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RESEARCH

Seasonal Changes in Acceleration-Speed Profiles: Insights from Soccer Players Across Diverse Age Groups

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Abstract

This study aimed to investigate the variation of the Acceleration–Speed (A-S) profile throughout one season in different age groups of elite young and professional soccer athletes. A total of 126 athletes from under-14 to B-team levels were analyzed in terms of their A-S profile, across a season divided in six training blocks. For all the blocks, we have calculated maximal theoretical acceleration (A0) and maximal theoretical speed (S0). Results revealed significant increases only in the S0 value for the under-15 age group ($p < 0.05$) during the season, while other age groups did not exhibit significant differences in the A-S profile over the same period. These findings emphasize the necessity of tailored training interventions to optimize acceleration and sprint capacities, particularly among younger players in the midst of physical development. Furthermore, the establishment of standardized norms tailored to different age groups based on these findings could facilitate the identification of outliers and inform individualized training strategies. This research could contribute to our understanding of the dynamic nature of sprinting performance and training demands in elite young soccer athletes, offering insights for optimizing performance outcomes and player development within soccer academies.

Keywords Youth development · Sprint · Testing · Individualization

Introduction

Soccer is a popular sport worldwide, and athletes are continuously striving to improve their performance on the field [1, 2]. Physical fitness plays a crucial role in soccer, as it directly influences an athlete's ability to accelerate, rapidly change direction, and achieve higher running speeds [1]. The ability to sprint fast has been recognized as one of the most important physical capacities in soccer performance, with elite soccer athletes spending approximately 11% of the game in sprinting actions [3–5]. Furthermore, goal scoring opportunities are preceded by short (< 10 m) or long-distance sprinting action (> 20 m) [6, 7].

Developing sprint ability often involves inducing favorable neural and morphological adaptations through both non-specific methods (strength, power, plyometric training) and specific techniques that simulate sprinting actions (technical drills, overload sprints). Given the demands of team sports, a balanced development of physical attributes (strength, power, endurance, speed) becomes essential. This not only enhances performance, but also facilitates efficient recovery between training and matches or during congested periods or tournaments within a season [8]. During the maturation process, morphological changes (i.e., increase in muscle mass) and the development of the nervous system may create an optimal environment for the improvement of a young athlete's performance [9, 10]. In this sense, strength, power or stiffness improvements, due the natural physical development that could occur during childhood and adolescence,

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could be linked to significant changes in sprint performance [11]. In fact, younger athletes demonstrate lower speed performance when compared to older ones [11–13]. However, no significant changes in sprint performance after maturation are expected [1]. Despite the differences at older ages possibly not being significant, the constant development and optimization of kinetic and kinematic characteristics may be a priority to achieve minor gains that could make a difference in high-level competitive contexts [14].

During the in-season period, the training frequency of physical capacities, such as strength, speed or endurance, may be reduced in favor of the player's training regimes being more oriented to the technical and tactical sessions [8, 15]. A reduced strength training frequency, coupled with post-match muscle damage, can potentially lead to declines in muscle performance, posing challenges for strength and power maintenance during the in-season period [15].

In recent years, force–velocity profile (FVP) has been proposed as a method to evaluate the athlete's ability to generate horizontal force across various velocities during a linear sprint, which can allow for a more precise assessment and consequently to prioritize specific training needs for each athlete [16]. Lately, the evaluation of the FVP have been suggested to be assessed by the acceleration–speed (A-S) profile [17–19], since it could provide an ecological evaluation of an athlete's acceleration ability at different speeds, assessed through GPS data collected during soccer training sessions [17, 18, 20, 21]. This ecological evaluation allows the characterization of the athlete's theoretical maximum acceleration (A0), theoretical maximum speed (S0), and the slope of their profile (A-S slope).

The A-S profile has been reported as an effective tool to detect seasonal changes in sprint performance [21]. Haugen et al. (2016) showed that theoretical maximum horizontal force (F0), horizontal force–velocity slope (F-V slope), and theoretical maximum horizontal power (Pmax) are higher during the off-season period compared to in-season. Jimenez-Reyes et al. (2020) observed that soccer athletes have fluctuations in their sprint profile during the season showing that F0 and Pmax reached their maximum values in the middle of the competitive period and they were decreased at the end of the competitive period. Similar results were also observed in the A-S profile of elite soccer athletes, with A0 showing fluctuations during the season [21]. These reported fluctuations in FVP [22] and A-S profile [21] are mostly related to the force side of the curve, showing that the ability to produce force could be compromised in later stages of the season and that the maximal speed in senior soccer athletes do not have significant fluctuations throughout the season. This can potentially be explained by soccer training not promoting a sufficient stimulus to increase maximal velocity capacity over the season [21, 22]. Also, the observed decrease in strength capabilities could be associated with a decrease in sprint performance or with a higher risk of hamstring injury [23, 24], which is one the most common injuries in soccer athletes during the competitive season.

While the aforementioned findings revealed to be interesting and insightful for athlete's monitoring, they are limited to senior athletes. Youth, on the other hand, are still in the development of their strength, technical, and power characteristics and may show different patterns. Therefore, a continuous monitoring of these athlete's maximal speed capacity could infer about individual development patterns and talent identification. This gap needs to be considered as the current literature is limited to observational comparisons between age groups during the same time period [12, 13, 22], failing to understand if and how the F-V or A-S profile variables significant increase across the season for younger age groups.

Global positioning system (GPS) monitoring systems have demonstrated reliability and validity in tracking player activity levels within running-based team sports [25, 26]. The information about the demands imposed on athletes by training—external load—provided by these systems allows the practitioners to have a global view of load provided by training or match session, comprising data from total distance and distances covered at different speed rates [25, 26]. This information is useful for practitioners to establish individual profiles, allowing to optimize performance and minimize the incidence of injury associate with spikes in load volume or intensity [25, 27]. Given the long duration of a soccer season, it could be expected that training load fluctuates. This variation could be due to several factors: different levels of match participation, since starters have shown to accumulate more weekly load than non-starters [28]; congested match periods, since players participating in more than one match per week presented greater weekly loads for the overall distance metrics than players with lesser match participation [29]; or the period of the season, since acute load or training monotony during the pre-season were shown to be greater than the mid-season or end-season, whereas the sprint distance (> 25.2 km.h-1) and high-speed running distance (> 19.8 km.h-1) values were greater for mid-season and end-season when compared to pre-season [30, 31]. Furthermore, it has also been reported that between youth level and professional athletes, there are differences between weekly external intensity and within-week load [32].

Thus, the aim of the present study was to investigate if the A-S profile vary throughout a season in different age groups. Since athletes in the under-14 and under-15 age groups are potentially in a maturation process, we hypothesized that these age groups would experience a significant increase in their A-S profile variables (A0 and S0) over the course of the season. In contrast, we hypothesized that athletes in older age groups (under-16 to B-team) with a stabilization in their physical development would exhibit a significant decrease in the A-S profile variables during the later stages of the season (Blocks 4 to 6), due to accumulation of external load and fatigue.

Methods

Participants

One hundred and twenty-six elite academy soccer athletes participated in the current study. The athletes were scaled by age groups in under-14 ($n = 12$, 12.65 ± 0.60 years, 1.69 ± 0.04 m, 53.16 ± 6.23 kg), under-15 ($n = 21$, 13.87 ± 0.34 years, 1.72 ± 0.07 m, 59.02 ± 6.62 kg), under-16 ($n = 20$, 14.60 ± 0.74 years, 1.77 ± 0.08 m, 64.22 ± 5.75 kg), under-17 ($n = 23$, 15.57 ± 0.59 years, 1.77 ± 0.08 m, 68.64 ± 7.29 kg), under-19 ($n = 19$, 17.22 ± 0.63 years, 1.80 ± 0.08 m, 71.59 ± 8.31 kg), under-23 ($n = 13$, 17.90 ± 0.97 years, 1.78 ± 0.05 m, 71.48 ± 5.45 kg), and B-team ($n = 19$, 18.87 ± 1.46 years, 1.83 ± 0.06 m, 73.49 ± 7.84 kg).

The athletes were monitored during all training sessions and matches across the 2021–2022 season. The players were continuously monitored with the same GPS unit (APEX, StatsSports, UK), with the device being placed at the upper back of each athlete using an adjustable neoprene harness. Speed data were collected at 10 Hz, with horizontal dilution of precision over the period averaged 0.45 ± 0.16 and 18.4 ± 2.6 satellites.

Athletes provided informed consent prior to starting the study and they gave their informed consent in accordance with the Declaration of Helsinki. The study was approved by the Ethics Committee of institutional review board (approval number 38/2021).

Data sample and A-S profile

To estimate the A-S profile, raw data from all training and match sessions were analyzed. The A-S profile was estimated based on the previous work reported by Morin et al. [17], with the raw GPS data from 10 consecutive sessions generated approximately 500,000 data points for each player, enabling comprehensive coverage of the entire spectrum of running speeds from 0 to the maximum for each individual. The initial raw speed data underwent custom Gaussian filtering based on time-averaged running acceleration. The scatter plot, including filtered speed and derived acceleration data, was formed. Individual AS profiles were generated using maximal acceleration for each running speed within the interval of 3 m/s to the individual's maximal speed. The two maximal acceleration values for 0.2 m/s subintervals were selected. A linear regression was initially fitted, and outlier points were removed based on a 95% confidence interval around the linear function. The remaining points underwent a second linear regression, with three main variables determined: theoretical maximal acceleration (A0); theoretical maximal running speed (S0); and the overall orientation of the profile (A-S slope) (Fig. 1). Importantly, previous research has shown low week-to-week variability for A0, S0 e AS slope [18].

External load variables

The variables used in the present study were: total distance (in meters), high-speed running (distance above 19.8 km.h^{-1}, in meters), sprint distance (distance above 25.2 km.h^{-1}, in meters), distance in accelerations or decelerations above 2 m.s^{-2} (in meters) and frequency of accelerations or decelerations above 3 m.s^{-2}. The analysis incorporates standard GPS metrics commonly used in professional soccer, comprising locomotor-related variables such as distance, distances traveled across different velocity zones, and changes in speed [25, 26].

Training blocks

For each age group, the season was divided into six training blocks, similar to a previous study [21]. Block 1 represented the pre-season phase, consisting of the first 4–5 weeks of training. Blocks 2 to 6 corresponded to the competitive phase, with each block spanning 5–8 weeks of training across all age groups. The conclusion of Block 3 marked the end of the first phase of competition and coincided with the winter break. During this break, the frequency of training sessions was reduced to 2–3 per week, with no matches played. Consequently, the winter break period was excluded from any training block for subsequent analysis. Blocks 4 to 6 encompassed the second phase of the season, including the championship phases for all age groups. The overview of each training block is summarized in Table 1.

For each athlete, the maximum value of A0, S0, and A-S slope was determined for each training block and used for statistical analyses.

Statistical analyses

All statistical analyses were completed using SPSS (Version 29 for Mac, SPSS Inc., Chicago, IL). Descriptive statistics were used to calculate mean and standard deviation of A-S profile—A0, S0 and A-S slope, for all age groups in each training block. A repeated measures one-way ANOVA test was conducted, for each dependent variable to study differences between training blocks, for each age group separately. Tukey's post hoc tests were used to assess the differences in A-S profile between training blocks.

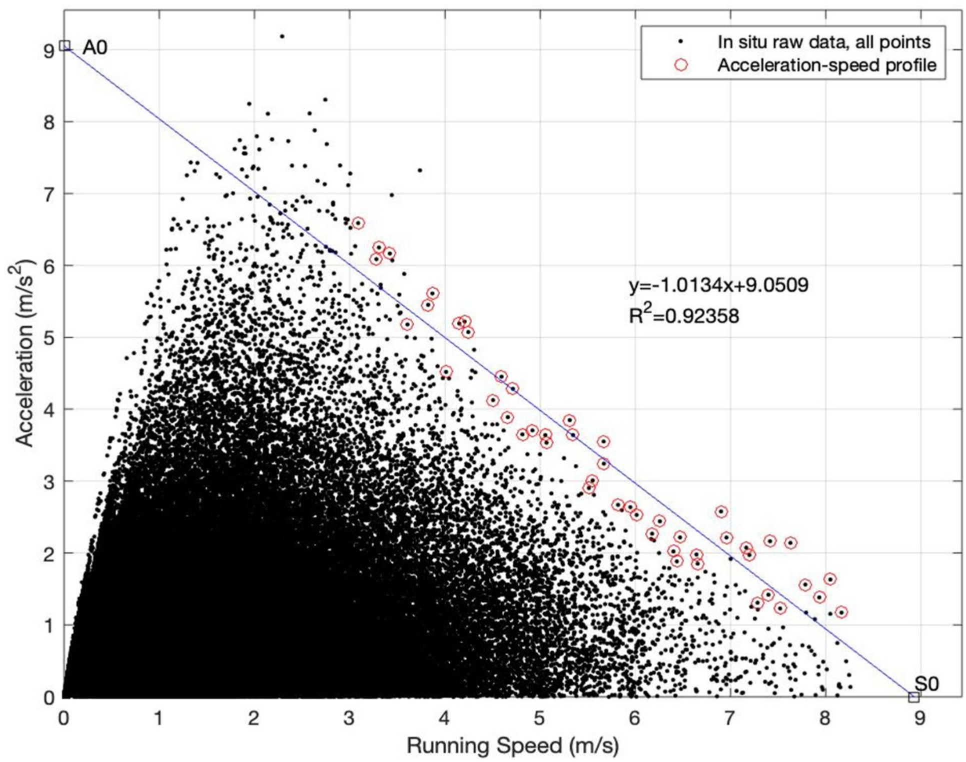

Fig. 1 Example of an individual acceleration-speed profile obtained from the raw data of 10 consecutive training sessions

Results

The characteristics of all age groups are displayed in Table 2.

The results of the A-S profile for all age groups, per training block are presented in Table 3.

A-S profile and external load variables

No changes were verified in under-14 in A-S profile (A0, S0 or A-S slope) across the different training blocks.

In under-15 age group, S0 showed significant increases, but no differences were found in A0 or A-S slope across the training blocks. Post hoc tests revealed that under-15 displayed differences between Block 1 and Blocks 2, 4, 5, and 6 ($p < 0.05$) and between Block 3 and 5 ($p < 0.05$).

Under-16 did not demonstrate any differences in A-S profile (A0, S0 or A-S slope) across the different training blocks.

Under-17 did not have any differences in A-S profile (A0, S0 or A-S slope) across the different training blocks.

S0 showed significant increases in under-19 between Block 1 and 5 ($p < 0.05$), but no differences were found between blocks in A0 or A-S slope.

A0 showed a positive difference in under-23, but no post hoc differences were found between blocks. No differences were found in S0 or A-S slope across the training blocks.

S0 showed significant increases in B-team but no post hoc differences were found between training blocks. No differences were found between A0 and A-S slope between training blocks.

Discussion

This study investigated potential A-S profile variations throughout a season in different age groups. To the best of our knowledge, this was the first study to compare the differences in this profile, in various age groups during a full-season period. We hypothesized that 1) A0 and S0 would increase in under-14 and under-15 age groups during the season as a consequence of growth and maturation; and 2) A0 and S0 would decrease during the season in the other age groups, due to the accumulated external load. Our hypotheses were not observed as the A-S profile remained constant in almost every age group throughout the season. Overall, our results demonstrate that soccer players do not significantly change their sprint capacity during the season, indicating that maximum acceleration capacity (A0) or the maximum speed capacity (S0) tend to remain stable in soccer players independent of their age group [1, 21, 33].

In younger age groups (i.e., under-14 and under-15), increases in the A-S profile throughout the season were expected due to lower values of S0 and V0 observed during the beginning of the season in preview research [12, 13]. Nevertheless, in the present study, an increase in S0 was not observed between training blocks in the under-14

Table 1 Training blocks characterization

Age group	Training block	Number of weeks	Training sessions (n)	Matches (n)	Total distance (m)	High-speed running (> 19.8 km/h) (m)	Sprint distance (> 25.2 km/h) (m)	Accelerations + decelerations > 2 m/s^2 (m)	Accelerations + decelerations > 3 m/s^2 (n)
Under-14	1	4	16.5 ± 1.2	1.7 ± 0.5	108,996 ± 13,450	2503 ± 1499	233 ± 257	18,203 ± 3547	1865 ± 420
	2	5	14.6 ± 3.2	0.6 ± 0.5	92,710 ± 21,982	3114 ± 1557	248 ± 218	17,479 ± 4670	1743 ± 500
	3	5	15.6 ± 3.8	2.2 ± 0.8	99,844 ± 30,023	3278 ± 1755	402 ± 322	17,435 ± 5869	1642 ± 593
	4	6	17.4 ± 6.9	4.2 ± 1.8	122,895 ± 55,799	4956 ± 3498	669 ± 724	23,929 ± 11,618	2285 ± 1131
	5	8	31.1 ± 10.5	6.3 ± 3.1	208,756 ± 81,535	8585 ± 5143	1048 ± 974	40,705 ± 17,049	3889 ± 1653
	6	8	10.8 ± 4.2	5.1 ± 1.4	67,182 ± 27,267	2619 ± 1620	302 ± 304	13,538 ± 5557	1243 ± 505
Under-15	1	4	18.3 ± 1.0	6.4 ± 0.8	99,769 ± 10,709	3942 ± 1189	621 ± 326	18,713 ± 3472	1943 ± 415
	2	7	31.4 ± 6.4	4.7 ± 1.6	176,921 ± 43,862	7195 ± 2482	1388 ± 601	31,993 ± 9291	3317 ± 997
	3	8	30.5 ± 8.1	3.9 ± 1.2	189,366 ± 58,061	7044 ± 2614	1269 ± 641	35,821 ± 10,961	3670 ± 1118
	4	6	27.1 ± 4.9	4.1 ± 1.9	178,673 ± 45,200	7899 ± 2702	1701 ± 762	34,185 ± 9967	3368 ± 970
	5	8	32.8 ± 5.3	4.9 ± 2.1	202,954 ± 39,156	9259 ± 2957	1902 ± 661	39,013 ± 9705	3853 ± 958
	6	8	32.1 ± 6.2	5.4 ± 1.9	182,646 ± 40,102	7659 ± 2730	1343 ± 611	34,810 ± 8842	3297 ± 839
Under-16	1	4	14.1 ± 3.9	0.0 ± 0.0	72,652 ± 20,154	3446 ± 1324	758 ± 424	12,456 ± 3861	1173 ± 377
	2	7	32.4 ± 6.4	5.0 ± 1.5	208,350 ± 46,051	10,817 ± 3626	2439 ± 1186	36,030 ± 9260	3508 ± 966
	3	8	39.0 ± 8.2	6.2 ± 1.6	214,292 ± 49,869	9816 ± 2579	2220 ± 744	39,298 ± 9511	4066 ± 1045
	4	6	27.1 ± 5.0	5.4 ± 1.3	149,371 ± 38,190	7525 ± 2562	1822 ± 530	29,850 ± 7860	3116 ± 799
	5	8	41.3 ± 5.8	4.1 ± 1.4	214,790 ± 34,593	10,247 ± 3364	2631 ± 720	40,991 ± 8391	4394 ± 1023
	6	8	37.7 ± 5.9	4.6 ± 2.5	204,920 ± 39,878	10,424 ± 2982	2668 ± 798	36,734 ± 8406	3596 ± 982
Under-17	1	5	24.0 ± 5.3	2.4 ± 0.7	138,996 ± 37,139	5978 ± 2451	992 ± 565	26,317 ± 7532	2727 ± 823
	2	8	35.3 ± 8.1	4.8 ± 2.2	221,967 ± 57,185	11,462 ± 4256	2336 ± 1041	42,483 ± 12,212	4043 ± 1259
	3	8	47.4 ± 8.8	5.9 ± 2.9	271,036 ± 37,756	15,443 ± 4994	3133 ± 1548	51,932 ± 8489	4744 ± 908
	4	6	31.0 ± 5.9	5.2 ± 1.6	186,241 ± 38,434	10,554 ± 3739	2042 ± 1098	35,465 ± 7698	3309 ± 785
	5	8	43.3 ± 11.4	5.0 ± 2.2	251,122 ± 64,344	14,196 ± 5110	2876 ± 1369	47,307 ± 13,982	4495 ± 1429
	6	8	33.8 ± 8.9	4.3 ± 1.4	214,037 ± 41,275	11,396 ± 3670	2217 ± 991	34,770 ± 10,211	3263 ± 1029
Under-19	1	5	22.9 ± 5.7	5.4 ± 2.6	128,911 ± 41,302	7003 ± 2915	1249 ± 723	24,839 ± 9313	2382 ± 956
	2	8	41.6 ± 6.4	6.3 ± 2.3	242,467 ± 49,465	14,050 ± 4957	2642 ± 1287	48,119 ± 12,003	4850 ± 1571
	3	8	43.9 ± 10.5	6.8 ± 2.8	226,240 ± 61,120	12,659 ± 4689	2234 ± 1063	43,525 ± 11,867	4287 ± 1194
	4	6	32.1 ± 11.5	5.3 ± 1.5	170,778 ± 67,983	9563 ± 4161	1646 ± 882	33,741 ± 13,756	3366 ± 1389
	5	8	40.5 ± 8.3	6.1 ± 1.2	219,852 ± 46,113	11,593 ± 4214	2101 ± 1016	43,401 ± 10,002	4427 ± 1214
	6	8	32.4 ± 9.2	4.7 ± 2.4	176,206 ± 61,234	9969 ± 4412	1932 ± 1001	33,584 ± 11,595	3309 ± 1172
Under-23	1	5	24.4 ± 6.6	1.6 ± 1.6	141,890 ± 43,293	8079 ± 2571	1634 ± 768	26,789 ± 8637	2533 ± 894
	2	8	28.3 ± 11.7	5.0 ± 1.6	171,033 ± 76,844	9883 ± 4551	2195 ± 1201	32,771 ± 14,932	3194 ± 1441
	3	8	40.5 ± 15.8	5.3 ± 1.8	210,053 ± 82,694	11,304 ± 5286	2350 ± 1493	40,276 ± 16,350	3920 ± 1597
	4	6	29.3 ± 5.3	4.9 ± 2.6	155,964 ± 36,486	8260 ± 3098	1730 ± 1076	30,312 ± 7992	3013 ± 828
	5	8	40.4 ± 5.8	5.1 ± 2.6	223,875 ± 51,187	11,916 ± 4768	2474 ± 1399	45,296 ± 11,746	4496 ± 1209
	6	8	18.9 ± 7.8	3.4 ± 2.5	87,969 ± 50,147	4920 ± 4126	1044 ± 969	17,859 ± 10,513	1914 ± 1038
B-Team	1	5	29.7 ± 8.3	5.0 ± 1.1	148,562 ± 34,093	7443 ± 2089	1620 ± 691	27,777 ± 6529	2808 ± 693
	2	8	38.8 ± 5.9	5.1 ± 2.4	240,659 ± 50,486	14,969 ± 4454	3521 ± 1443	45,729 ± 9504	4657 ± 1224
	3	8	36.9 ± 7.9	4.8 ± 2.6	245,492 ± 30,013	16,626 ± 3765	4144 ± 1250	48,339 ± 7955	4699 ± 1142
	4	6	31.4 ± 6.7	5.7 ± 2.0	186,471 ± 42,611	11,374 ± 3905	2684 ± 1343	37,523 ± 8600	3751 ± 898
	5	8	34.3 ± 5.0	5.1 ± 1.1	205,467 ± 31,566	14,363 ± 2925	3645 ± 1278	40,775 ± 7991	4032 ± 975
	6	8	29.9 ± 5.8	5.1 ± 1.5	173,011 ± 37,700	9206 ± 3607	2131 ± 1162	32,992 ± 7805	3316 ± 808

group, but it was observed in the under-15 group. The differences found in under-15 may suggest that the training exposure and the maturation process could be inducing changes that could potentially lead to a better sprint performance [34, 35], reinforcing that after this age, any improvement in sprint capacity in athletes could be residual [11, 36, 37]. Also, since the under-14 group did not have much improvement in S0 during the season, and this

Table 2 Age group characterization

Age group	n	Chronological age (years) (Mean ± SD)	Height (cm) (Mean ± SD)	Body mass (kg) (Mean ± SD)
Under-14	12	12.65 ± 0.60	1.69 ± 0.04	53.16 ± 6.23
Under-15	21	13.87 ± 0.34	1.72 ± 0.07	59.02 ± 6.62
Under-16	20	14.60 ± 0.74	1.77 ± 0.08	64.22 ± 5.75
Under-17	23	15.57 ± 0.59	1.77 ± 0.08	68.64 ± 7.29
Under-19	19	17.22 ± 0.63	1.80 ± 0.08	71.59 ± 8.31
Under-23	13	17.90 ± 0.97	1.78 ± 0.05	71.48 ± 5.45
B-team	18	18.87 ± 1.46	1.83 ± 0.06	73.49 ± 7.84

group have a chronological age that is associated with some improvements in strength and sprint performance [11, 35], we identify two potential major aspects that are underpinning these results: 1) the training load could not be leading to an exposure that would allow the athletes to develop their maximum theoretical speed. It has been previously demonstrated that to express a higher S0, the exposure to higher volumes of sprint distance could be detrimental for a valid A-S profile [18] and that this volume of sprint training could be needed in a training perspective; or 2) the increase in height observed during the season in the under-14 age group (i.e., 3.44 ± 1.87 cm between block 1 and 6) could possibly be related to a decreased coordination and effectiveness in force application, a phenomenon described as "movement awkwardness" [35].

In older age groups, a decrease in A0 or S0 was expected since the players are exposed to a greater training and match demands, that could lead to an increased fatigue level and a decreased sprint capacity. However, a decrease in A0 or S0 was not observed in older age groups (i.e., under-16, under-17, under-19, under-23 or B-team). This runs contrary to our hypothesis as we were expecting a decrease in S0 during later stages of the in-season period (block 4 to 6), in under-16, under-17, under-19, under-23, and B-team. In fact, similar findings were previously observed in the A-S profile during the season in adult soccer players, since A0 and S0 did not fluctuate between training periods [21]. Nevertheless, the authors observed that at an individual level analysis, the difference between periods in A0 and S0 could exist. A key aspect that could influence the lack of S0 fluctuations observed, in the present study, could be the training methodology implemented in this elite academy. The club methodology has been designed to include a weekly maximal sprinting situations, in all age groups. This weekly exposure to maximal velocities increases the reliability of the assessment of S0 in the athletes' profiles [18], but also increases the number of data points of the cloud that are closer to S0, minimizing a possible significant fluctuation observed in S0,

Table 3 A-S profile characteristics between age groups

Age group	Training block	A0 (m/s^2) (Mean ± SD)	S0 (m/s) (Mean ± SD)	A-S slope (Mean ± SD)
Under-14	1	8.74 ± 1.00	8.59 ± 0.47	− 0.92 ± 0.06
	2	8.57 ± 1.15	8.76 ± 0.68	− 0.89 ± 0.11
	3	8.09 ± 0.55	8.57 ± 0.64	− 0.91 ± 0.11
	4	8.13 ± 0.56	8.65 ± 0.58	− 0.87 ± 0.07
	5	8.24 ± 0.60	8.98 ± 0.74	− 0.84 ± 0.08
	6	8.36 ± 0.71	8.90 ± 0.89	− 0.91 ± 0.05
Under-15	1	8.94 ± 0.61	8.97 ± 0.59	− 0.89 ± 0.11
	2	8.77 ± 0.84	9.61 ± 0.38#	− 0.80 ± 0.05
	3	8.82 ± 0.62	9.30 ± 0.49	− 0.87 ± 0.09
	4	8.74 ± 0.62	9.46 ± 0.55#	− 0.85 ± 0.08
	5	8.93 ± 0.65	9.87 ± 0.51#, ###	− 0.80 ± 0.08
	6	8.80 ± 0.54	9.75 ± 0.51#	− 0.83 ± 0.06
Under-16	1	8.59 ± 0.68	9.59 ± 0.73	− 0.84 ± 0.12
	2	8.82 ± 0.79	9.66 ± 0.65	− 0.81 ± 0.10
	3	9.24 ± 0.97	9.64 ± 0.51	− 0.85 ± 0.08
	4	9.06 ± 1.00	9.53 ± 0.50	− 0.85 ± 0.08
	5	8.96 ± 0.75	9.69 ± 0.44	− 0.82 ± 0.08
	6	8.52 ± 0.59	9.77 ± 0.47	− 0.81 ± 0.09
Under-17	1	8.98 ± 0.62	9.62 ± 0.38	− 0.83 ± 0.06
	2	8.82 ± 0.56	9.93 ± 0.50	− 0.80 ± 0.06
	3	8.97 ± 0.47	9.89 ± 0.49	− 0.81 ± 0.06
	4	8.86 ± 0.58	9.85 ± 0.48	− 0.80 ± 0.05
	5	9.34 ± 0.91	9.91 ± 0.49	− 0.81 ± 0.08
	6	9.09 ± 0.77	9.96 ± 0.51	− 0.82 ± 0.08
Under-19	1	9.13 ± 0.93	9.58 ± 0.44	− 0.84 ± 0.08
	2	9.24 ± 0.93	9.76 ± 0.49	− 0.83 ± 0.09
	3	8.88 ± 0.51	9.95 ± 0.52	− 0.80 ± 0.12
	4	8.75 ± 0.68	9.77 ± 0.40	− 0.81 ± 0.07
	5	8.89 ± 0.71	10.05 ± 0.39#	− 0.78 ± 0.07
	6	8.85 ± 0.86	10.04 ± 0.46	− 0.78 ± 0.06
Under-23	1	8.40 ± 0.46	9.74 ± 0.56	− 0.79 ± 0.06
	2	8.52 ± 0.22	9.71 ± 0.46	− 0.81 ± 0.07
	3	8.97 ± 1.02	9.74 ± 0.43	− 0.79 ± 0.07
	4	9.11 ± 1.04	9.77 ± 0.57	− 0.79 ± 0.07
	5	8.90 ± 0.70	10.00 ± 0.41	− 0.77 ± 0.04
	6	8.80 ± 0.69	9.78 ± 0.78	− 0.87 ± 0.12
B	1	9.06 ± 0.55	9.56 ± 0.44	− 0.88 ± 0.08
	2	9.24 ± 0.64	9.78 ± 0.51	− 0.83 ± 0.08
	3	9.12 ± 0.95	9.94 ± 0.42	− 0.80 ± 0.06
	4	9.48 ± 1.06	10.02 ± 0.40	− 0.84 ± 0.09
	5	9.37 ± 1.40	10.06 ± 0.41	− 0.80 ± 0.03
	6	8.86 ± 0.74	10.09 ± 0.47	− 0.81 ± 0.11

#-$p < 0,05$ from Block 1; ###-$p < 0,05$ from Block 3

at a longitudinal level. In this regard, the fluctuation that could exist in S0 should be considered in terms of individual approach to the training regime and could be also linked to lack of frequent exposure to maximal sprinting speed situations during the training or match situation.

In the present study, athletes' acceleration capacity did not vary significantly throughout the season. Acceleration capacity has been previously related to the ability of producing high levels of lower body strength and power [33, 38]; therefore, any significant decreases in A0 during the season could be an indication of a decreased ability to express optimal levels of muscular strength and power. In addition, this potential decrease could be related to a decline in match performance [39] or an increased predisposition to injury [40, 41]. Given the importance of acceleration in soccer athletic performance, constant monitoring of A0 should be a priority for performance enhancement and injury prevention regimes [42].

In the majority of the age groups, the A-S profile did not vary much significantly through the season. However, it was not investigated the influence that soccer external demands (i.e., external load) could have on the A0 or S0 variables. It would be of interest to study the effect of the 10-day training load that allowed the expression of the different variables of the A-S profile. This information could, in part, explain if the soccer training load could be responsible for a better expression of the A-S profile and enlighten us if the volume of any external load measurement could be detrimental in the development of faster athletes. This information would be of much importance in the training approach between and within the different age groups.

Although the A-S profile did not seem to have a significant fluctuation across the training blocks, the majority of players evaluated in the present study showed increases in both A0 and S0 values in blocks 4, 5, and 6 compared to block 1 (Supplementary Data: Table 1). Although these improvements may have not reached statistical significance, they could be highly relevant from an athletic performance and athletes' development. One should note that the athletes from this study are high-level players at the national and international level. Therefore, a potential increase, for example, of 0.49 m/s in S0, can make significant difference in a real-world scenario, i.e., a match. In addition to the majority of players showing improvements in both A0 and S0, no specific training block was identified where improvements in profile variables were more frequent across all age groups. Thus, the timing of the response appears to be individual and variable, with some players reaching their peak values earlier, while others reach them later. Consequently, there may not be a statistically significant mean difference between training blocks, as shown in the present study. These data may confirm 1) the importance of training physical qualities during the athletic development process in a soccer academy, as most players may improve over the season; and 2) the increased importance of monitoring the A-S profile during the season to manage individual responses to the training process to identify possible outliers or to have training interventions that could be specific and individualized training to improve acceleration and sprint capacities or to daily monitor and control the training quality [42]. The present results of this study could guide to a clearer vision about sprinting interventions during the season in a soccer academy setting. However, generalization of our findings might be limited given the small sample size in some of the age groups, and considering the context of the assessed athletes—elite academy. Despite this contextual factor, we believe that the data retrieved from our study could potentially serve as reference values. Similar studies are, however, needed to support this claim.

Since we observed that a high percentage of athletes across the evaluated age groups exhibited variations in their maximum speed from the beginning of the season to the later training blocks (blocks 4 to 6) despite the absence of statistically significant differences, it may be important to maintain stimuli that underpin higher speed development. These could include frequent exposure to maximum speed efforts and/or complementary speed training [33]. This individual variation is particularly pronounced in the under-15 age group, where 100% of the athletes showed an increase in their S0 values (Supplementary Table 2). In terms of acceleration (A0), the observed individual variation was smaller, likely because the stimulus provided by the sport-specific training could be sufficient to maintain this capacity. However, for athletes with lower A0 values, the development of greater strength levels may be a critical factor in enhancing this ability [33, 39].

Conclusion

The current findings emphasize the stability of the A-S profile throughout a season across various age groups in elite youth soccer players. We found minimal longitudinal changes observed in sprint capacity, throughout different age groups, suggesting that elite young soccer players tend to have a stability in their sprint capacity throughout the season. However, monitoring individual variability in the A-S profile remains critical for identifying and addressing outliers. While most age groups showed consistent sprint capacities, individual fluctuations in S0 and A0 underline the necessity of personalized tracking and tailored training interventions. For younger players, particularly those in the under-15 age group, regular exposure to maximum speed stimuli and monitoring growth-related changes are essential for maintaining and enhancing sprint performance. Athletes with lower acceleration capacities (A0) should focus on strength training to improve force production, a key factor in acceleration.

Future research could explore the effects of soccer-specific external demands on A-S profile variables to better understand their influence and optimize training strategies. In addition, establishing standardized norms for different age groups based on these findings could aid in identifying outliers and tailoring individualized training interventions to enhance acceleration and sprint capacities.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Conflict of interest The authors declare no competing interests.

Ethical approval Athletes provided informed consent prior to starting the study and they gave their informed consent in accordance with the Declaration of Helsinki. The present study was approved by the Ethical Committee of Faculty of Human Kinetics (CEIFMH No.: 38/2021).

Human rights The study protocol adhered to the tenets of the Declaration of Helsinki and was approved by the institutional review board.

Informed consent All participants were informed about the research purpose and procedures of the study prior to signing a written informed consent form.

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