Seasonal Changes in the Sprint Acceleration Force-Velocity Profile of Elite Male Soccer Players

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Abstract

Jiménez-Reyes, P, Garcia-Ramos, A, Párraga-Montilla, JA, Morcillo-Losa, JA, Cuadrado-Peñafiel, V, Castaño-Zambudio, A, Samozino, P, and Morin, J-B. Seasonal changes in the sprint acceleration force-velocity profile of elite male soccer players. *J Strength Cond Res* XX(X): 000–000, 2020—This study aimed to describe the seasonal changes in the sprint force-velocity (Fv) profile of professional soccer players. The sprint Fv profile of 21 male soccer players competing in the first division of the Spanish soccer league was evaluated 6 times: preseason 1 (September 2015), in-season 1 (November 2015), in-season 2 (January 2016), in-season 3 (March 2016), in-season 4 (May 2016), and preseason 2 (August 2016). No specific sprint capabilities stimuli other than those induced by soccer training were applied. The following variables were calculated from the velocity-time data recorded with a radar device during an unloaded sprint: maximal force (F_0), maximal velocity (v_0), Fv slope, maximal power (P_{max}), decrease in the ratio of horizontal-to-resultant force (D_{RF}), and maximal ratio of horizontal-to-resultant force (RF_{peak}). F_0 (effect size [ES] range = 0.83–0.93), P_{max} (ES range = 0.97–1.05), and RF_{peak} (ES range = 0.56–1.13) were higher at the in-seasons 2 and 3 compared with both preseasons ($p \leq 0.006$). No significant differences were observed for v_0, Fv slope, and D_{RF} ($p \geq 0.287$). These results suggest that relevant Fv profile variables may be compromised (F_0 more compromised than v_0) toward the end of the competitive season when specific sprint stimuli are not systematically applied.

Key Words: linear sprint, maximal force, maximal velocity, maximal power

Introduction

The ability to perform soccer-specific actions at high speed is one of the main characteristics of high-level soccer players (31). Short accelerations and linear sprints are 2 of the most important actions in soccer because they frequently precede goals and other decisive actions (9,13). The importance of linear sprints is further reinforced by the large number of studies that have been conducted to identify effective conditioning programs to improve linear sprint performance in soccer players (3,6,7,26,27). A recent meta-analysis has highlighted that the addition of either resistance training, plyometric training, or sprint training to regular soccer training is effective at enhancing linear sprint performance compared with performing only soccer training (combined effect size = 0.79) (14). However, some practitioners still prescribe specific physical training to improve explosive performance only during the preseason, expecting that soccer training and competitive matches will provide enough stimuli for maintaining the performance of explosive actions throughout the competitive season.

Linear sprint performance of soccer players has been traditionally assessed by the time needed to run a given distance (e.g., time to 20 m) (3,7,26,27). More recently, Morin and Samozino (23) have recommended the assessment of the entire force-velocity (Fv) spectrum during sprint acceleration (i.e., horizontal Fv profile) to obtain more comprehensive and meaningful information about the determinants of linear sprint performance. Owing to the consistent and clear linearity of the sprint Fv relationship, the maximal capacities of the muscles to produce force (F_0), velocity (v_0), and power (P_{max}) can be determined through the application of a linear regression model (17,30). Other variables that are also known to influence linear sprint performance can also be determined using this novel testing procedure: Fv slope (i.e., the ratio between F_0 and v_0), decrease in the ratio of horizontal-to-resultant force (D_{RF}), and maximal ratio of horizontal-to-resultant force (RF_{peak}) (23,30). All the variables of the sprint Fv profile (i.e., F_0, v_0, Fv slope, P_{max}, D_{RF}, and RF_{peak}) can now be simply but accurately determined during an unloaded maximal sprint in which the athlete reaches top speed (≈30 m is needed in soccer players) through the recording of either the displacement- or velocity-time data (16,29,30).

Several studies have already reported the sprint Fv profile of soccer players (4,6,15,17,19–21,24). Baumgart et al. (2) and Jiménez-Reyes et al. (17) provided reference values of the sprint Fv profile of soccer players according to age, sex, and level of practice. Mendiguchia et al. (20,21) suggested that the regular monitoring of the sprint Fv profile in soccer players may provide useful information both from a performance and injury prevention perspective. Nagahara et al. (24) showed that the sprint Fv profile is sensitive to detect the fatigue induced by an actual

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soccer match. However, only 1 study has examined the seasonal changes in the sprint Fv profile of soccer players by collecting from a database the sprint times of 44 male professional soccer players from 6 different clubs of the upper Norwegian league at 3 time points (preseason, in-season, and off-season) (15). Haugen revealed meaningful differences between the time points for F_0 (greater off-season compared with in-season), v_0 (lower preseason compared with in-season and off-season), Fv slope (higher off-season compared with preseason and in-season), and P_{max} (greater off-season compared with preseason and in-season). However, a limitation of this study is that soccer players were not necessarily tested at the same time of the season. For example, the in-season period lasted more than 6 months (from April 1st to October 15th), but it was not specified when the test was performed within this period of time. This is important because the sprint Fv profile may change from the initiation to the end of the competitive period. Therefore, more measurements should be collected in-season to determine the behavior of the sprint Fv profile during the course of the competitive period. This could bring potential tracks for a more accurate follow-up of sprint capabilities toward more individualized and effective training or rehabilitation interventions.

Therefore, the aim of this study was to describe the seasonal changes (6 time points: preseason 1, in-season 1, in-season 2, in-season 3, in-season 4, and preseason 2) in the sprint Fv profile of elite male soccer players. We hypothesized that the regular soccer training and competitive matches would induce a progressive improvement in the sprint Fv profile (i.e., higher values of F_0, v_0, and P_{max}) from the preseason until the middle of the season (i.e., in-season 2 and 3), whereas the no modification of the training content and no application of specific sprint stimuli toward the end of the competitive season would lead to a stabilization or deterioration in the sprint Fv profile.

Methods

Experimental Approach to the Problem

A longitudinal study was used to assess the sprint Fv profile of professional male soccer players at 6 time points of the season: preseason 1 (September 2015), in-season 1 (November 2015), in-season 2 (January 2016), in-season 3 (March 2016), in-season 4 (May 2016), and preseason 2 (August 2016). No specific sprint capability stimuli other than those induced by soccer training and competitive matches were applied. All tests were performed at least 48 hours after a friendly (preseason assessments) or competitive match (in-season assessments). Subjects wore the same sport shoes and clothes that they typically use during training. All tests were conducted on the same outdoor soccer pitch.

Subjects

Twenty-one professional male soccer players (mean ± *SD*: age: 26.9 ± 3.1 years, height: 180.3 ± 4.9 cm, body mass: 77.9 ± 8.5 kg) participated in this study. All subjects were members of a soccer team that classified above the relegation positions in the first division of the professional Spanish soccer league. Therefore, during the in-season period, soccer players frequently performed 2 competitive matches per week. Subjects were informed about the study procedures and signed a written informed consent form before initiating the study. The study protocol adhered to the tenets of the Declaration of Helsinki and was approved by the institutional review board of the University of Jaen.

Procedures

Identical procedures were followed during the 6 testing sessions. All sessions began with a standardized warm-up consisting of 5 minutes of jogging, dynamic stretching, and 3 sprints of 30–40 m at 50, 70, and 90% of the subjects' self-perceived maximal velocity. Once the warm-up was completed, subjects rested 5 minutes, and then, they performed the 2-maximal sprints of 40 m which were used for the assessment of the sprint Fv profile. A rest period of 3–5 minutes was implemented between successive sprints. The sprint with the shortest time to 40 m was used for statistical analyses. Players started all sprints from a crouching position (staggered stance).

A Stalker Acceleration Testing System II radar device (Dallas, TX) was used to record the velocity-time data at a frequency of 46.9 Hz. The radar device was attached to a tripod that was placed 10 m behind the starting line at a height of 1 m which corresponds approximately to the height of subjects' center of mass. The variables of the sprint Fv profile (i.e., F_0, v_0, Fv slope, P_{max}, D_{RF}, and RF_{peak}) were calculated from the velocity-time data using the inverse dynamic analysis validated by Samozino et al. (30). Briefly, a monoexponential function was used to fit raw velocity-time data using a custom-made spreadsheet. The horizontal acceleration of the subject's center of mass was then calculated from the changes in velocity over time, and the net horizontal ground reaction forces were calculated by considering the body mass and aerodynamic friction force (30). Finally, the individual Fv linear relationship was modeled to determine F_0 (force-intercept), v_0 (velocity-intercept), Fv slope, and P_{max} ($P_{max} = F_0 \times v_0/4$). The ratio of force (RF) was calculated as the ratio of horizontal-to-resultant force after 0.3 seconds from the start of the sprint until the end of the sprint (30), whereas the RF_{peak} corresponded to the maximal RF value which is typically observed at the beginning of the sprint (22). The linear decrease in the RF (D_{RF}) with the increment of running velocity was calculated and presented as an index of the ability to maintain a high RF throughout the acceleration phase (22).

Statistical Analyses

Descriptive data of the dependent variables (i.e., F_0, v_0, Fv slope, P_{max}, D_{RF}, and RF_{peak}, time to 10 m) are presented as means and *SD*s. Before further statistical analyses, the normal distribution of the variables (Shapiro-Wilk test) and the homogeneity of the variances (Levene test) were confirmed ($p > 0.05$). A 1-way repeated-measures analysis of variance (ANOVA) with least significant difference post hoc comparisons was used to explore the effect of the period of the season (preseason 1, in-season 1, in-season 2, in-season 3, in-season 4, and preseason 2) on the magnitude of each dependent variable. The Cohen's ES was calculated to evaluate the magnitude of the differences using the following scale: negligible (<0.2), small (0.2–0.5), moderate (0.5–0.8), and large (≥0.8) (5). Statistical analyses were performed using the software package SPSS (IBM SPSS version 22.0, Chicago, IL). Statistical significance was set at $p \leq 0.05$.

Results

The ANOVAs revealed significant differences between the time points for F_0, P_{max}, and RF_{peak} and the time to 10 m ($p \leq 0.006$) but not for v_0, Fv slope, and D_{RF} ($p \geq 0.287$) (Table 1). The magnitude of F_0 was significantly higher at in-season 2 and in-season

Table 1
Comparison of the sprint force-velocity profile and time to 10 m between the different time points of the season.*†

	Preseason 1	In-season 1	In-season 2	In-season 3	In-season 4	Preseason 2	ANOVA
F_0 (N·kg^{-1})	6.85 ± 0.53	7.14 ± 0.58	7.40 ± 0.70‡§	7.23 ± 0.40‡§	7.13 ± 0.58	6.91 ± 0.36	$F = 3.47$, $p = 0.006$
v_0 (m·s^{-1})	9.21 ± 0.45	9.25 ± 0.46	9.30 ± 0.39	9.29 ± 0.33	9.31 ± 0.55	9.18 ± 0.37	$F = 0.30$, $p = 0.913$
Fv slope (N·s·m^{-1}·kg^{-1})	55.6 ± 7.5	56.8 ± 8.1	58.3 ± 8.0	61.4 ± 9.8	58.7 ± 7.8	56.8 ± 7.9	$F = 1.26$, $p = 0.287$
P_{max} (W·kg^{-1})	15.6 ± 1.2	16.4 ± 1.4	17.1 ± 1.7‡§	16.7 ± 0.8‡§	16.5 ± 1.6	15.8 ± 1.1	$F = 4.01$, $p = 0.002$
D_{RF} (%)	6.80 ± 0.69	6.98 ± 0.73	7.14 ± 0.72	7.01 ± 0.56	6.90 ± 0.76	6.85 ± 0.46	$F = 0.77$, $p = 0.577$
RF_{peak} (%)	45.2 ± 3.9	47.7 ± 3.7‡	48.9 ± 3.9‡§	48.4 ± 1.7‡§	48.2 ± 3.2‡§	45.8 ± 3.3	$F = 4.53$, $p = 0.001$
Time to 10 m (s)	2.171 ± 0.058	2.134 ± 0.063	2.104 ± 0.079‡§	2.118 ± 0.037‡§	2.131 ± 0.073‡	2.161 ± 0.050	$F = 3.93$, $p = 0.003$

*ANOVA = analysis of variance; F_0 = theoretical maximal force; v_0 = theoretical maximal velocity; Fv slope = slope of the force-velocity relationship; P_{max} = maximal power; D_{RF} = decrease in the ratio of horizontal-to-resultant force; RF_{peak} = maximal ratio of horizontal-to-resultant force.
†Mean ± *SD*.
‡Significantly higher (or lower for the time to 10 m) than preseason 1.
§Significantly higher (or lower for the time to 10 m) than preseason 2.

3 compared with the preseason 1 (ES = 0.91 and 0.83, respectively) and preseason 2 (ES = 0.93 and 0.86, respectively). The magnitude of P_{max} was also significantly higher at in-season 2 and in-season 3 compared to the preseason 1 (ES = 1.01 and 1.05, respectively) and preseason 2 (ES = 0.97 and 0.99, respectively). The RF_{peak} obtained at both preseasons were significantly lower compared with all in-seasons (ES range = 0.66 to 1.13) with the only exception being the comparison between preseason 2 and in-season 1 ($p = 0.069$, ES = 0.56). The time to 10 m was significantly higher at preseason 1 compared with in-season 2 ($p = 0.002$, ES = 0.98), in-season 3 ($p < 0.001$, ES = 1.12), and in-season 4 ($p = 0.047$, ES = 0.62), whereas at preseason 2, the time to 10 m was significantly higher compared with in-season 2 ($p = 0.009$, ES = 0.89) and in-season 3 ($p = 0.011$, ES = 0.99) (Figure 1).

Discussion

This study was designed to explore the changes in the sprint Fv profile of an elite male soccer team during a 1-year period in which no specific training stimuli were applied to enhance linear sprint performance. The main findings of the study showed that 3 variables of the sprint Fv profile significantly changed over the season (F_0, P_{max}, and RF_{peak}), whereas no significant changes were observed in the other 3 variables (v_0, Fv slope, and D_{RF}). Specifically, F_0, P_{max}, and RF_{peak} reached their maximum values at the middle of the competitive period (in-season 2 and 3), and they were submaximal at the beginning (in-season 1) and at the end (in-season 4) of the competitive period. The time to 10 m was used as a performance variable, and it showed a similar behavior than F_0, P_{max}, and RF_{peak}. Therefore, these results suggest that elite soccer players should perform specific training to improve sprint performance at the end of the season to avoid a deterioration of the Fv profile variables related to maximal acceleration capacity, which could be associated with a reduction in sprint acceleration performance and possibly with a higher risk of hamstrings injury (18,21).

Soccer is a multifactorial team sport in which performance is determined by the interaction of technical, tactical, physical, physiological, and psychological components (28,31). All factors need to be considered due to the little difference in performance that currently exists between professional soccer teams. One of the main attributes of top soccer players is their ability to perform soccer-specific actions at high speed (31). Specifically, it has been shown that scoring goals during soccer competitions is commonly preceded by powerful actions, a linear sprint being one of the most frequent actions (13). Therefore, it is evident that soccer players should maintain throughout the whole competitive season a high performance during explosive actions that are performed at high velocities such as jumps, accelerations, linear sprints, change of direction, or kicks.

The analysis of the sprint Fv profile allows practitioners to assess and monitor the mechanical determinants of performance during short accelerations (F_0 and RF_{peak}) and longer distance sprints (v_0 and D_{RF}) (30). The Fv slope and P_{max} could be considered as performance indicators of both short accelerations and longer distance sprints because their computations are based on both F_0 and v_0. In this regard, it is important to highlight that the significant changes observed in P_{max} throughout the season were mainly caused by the modification of F_0, while v_0 remained more stable.

To date, the only study that has compared the sprint Fv profile of soccer players between the pre- and in-season periods revealed a clearly lower v_0 during the preseason, whereas no meaningful differences were observed for F_0, Fv slope, and P_{max} (15). However, Haugen (15) did not specify the point of the season in which the measurement was collected. This is important because the results of this study suggest that the sprint Fv profile may fluctuate during the in-season period because it has been shown to fluctuate at different time points within a single soccer game (24). Interestingly, higher fluctuations were observed for the variables related to the left (force) side of the Fv spectrum (i.e., early acceleration components; F_0 and RF_{peak}) compared with the ones related to right (velocity) side of the Fv spectrum (i.e., late phase of the acceleration; v_0 and D_{RF}). The absence of significant changes in v_0 suggests that soccer training alone does not promote a sufficient stimulus to increase maximal velocity capacity over the season. This could be explained because the sprints typically performed by soccer players are of short distance, may be not long enough to allow reaching and maintaining maximal velocity (1,8). Thus, although the capabilities related to high-velocity force application (v_0) remained fairly unchanged throughout the season, those related to longer application times (F_0) experienced considerable fluctuations during the competitive period. Therefore, specific training stimuli in which soccer players are able to sprint maximally should be systematically applied to increase not only the top speed but also early acceleration capabilities. In addition, it has been recently suggested that both the optimal exposure to maximal running velocity alongside with proper horizontal force production at low

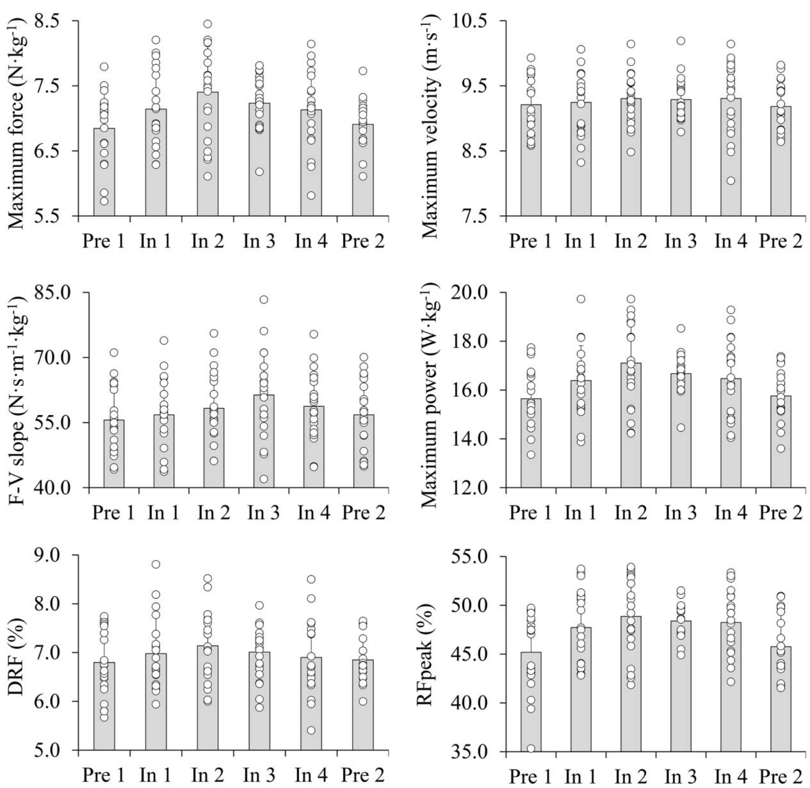

Figure 1. Magnitude of maximum force (upper-left panel), maximum velocity (upper-right panel), force-velocity slope (Fv slope; middle-left panel), maximum power (middle-right panel), decrease in the ratio of horizontal-to-resultant force (D_{RF}; lower-left panel), and maximal ratio of horizontal-to-resultant force (RF_{peak}; lower-right panel) different time points of the season. The individual values (dots), averaged across the subjects values (bars) and *SD*s (error bars), are depicted. Pre, preseason; In, in-season.

speed could play a role not only on the performance side but also on the injury prevention process (11,20).

The progressive increase of F_0 and RF_{peak} from the preseason 1 until the middle of the in-season suggests that the common actions performed during soccer training and competitions may provide a sufficient stimulus to enhance short acceleration performance (e.g., time to 10 m) and the force side of the sprint Fv spectrum. However, it is important to note that both F_0 and RF_{peak} tended to decrease toward the end of the competitive season. The decrease in F_0 is important not only from a performance perspective but also because previous studies have suggested that a decrease in F_0 could be associated with a higher risk of hamstring injury (10,20,21), which is one of the most frequent injuries in soccer players (32). Interestingly, the peak of sprint-related hamstring injuries reported in soccer players occurs at approximately the same time points as the group decrease in sprint maximal force output (F_0) reported in the current study (12). The incidence of injuries has also been reported to be higher in first division Spanish soccer players during the preseason and toward the end of the competitive season (25), which were the time points with lower F_0 in the current study. Although it remains speculative to infer a potential link between these 2 observations, it definitely supports the interest of further research in that direction (20,21). These results also suggest that coaches could aim at modifying the training stimulus during the latter part of the season to further increase, or at least maintain, the values of the Fv profile variables related to maximal acceleration capacity (F_0 and RF_{peak}). At least, individual in-season monitoring of this F_0 variable is of interest to inform about the need for a specific training "update," be it for performance maintenance or for a complete and optimal return to performance process (21).

Regarding the possible limitations and future research, it is reasonable to argue that the changes in the sprint Fv profile described in this study may not be extrapolated to other soccer teams and training contexts because all data were collected from a single team. However, the high quality of this team (competing in the first division of an elite European league [Spain]) should be regarded as a strength of this study. Thus, the decrease in F_0 and RF_{peak} observed in this study toward the end of the season may be especially important information for top soccer teams that are programming the highest level of physical performance at that specific "money time" of the season. Future studies should explore the behavior of the sprint Fv profile at different points of a season in which specific conditioning programs are applied to enhance linear sprint performance and potentially address the specific decreases in some of the Fv variables observed in this study.

Practical Applications

The 2 Fv profile variables more related to maximal acceleration capacity (F_0 and RF_{peak}) and P_{max} were sensitive to the period of the season. Specifically, F_0, P_{max}, and RF_{peak} reached their maximum values at the middle of the competitive period (in-season 2 and 3), and they were submaximal at the beginning and at the end of the season. Therefore, to avoid a deterioration of the Fv profile variables at the end of the competitive season, it is recommended that the training content is modified at the end of the season to further stimulate the maximal acceleration capacity, if necessary, on an individual basis. Note that the sprint acceleration performance assessed by the time to 10 m was also maximized at the middle part of the competitive period. On the other hand, the sprint Fv profile variables more related to maximal sprint velocity (v_0 and D_{RF}) and the Fv slope did not significantly differ between the different points of the season. This suggests that highly trained soccer players may need specific stimuli in which they are required to run at high velocities to increase the maximal running velocity capacity.

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