ± 4.73	39.7 ± 4.03
TDec	5058 ± 382	5279 ± 424	5344 ± 362	5388 ± 368	5100 ± 1000	5322 ± 507	5431 ± 288	5236 ± 777	4720 ± 678	4832 ± 610	5132 ± 668	5245 ± 552
MDec	98.9 ± 21.9	109 ± 22.4	155 ± 40.7	165 ± 31.5	136 ± 47.6	154 ± 33.1	161 ± 24.3	157 ± 36.4	165 ± 45.7	184 ± 32.4	139 ± 44.8	152 ± 39.3
HDec	229 ± 32.6	241 ± 34.9	306 ± 31.8	300 ± 38.9	274 ± 75.2	295 ± 36.6	308 ± 27.6	285 ± 58.0	315 ± 56.1	321 ± 42.5	281 ± 59.1	287 ± 48.6
IDec	867 ± 111	917 ± 88.8	987 ± 110	997 ± 101	926 ± 221	992 ± 112	979 ± 61.3	957 ± 153	869 ± 167	876 ± 140	92.6 ± 15.9	95.5 ± 12.4
LDec	3864 ± 310	4012 ± 357	3896 ± 289	3927 ± 296	3764 ± 700	3882 ± 420	3983 ± 220	3837 ± 559	3371 ± 503	3451 ± 485	3784 ± 493	3851 ± 448
TDec /min	54.4 ± 3.08	55.9 ± 3.88	56.3 ± 3.81	57.3 ± 3.44	55.8 ± 9.37	58.3 ± 5.11	58.1 ± 4.12	60.3 ± 7.73	54.3 ± 5.73	54.5 ± 6.10	55.6 ± 6.01	57.3 ± 5.43
MDec /min	1.06 ± 0.23	1.16 ± 0.24	1.63 ± 0.43	1.75 ± 0.32	1.47 ± 0.48	1.69 ± 0.36	1.72 ± 0.31	1.80 ± 0.37	1.92 ± 0.55	2.07 ± 0.30	1.51 ± 0.49	1.66* ± 0.43
HDec /min	2.46 ± 0.37	2.55 ± 0.35	3.22 ± 0.33	3.19 ± 0.42	3.00 ± 0.75	3.23 ± 0.34	3.30 ± 0.40	3.27 ± 0.54	3.64 ± 0.53	3.62 ± 0.42	3.06 ± 0.63	3.14 ± 0.53
IDec /min	9.30 ± 0.99	9.70 ± 0.80	10.4 ± 1.16	10.6 ± 1.04	10.1 ± 2.14	10.9 ± 1.14	10.5 ± 0.83	11.0 ± 1.57	10.0 ± 1.69	9.92 ± 1.79	10.0 ± 1.54	10.4* ± 1.33
LDec /min	41.5 ± 2.65	42.5 ± 3.40	41.0 ± 3.04	41.7 ± 2.77	41.2 ± 6.54	42.6 ± 4.38	42.6 ± 2.88	44.2 ± 5.67	38.8 ± 4.06	38.8 ± 4.60	41.0 ± 4.38	42.0 ± 4.35

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	4548 ± 621	4235 ± 296	4695 ± 832	4251 ± 365	4263 ± 1018	4104 ± 541	4439 ± 878	3785 ± 434	4032 ± 944	4079 ± 629	4422$ ± 870	4116 ± 526
MAcc	29.7 ± 6.66	36.3 ± 6.16	34.0 ± 7.15	38.4 ± 6.45	33.9 ± 10.2	42.9 ± 7.25	38.2 ± 5.92	37.6 ± 0.79	35.6 ± 8.23	41.3 ± 9.36	33.7 ± 8.20	39.4* ± 7.68
HAcc	93.7 ± 13.6	105 ± 11.7	106 ± 13.9	111 ± 12.7	99.2 ± 27.0	115 ± 13.4	106 ± 7.82	110 ± 8.03	97.0 ± 19.4	104 ± 11.8	100 ± 19.0	110* ± 14.2
IAcc	375 ± 39.8	389 ± 31.1	442 ± 47.2	434 ± 36.5	390 ± 88.4	407 ± 44.0	394 ± 34.7	391 ± 19.6	363 ± 69.2	362 ± 47.7	397 ± 67.5	401 ± 51.1
LAcc	4049 ± 664	3705 ± 305	4113 ± 875	3668 ± 379	3740 ± 953	3539 ± 511	3901 ± 904	3246 ± 72.5	3537 ± 949	3572 ± 629	3891$ ± 865	3567 ± 507
TAcc /min	49.3 ± 9.95	44.9 ± 4.25	49.4 ± 8.76	45.3 ± 4.36	46.4 ± 8.99	44.9 ± 4.76	47.3 ± 8.67	43.4 ± 3.78	46.1 ± 7.34	45.8 ± 4.89	47.9$ ± 8.72	44.9 ± 4.97
MAcc /min	0.32 ± 0.06	0.38 ± 0.06	0.36 ± 0.08	0.41 ± 0.07	0.37 ± 0.10	0.47 ± 0.08	0.41 ± 0.05	0.43 ± 0.01	0.42 ± 0.11	0.46 ± 0.09	0.37 ± 0.09	0.43* ± 0.08
HAcc /min	1.01 ± 0.13	1.11 ± 0.12	1.12 ± 0.15	1.18 ± 0.13	1.09 ± 0.28	1.26 ± 0.14	1.13 ± 0.06	1.27 ± 0.09	1.12 ± 0.20	1.17 ± 0.16	1.09 ± 0.19	1.20* ± 0.16
IAcc /min	4.04 ± 0.39	4.11 ± 0.29	4.65 ± 0.50	4.62 ± 0.37	4.26 ± 0.84	4.46 ± 0.39	4.22 ± 0.44	4.49 ± 0.21	4.17 ± 0.62	4.10 ± 0.61	4.30 ± 0.63	4.37 ± 0.50
LAcc /min	44.0 ± 10.1	39.3 ± 4.29	43.3 ± 9.21	39.1 ± 4.47	40.7 ± 8.56	38.7 ± 4.65	41.6 ± 9.03	37.2 ± 0.70	40.4 ± 7.92	40.0 ± 5.10	42.1$ ± 8.83	38.9 ± 4.92
TDec	2969 ± 278	3106 ± 249	3023 ± 165	3070 ± 237	2844 ± 549	2957 ± 302	2941 ± 235	2780 ± 0.01	2717 ± 285	2780 ± 315	2909 ± 360	2964 ± 327
MDec	30.6 ± 5.83	34.0 ± 6.55	45.5 ± 10.1	49.1 ± 7.95	41.3 ± 14.1	47.4 ± 8.87	46.4 ± 5.88	45.9 ± 0.58	47.1 ± 11.5	51.9 ± 8.91	41.4 ± 12.0	45.3* ± 10.4
HDec	79.9 ± 12.2	85.2 ± 12.3	104 ± 10.4	102 ± 11.9	94.9 ± 26.0	103 ± 11.5	100 ± 6.35	93.5 ± 10.5	102 ± 16.5	102 ± 12.5	95.8 ± 19.1	97.3 ± 14.8
IDec	362 ± 48.1	382 ± 33.3	411 ± 40.8	408 ± 34.1	373 ± 86.9	397 ± 43.4	387 ± 22.6	368 ± 18.7	342 ± 58.1	345 ± 47.1	378 ± 63.0	384 ± 47.8
LDec	2496 ± 263	2604 ± 250	2462 ± 158	2510 ± 230	2335 ± 459	2410 ± 269	2408 ± 230	2273 ± 62.2	2226 ± 244	2281 ± 298	2394 ± 312	2436 ± 299
TDec /min	31.8 ± 1.65	32.9 ± 2.28	31.8 ± 1.73	32.6 ± 2.19	31.1 ± 4.73	32.4 ± 2.41	31.4 ± 1.65	31.9 ± 0.00	31.3 ± 1.01	31.2 ± 1.72	31.5 ± 2.80	32.3* ± 2.53
MDec /min	0.33 ± 0.06	0.36 ± 0.07	0.48 ± 0.11	0.52 ± 0.08	0.45 ± 0.14	0.52 ± 0.09	0.50 ± 0.08	0.53 ± 0.01	0.55 ± 0.14	0.58 ± 0.08	0.45 ± 0.13	0.50* ± 0.11
HDec /min	0.86 ± 0.15	0.90 ± 0.13	1.10 ± 0.11	1.09 ± 0.13	1.04 ± 0.26	1.12 ± 0.10	1.07 ± 0.09	1.07 ± 0.10	1.18 ± 0.15	1.15 ± 0.14	1.04 ± 0.20	1.06 ± 0.16
IDec /min	3.89 ± 0.43	4.04 ± 0.30	4.33 ± 0.43	4.34 ± 0.34	4.08 ± 0.82	4.35 ± 0.41	4.13 ± 0.22	4.23 ± 0.17	3.94 ± 0.56	3.90 ± 0.60	4.09 ± 0.58	4.20 ± 0.47
LDec /min	26.8 ± 1.78	27.6 ± 2.40	25.9 ± 1.66	26.7 ± 2.20	25.5 ± 3.98	26.4 ± 2.22	25.7 ± 1.75	26.1 ± 0.60	25.6 ± 0.91	25.6 ± 1.71	25.9 ± 2.49	26.5 ± 2.41

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 ($p<0.05$).

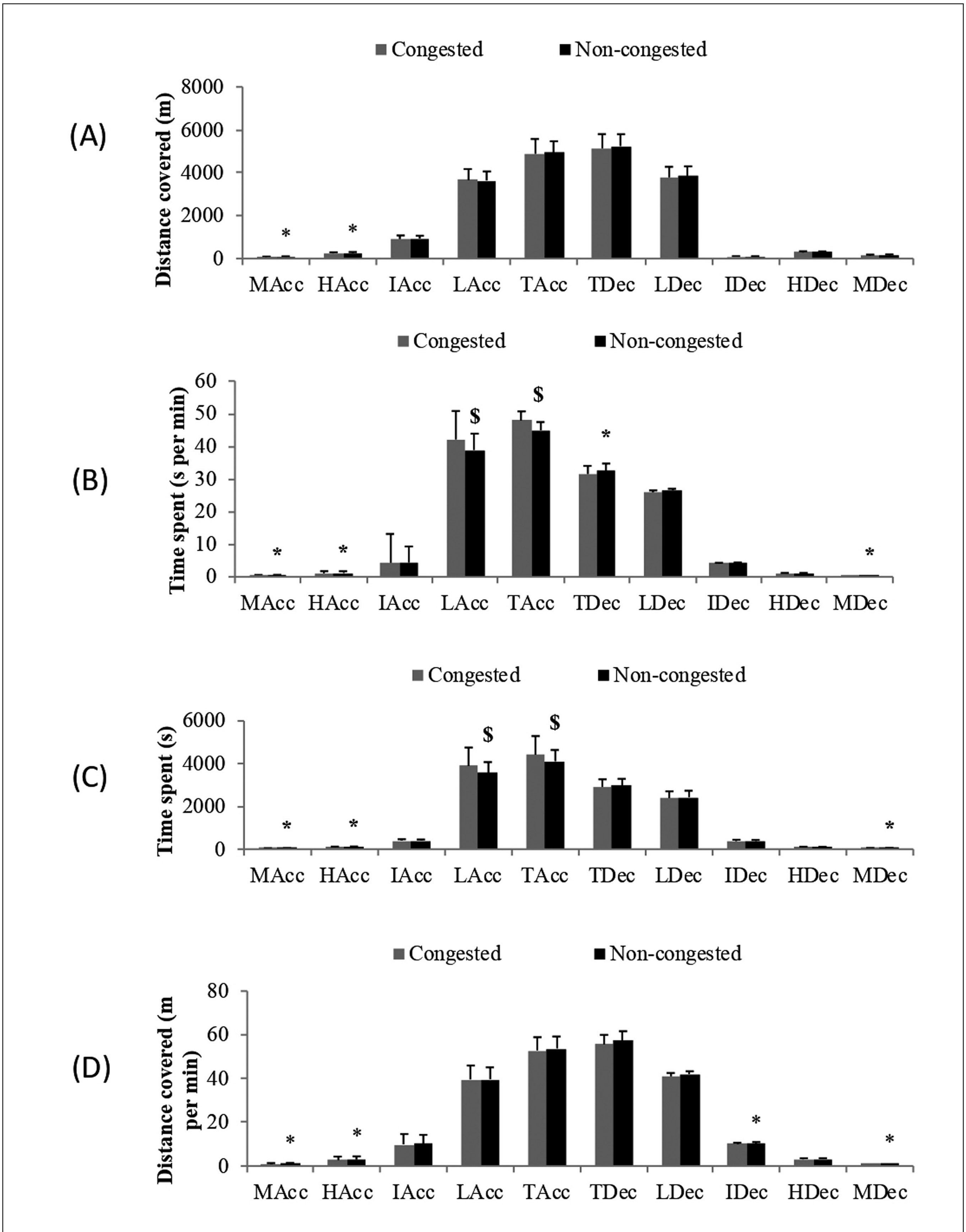

FIG. 1. Distance covered and time spent accelerating and decelerating during congested and non-congested period of professional soccer matches.
TAcc, MAcc, HAcc, IAcc, LAcc: total, maximal, high, intermediate and low accelerations, respectively; TDec, MDec, HDec, IDec, LDec: total, maximal, high, intermediate 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 RIDec ($F(1,269) = 4.02$, 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 RTAcc ($F(1,269) = 10.4$, 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 notify 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 suggested by Penedo-Jamardo et al. [35] that the observation that offensive players were less affected by the congested calendar was due to a better physical profile or because they beneficiated more from 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 Djaoui 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 coverer ~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 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 fatiguing 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.

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Conflict of Interest

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

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