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Seasonal Changes in the Acceleration–Speed Profile of Elite Soccer Players: A Longitudinal Study

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Abstract: This study aimed to describe the acceleration–speed (AS) profile of soccer players during competition and to analyse their seasonal changes and inter-player differences. The AS profile values (theoretical maximum acceleration (A_0) and speed (S_0)) of 14 elite soccer players were studied in 18 matches, which were divided into five season periods. The main findings showed the A_0 (6.20 ± 0.51 m/s^2) and S_0 (9.18 ± 0.58 m/s) average team season values. Significant individual changes ($p < 0.05$ and effect size (Eta-squared, η^2) > 0.5) were confirmed for A_0 (Players 4 and 8) and S_0 (Players 6, 8 and 11). Additionally, standard deviations (SD±) confirmed small (±0.20–0.60) to moderate (±0.60–1.20) seasonal variations for most players in A_0 (SD range: ±0.22 to ±0.69 m/s^2) and S_0 (SD range: ±0.27 to ±0.90 m/s). SD showed small to moderate inter-player differences for each period for A_0 (SD range: ±0.39 to ±0.61 m/s^2) and S_0 (SD range: ±0.53 to ±0.61 m/s). In summary, coaches are recommended to assess the AS profile to diagnose potential player seasonal changes in sprinting performance, especially for A_0, which seems to be more sensitive to variations than S_0.

Keywords: competition; football; monitoring; performance; team sports

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1. Introduction

Soccer is an intermittent sport characterized by long periods of low-intensity activity interspersed with short periods of high-intensity activity actions, such as sprints and acceleration [1–3]. Through the use of electronic performance tracking systems, several studies [2–7] have reported that approximately 91–119 high-intensity acceleration efforts (>2.5−3 m/s^2) and 16–27 sprint efforts (>24−25.2 km/h) are performed during match play. Specifically, short sprints (<10 m) usually precede decisive key situations [3,8], with elite players showing greater sprinting distances and higher frequency of accelerations than lower-level players [5,7]. Given the potential to significantly affect match outcomes, proper assessment and training are needed to maximize the acceleration capabilities in elite soccer [5].

Monitoring sprint and acceleration performance throughout season is crucial to effectively managing training load [5,9], reducing the risk of injury [10–12], and individualizing training interventions [13]. Novel approaches have been proposed to provide deeper insight into the mechanical determinants of sprinting. In this vein, Samozino et al. (2016) [14] proposed a field method to describe the players' ability to apply ground reaction forces in the horizontal direction during sprinting. Known as the force–velocity (FV) profile, this method has been recently used to study the seasonal changes in the mechanical limits of the neuromuscular system to produce force (F_0), velocity (V_0), and power output (P_{max}) during sprints in soccer [9,15]. In detail, Haugen (2018) [15] analysed 44 soccer players at three time points (pre-season, in-season, and off-season), while Jiménez-Reyes et al. (2020) [9]

examined 21 players twice pre-season and four times in-season. Although both studies revealed significant differences in F_0 and P_{max}, the variations are not consistent across the period of the season [9,15]. Additionally, the time elapsed between testing points—2 months for Jiménez-Reyes et al. (2020) [9] and 1–6 months (unspecified) for Haugen (2018) [15]—was excessive, which might inherently predispose to changes in the sprint mechanical properties. In that sense, frequent FV profile assessment may increase stress levels in elite teams with limited training time [16], so that new approaches are needed to monitor sprint performance in a more efficient way.

Interestingly, Morin et al. (2021) [16] proposed the acceleration–speed (AS) profile, obtained from global positioning system (GPS) devices that players wear during training and matches. Note that GPS data has proven valid and reliable for time-motion analysis [17–20]. To highlight, the AS profile allows coaches to monitor individual acceleration capacity daily without requiring players' implications. This new method is summarized through the A_0: theoretical maximal acceleration (y-intercept of the AS linear relationship) and S_0: theoretical maximum speed (x-intercept of the AS linear relationship). In addition to the results presented by Morin et al. (2021) [16] gathered only from training sessions (6.55; 8.43 m/s^2 and 8.41; 10.3 m/s range values for A_0 and S_0, respectively), recently, the data for different match days of a microcycle has also been described [21]. However, since these previous studies only gathered session data for the first period of season without showing individual player data, it is still unknown whether the A_0 and S_0 vary throughout the season and if there are differences between players.

Therefore, the objectives of this study were (i) to describe the average AS profile of elite soccer players during match season, (ii) to analyse team and individual seasonal changes, and (iii) explore intra-player differences in AS profile values over the five analysed periods (pre-season 1, in-season 1, in-season 2, pre-season 2 and in-season 3).

2. Materials and Methods

2.1. Experimental Approach to the Problem

Eleven official games and seven friendly matches were played during the 2019−2020 season, which were grouped into five periods: two pre-season (Pre 1 and Pre 2) and three in-season (In 1, In 2 and In 3) (Figure 1). There was no In 4 due to the coronavirus disease 2019 (COVID-19) lockdown. The season was divided into five periods considering the following criteria: (i) to separate pre-season from in-season and (ii) to split the longer in-season periods to detect possible short-term changes in values.

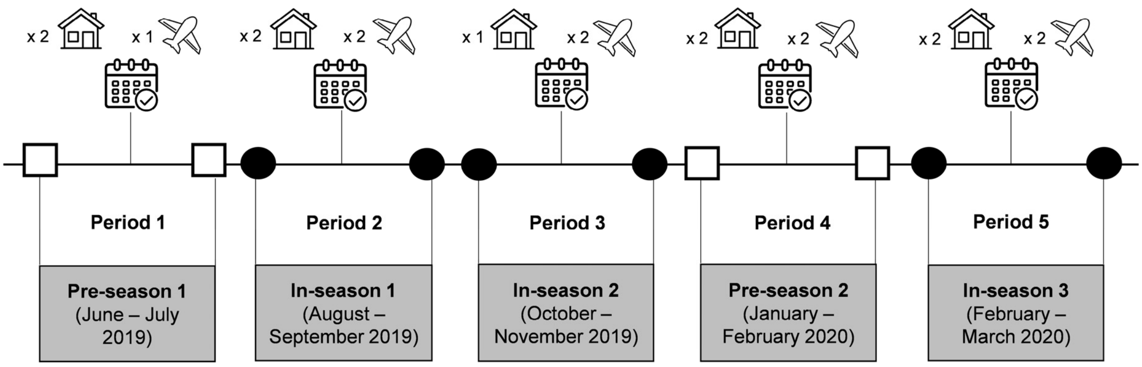

Figure 1. Distribution of periods throughout the season. For each period the number of the analysed matches played at home (home symbol) and away (airplane symbol) are shown.

The team formation was 4-4-2 in every match. All official matches analysed belong to the same competition, the Russian Premier League. The training program before all the official games analysed were five soccer training sessions and two strength training gym sessions per week. However, this weekly organization changed during Pre 1 and Pre 2 to 4–6 soccer training sessions, 2–3 strength training gym sessions and 1–2 friendly matches per week.

2.2. Subjects

Fourteen elite male soccer players participated voluntarily in this study (age: 23.7 ± 4.1 years; height: 1.83 ± 0.07 m; body mass: 76.7 ± 5.9 kg; body mass index: 22.9 ± 0.9 kg/m^2; soccer-playing experience: 17 ± 3.2 years; professional playing experience: 6.7 ± 3.8 years). All players belonged to the same team, which participated in the Russian Premier League and Europa League. Players from different positions were included in the analysis: forwards (FW: players 2 and 3), midfielders (MF: players 1, 4, and 9), wide-midfielders (WMF: players 10, 11, and 13), full-backs (FB: players 7, 8, and 14), and central defenders (CD: players 5, 6, and 12). Additionally, participants had to meet the following criteria: (i) players had to participate at least in two matches per period and (ii) play the full duration of the match (90 min). Goalkeepers were excluded from the analysis. Although no specific intervention was required for this study, the club and participants were informed of the risks, benefits, and objectives of the study and gave their written consent before the initiation of the study.

2.3. Procedures

Data were collected during soccer matches using WIMU Pro 18 Hz GPS tracking system technology (Real-Track Systems, Almería, Spain). The use of this device for time-motion analysis in soccer has proven to be a valid and reliable system with good inter-unit and intra-unit reliability (bias in mean velocity measurement 1.18−1.32 km/h; bias in mean distance was 2.32–4.32 m; and >0.93 intraclass correlation coefficients) [17]. Moreover, this device has been certified according to the FIFA quality standard for time-motion analysis [20] after rigorous testing procedures [22]. Importantly, during monitoring, 13.1 ± 2.4 satellites were connected and horizontal geometric dilution of precision was 0.55 ± 0.15, which is considered ideal and guarantees the quality of the recorded data by the GPS [23,24].

All devices were fully charged and calibrated before the start of the match to ensure an optimal quality data record. The recording button was then pressed, and the devices were placed in the vest pocket located on the player's upper back (figure showing the placement of a GPS device in a player's vest is added as Supplementary Material—Figure S1).

The devices were collected at the end of the match to extract the raw data of acceleration and speed from each player using SPro (version 980) software (Real-Track Systems, Almería, Spain). Note that the raw acceleration data were directly derived from raw speed data. The time window used to calculate acceleration raw data was 0.1 s. Approximately 52.000 and 200.000 AS points for each player were taken per match and period, respectively, to establish their AS profiles. Only positive accelerations were selected to exactly replicate the AS profile method proposed by Morin et al. (2021) [16].

2.4. Statistical Analyses

We followed the data analysis criteria used by Morin et al. (2021) [16] to obtain the A_0 and S_0 values per player per period (Figure 2). The team and player average values and standard deviation (SD) for A_0 and S_0 were calculated per each period and for the entire season. Then, an exploratory analysis of the data was performed to check the normal distribution of the values and the variance homogeneity. To study differences between team averages values over periods, the repeated measures one-way ANOVA test was calculated. Additionally, a one-way ANOVA was used to study players individually over the period. The effect size (ES) (Eta-squared, η^2) was calculated for each player, using the following scale: non-existent (<0.1), small (0.1–0.3), medium (0.3–0.5), large effects (>0.5) [25]. Post-hoc pairwise comparisons were made (Tukey's test), in which case significant differences were found ($p < 0.05$). Additionally, SDs were used to assess magnitudes of differences between periods for each player. The thresholds for assessing the observed intra-player differences in the SD of mean were 0.2, 0.6, and 1.2 for small, moderate, and large variations, respectively [26]. All statistical analyses were developed using statistical packages (openxlsx to edit worksheets; dplyr to manipulate data; ggplot2 to create graphs; rstatix to check assumptions for ANOVA test; ez to apply ANOVA test; and effectsize to calculate effect size) from RStudio software (R Core Team, 2020). Additionally, Prism software (GraphPad Software, San Diego, CA, USA) was also used to create graphs.

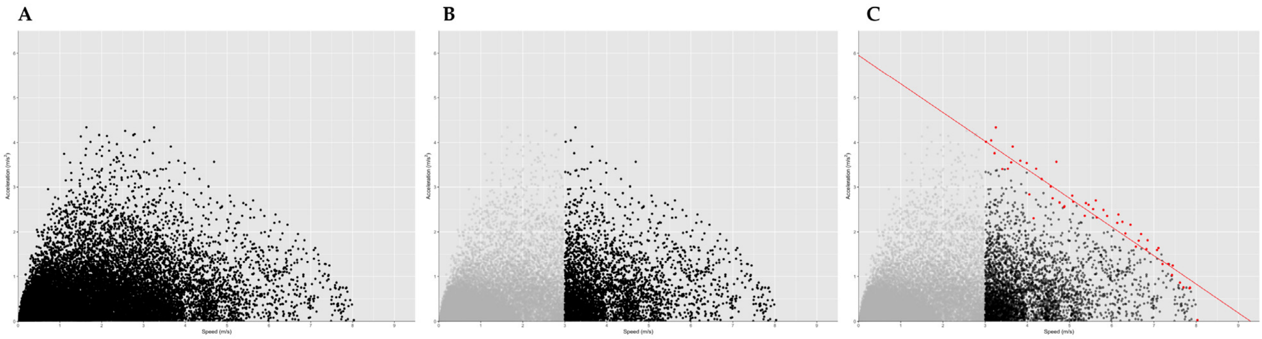

Figure 2. Acceleration–Speed (AS) profile analysis criteria proposed by Morin et. (2021) for a player in a match. (**A**) All acceleration–speed points are plotted. (**B**) Only accelerations between 3 m/s and the individual maximal speed were selected (black points). This selected range was divided into subintervals of 0.2 m/s velocity (e.g., 3, 3.2, 3.4 m/s, etc.). (**C**) The two maximum acceleration values were taken for each interval (red points). The statistical technique of simple linear regression (red line) was used to fit the two maximum acceleration–speed points per subinterval (approximately 50−55 ± 4 points depending on the maximum individual velocity). Outliers AS points were removed to increase the linear regression fitting and accuracy of the results. Finally, the A_0 (X = 0 and y-intercept) and S_0 (Y = 0 and x-intercept) values were obtained from linear regression (Y = a*X + b) for each player per match.

3. Results

The ANOVA revealed significant differences ($p < 0.05$; ES > 0.5) between periods for Player 4, Player 5, Player 8, Player 10, and Player 11 in the A_0 averages (Table 1) and for the Player 3, Player 6, Player 8, Player 11, Player 13, and Player 14 in the S_0 averages (Table 2) (all parameters per player and team analysis derived from ANOVA are added as Supplementary Material—Table S1). Tukey's test showed significant differences ($p < 0.05$) in A_0 and S_0 averages between In 2 and other periods for Player 4 (Pre 1, In 1, In 3 and Pre 2) and Player 8 (In 1 and In 3) (Table 1) and for Player 6 (In 1 and Pre 2) and Player 8 (In 3) (Table 2), respectively. Additionally, SD showed small to moderate intra-player variability for all players (SD range from ±0.22 to ±0.69) in the A_0 averages (Table 1) and for most players (SD range from ±0.27 to ±0.90) in the S_0 averages (Table 2). Inter-player variability was higher in Pre 1 and In 2 (SD = ±0.58 and ±0.61, respectively) for A_0 (Table 1) while it remained stable (SD range from ±0.53 to ±0.61) during all periods for S_0. Players out of SD ranges for A_0 and S_0 for all periods are shown in Figure 3.

Table 1. Theoretical maximal acceleration per player period and difference in means.

$A_{0\ (m/s^2)}$	Pre 1	In 1	In 2	Pre 2	In 3	Mean ± SD	*p*	ES
Player 1	6.44	6.25	5.90	6.39	6.42	6.28 ± 0.23	0.88	0.11
Player 2	6.31	6.25	5.99	6.62	6.31	6.30 ± 0.22	0.79	0.17
Player 3	7.12	6.24	6.45	6.64	6.54	6.60 ± 0.33	0.49	0.35
Player 4	6.29 ^{b}	6.75 ^{e}	5.24 ^{behi}	6.37 ^{h}	6.52 ^{i}	6.16 ± 0.65	0.01	0.91
Player 5	5.66	6.52	7.06	5.77	5.59	6.12 ± 0.64	0.19	0.59
Player 6	6.59	6.55	5.69	5.78	6.27	6.18 ± 0.42	0.59	0.34
Player 7	6.00	5.32	5.74	5.44	5.88	5.68 ± 0.29	0.33	0.49
Player 8	5.69	5.59 ^{e}	6.61 ^{ei}	5.89	5.62 ^{i}	5.88 ± 0.42	0.04	0.82
Player 9	5.35	5.47	6.80	6.53	5.46	5.92 ± 0.69	0.83	0.23
Player 10	6.22	6.15	6.93	6.47	6.09	6.37 ± 0.34	0.44	0.54
Player 11	7.26	6.49	6.19	6.66	7.10	6.74 ± 0.44	0.21	0.63
Player 12	5.83	6.11	5.29	6.53	5.78	5.91 ± 0.46	0.88	0.22
Player 13	6.42	6.33	6.73	6.21	6.17	6.37 ± 0.22	0.58	0.45

Table 1. *Cont.*

$A_{0\ (m/s^2)}$	Pre 1	In 1	In 2	Pre 2	In 3	Mean ± SD	*p*	ES
Player 14	5.32	6.16	6.84	6.37	6.39	6.22 ± 0.56	0.85	0.30
Mean ± SD	6.18 ± 0.58	6.15 ± 0.42	6.25 ± 0.61	6.26 ± 0.39	6.15 ± 0.45	6.20 ± 0.42	0.85	0.26

Significance level = 0.05; Pre: pre-season; In: in-season; ES: effect size; ^{b}: differences between Pre 1 and In 2; ^{e}: differences between In 1 and In 2; ^{h}: differences between In 2 and Pre 2; ^{i}: differences between In 2 and In 3; SD = standard deviation.

Table 2. Theoretical maximal speed per player period and difference in means.

$S_{0\ (m/s)}$	Pre 1	In 1	In 2	Pre 2	In 3	Mean ± SD	*p*	ES
Player 1	8.71	9.07	8.69	9.41	9.00	8.98 ± 0.30	0.17	0.48
Player 2	9.65	9.34	9.32	8.77	9.42	9.30 ± 0.32	0.58	0.27
Player 3	8.32	8.87	9.44	8.71	9.13	8.89 ± 0.42	0.17	0.56
Player 4	8.12	8.99	9.00	8.78	9.06	8.79 ± 0.39	0.38	0.46
Player 5	9.06	9.07	8.62	9.49	9.45	9.14 ± 0.35	0.61	0.33
Player 6	8.49	7.33^{ef}	9.77^{e}	9.14^{f}	8.78	8.70 ± 0.90	0.03	0.79
Player 7	9.94	9.73	10.02	10.36	9.68	9.95 ± 0.27	0.36	0.47
Player 8	9.62	9.75	8.94^{i}	9.87	10.91^{i}	9.82 ± 0.71	0.03	0.85
Player 9	9.29	8.51	8.73	8.76	9.01	8.86 ± 0.30	0.74	0.29
Player 10	9.37	9.28	8.94	8.82	9.69	9.22 ± 0.35	0.57	0.45
Player 11	8.39	9.08	10.77	9.50	9.26	9.40 ± 0.87	0.24	0.61
Player 12	9.25	9.40	9.29	8.43	10.39	9.35 ± 0.70	0.65	0.40
Player 13	8.97	8.57	9.01	8.90	8.79	8.85 ± 0.18	0.45	0.50
Player 14	9.21	9.04	9.04	9.06	9.85	9.24 ± 0.35	0.23	0.77
Mean ± SD	9.03 ± 0.55	9.00 ± 0.6	9.26 ± 0.59	9.14 ± 0.53	9.46 ± 0.61	9.18 ± 0.58	0.11	0.30

Significance level = 0.05; Pre: pre-season; In: in-season; ES: effect size; ^{e}: differences between In 1 and In 2; ^{f}: differences between In 1 and Pre 2; ^{i}: differences between In 2 and In 3; SD = standard deviation.

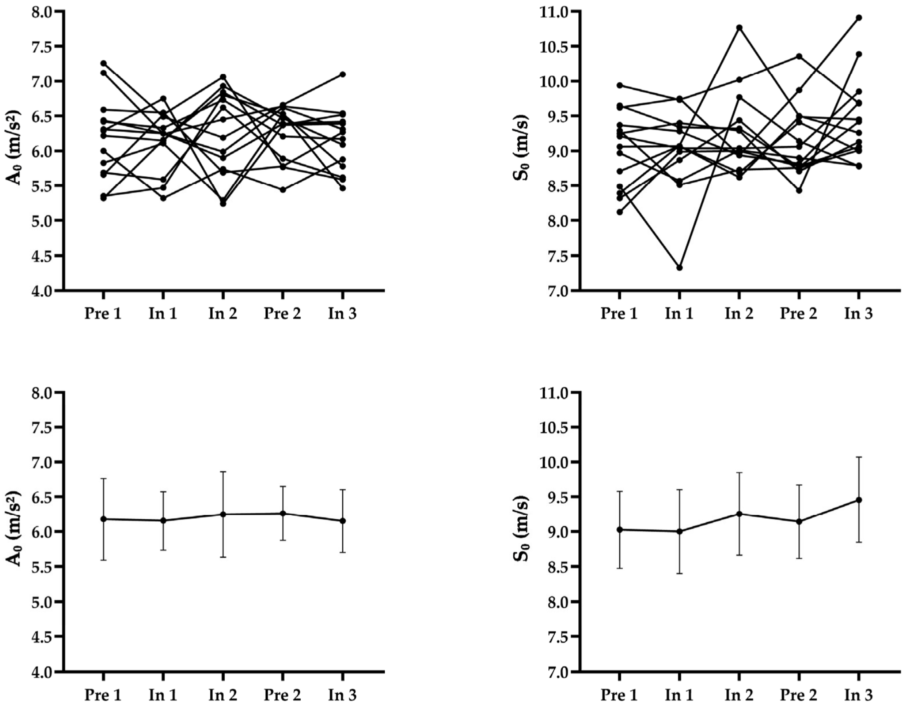

Figure 3. Individual player values (lines) of the theoretical maximal acceleration (A_0; **upper left** panel) and theoretical maximal speed (S_0; **upper right** panel) during season periods (Pre: pre-season; In: in-season). The evolution of average team values and SDs (error bars) are depicted for A_0 (**lower left** panel) and S_0 (**lower right** panel) during season periods.

4. Discussion

This study was designed to describe the AS profile of elite soccer players during competition and to analyse their seasonal changes and inter-player differences over seasons. The main findings of the study showed an average team season value of 6.20 ± 0.51 m/s^2 and 9.18 ± 0.58 m/s for A_0 and S_0, respectively. Second, although average team season values seem to be stable, substantial seasonal changes and different trends were observed in A_0 and S_0 when players were analysed individually. The inter-player differences were higher during the pre-season (Pre 1) and the middle of season (In 2) for A_0 while for S_0 were stable during all periods.

Monitoring game-specific performance brings a deep insight into the real competitive peculiarities [3,6]. Thus, the present study analysed the AS profile values during an elite soccer season matches. Our current results showed lower season A_0 averages values (Table 1) compared to Alonso-Callejo et al. (2022) [21] (8.41 ± 0.57 m/s^2) and Morin et al. (2021) [16] (7.20 ± 0.40 m/s^2), both gathered during the first part of season. Although caution is needed when comparing values from different teams and contexts, the lack of agreement between A_0 values is notable. Greater A_0 values from training sessions [16] could be explained by the potential use of some frequently used tasks in soccer (i.e., small side games) that might predispose players to show higher A_0 values during training than match [27–29]. Differences in playing style, tactical behaviour, or player level, which affect accelerations variables outcomes during matches [7,30,31], could explain the differences in A_0 values obtained by Alonso-Callejo et al. (2022) [21]. Regarding to the S_0, our results showed similar values (Table 2) compared to previous studies: 9.34 ± 0.49 m/s [21] and 9.47 ± 0.52 m/s [16]. In addition, our S_0 values concur with the V_0 values obtained from the F-V profile in soccer players: 9.25 ± 0.61 m/s [9] and 9.20 ± 0.40 m/s [15]. Considering the novelty of the AS profile, caution is still recommended to sports scientists and fitness coaches when using out of context data as reference values, especially for A_0.

Neuromuscular performance is sensitive to change during season [9], which helps coaches detect potential injury risks and guide training programs [10]. The present study analysed, for the first time, the team and individual seasonal changes in the AS profile. Although no significant differences were found when studying A_0 and S_0 at team level, substantial variations were found at individual level during season for most players (see SD in Tables 1 and 2). According to Hopkins et al. (2009) [26], the smallest meaningful change to optimally evaluate player seasonal performance in team sports can be assessed using sports-specific standardized differences. In that vein, a 0.2 intra-player SD in team sports is generally enough to detect small changes in performance [26]. Considering that winning margins in elite soccer can be a fraction of a second, small changes in sprint acceleration could be decisive during the game [19,26,32]. Haugen and Buchheit (2015) [19] showed how variations of 0.03–0.04 s in a 20 m sprint meant a difference of ~30 cm, which is decisive in one-on-one duels in soccer. Thus, it is recommended to prioritize individual player data to improve long-term monitoring of sprint performance.

Players are differently exposed to maximal accelerations and maximal velocities actions during competition [6]. In a macroscopic to microscopic approach, our current results showed substantial inter-player variability throughout each analysed period (Figure 3). In this sense, despite following similar training programs, players showed different A_0 and S_0 values, which may be explained by the actual differences in maximal acceleration and speed between player positions in competition [6]. Interestingly, inter-player differences were more variable for A_0 than S_0, which were notably wider during Pre 1 and In 2, when the training volume and the accumulation of weeks of competition were greater. Therefore, although these considerations should be interpreted with caution, A_0 could be a more sensitive variable affected by fitness status, fatigue, and conditioning strategies among soccer players. From a practical point of view, the AS profile could be a sensitive screening tool to understand how training and competition affects sprinting capabilities, allowing practitioners to develop programs tailored to each player's response.

This study has limitations that must be acknowledged. Although this is the first study analysing the seasonal AS profile of elite players, future studies with a larger sample should corroborate or contrast our results. Second, the season analysed in this study was shortened due to the competition lockdown due to COVID-19. Thus, further research, including the during last part of the season, is warranted to explore the entire competition period.

5. Conclusions

Elite soccer players showed an average team season value of 6.20 $\pm$ 0.51 m/s^2 (A_0) and 9.18 $\pm$ 0.58 m/s (S_0) using match-derived data. Individual player data should be prioritized over team average data to effectively detect seasonal variations in the AS profile. A_0 appears to be more sensitive to change over the season than S_0. Therefore, we recommend the assessment of the individual AS profile for diagnosing potential seasonal changes in sprinting performance and prescribing training interventions tailored to the players' specific responses in elite soccer.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app122412987/s1, Figure S1: Placement of a GPS device in a player's vest; Table S1: Analysis of variance (ANOVA) per player and team for A_0 and S_0: All relevant parameters.

Author Contributions: Conceptualization, A.L.-S., A.B.-R., P.G.-G. and M.A.R.-P.; Data curation, M.Á.C.-A. and P.G.-G.; Formal analysis, A.L.-S., A.B.-R. and M.Á.C.-A.; Methodology, A.L.-S., A.B.-R., P.G.-G. and M.A.R.-P.; Supervision, A.B.-R. and M.A.R.-P.; Visualization, A.L.-S. and M.Á.C.-A.; Writing—original draft, A.L.-S.; Writing—review and editing, A.B.-R., M.Á.C.-A. and M.A.R.-P. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted following the Declaration of Helsinki and was approved by the Bioethics Committee of the university of Almería (Ethical Application Ref: UALBIO2019/041).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author (andresbaenaraya@gmail.com). The data are not publicly available due to included information on the physical performance of an elite soccer team.

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Conflicts of Interest: The authors declare no conflict of interest.

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