Team sport players individual acceleration-speed profile *in-situ*: a proof of concept in professional football.

Jean-Benoit Morin^a, Yann Le Mat^a, Cristian Osgnach^b, Alessandro Pilati^c, Pierre Samozino^d, Pietro E di Prampero^{b,e}

^a Univ Lyon, UJM-Saint-Etienne, Laboratoire Interuniversitaire de Biologie de la Motricité, EA 7424, F-42023, Saint-Etienne, France.

^b Department of Sport Science, Exelio SRL, Udine, Italy

^c Performance Department, Genoa CFC, Genova, Italy

^d Univ Savoie Mont Blanc, Laboratoire Interuniversitaire de Biologie de la Motricité, EA 7424, F-73000 Chambéry, France

^e Emeritus Professor of Physiology, University of Udine, Italy

Corresponding author:

Pr Jean-Benoit Morin, LIBM

Campus Santé Innovations – Batiment IRMIS

10 rue de la Marandière – 42270 Saint-Priest-en-Jarez, FRANCE

Email: jean.benoit.morin@univ-st-etienne.fr

Tel: 0033 477 421 875

Twitter : @jb_morin

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ABSTRACT

Assessing football players' sprint mechanical outputs is key to the performance management process (e.g. talent identification, training, monitoring, return-to-sport). This is possible using linear sprint testing to derive force-velocity-power outputs (in laboratory or field settings), but (i) testing requires specific efforts and (ii) the movement assessed is not specific to the football playing tasks. This proof-of-concept short communication presents a method to derive the players' individual acceleration-speed (AS) profile *in-situ*, i.e. from global positioning system data collected over several football sessions (without running specific tests). Briefly, raw speed data collected in 16 professional male football players over several training sessions were plotted, and for each 0.2 m/s increment in speed from 3 m/s up to the individual top-speed reached, maximal acceleration output was retained to generate a linear AS profile. Results showed highly linear AS profiles for all players (all $R^2 > 0.984$) which allowed to extrapolate the theoretical maximal speed and accelerations as the individual's sprint maximal capacities. Good reliability was observed between AS profiles determined 2 weeks apart for the players tested, and further research should focus on deepening our understanding of these methodological features. Despite the need for further explorations (e.g. comparison with conceptually close force-velocity assessments that require, isolated and not football-specific linear sprint tests), this *in-situ* approach is promising and allows direct assessment of team sport players within their specific acceleration-speed tasks. This opens several perspectives in the performance and injury prevention fields, in football and other team sports, and the possibility to "test players without testing them".

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1. Introduction

Sprinting is a key physical determinant of performance in team sports (Faude et al., 2012; Haugen et al., 2014). Thus, assessing and monitoring team sport players individual sprint acceleration- or force-velocity profile is important to improve the training and injury management process (e.g. Jiménez-Reyes et al., 2020). Gold standard methods for ground reaction force measurement during sprint acceleration require instrumented treadmills or track-embedded multiple force plate systems, which is inaccessible to most athletes. For this reason, a simple field method based on position-time data and Newtonian laws of motion applied to the athlete's center of mass has been recently presented (Morin et al., 2019; Samozino et al., 2016). Due to a good ratio between overall validity and the overall reliability and simplicity of the model inputs (i.e. mainly athlete's body mass and center of mass position or speed over time), this method has been used in both training and medical practice and research (e.g. Mendiguchia et al., 2014). However, it is based on a single linear test of acceleration effort (from null to maximal running speed) that requires preparation and organization, and that is not specific to team sports such as football or rugby. In these team sports, athletes produce large amounts of linear accelerations and sprints of various durations, and starting from various levels of initial speed, and sometimes after a change of direction. Knowing the real "*in-situ*" sprint macroscopic force-velocity profile of team sport players could be of interest to (i) assess their acceleration sport-specific capabilities based on data collected "passively" (i.e. without specific intervention) during their actual practice, (ii) potentially save some testing time and physical/mental load induced by the aforementioned sprint testing protocol and (iii) bring continuous information to sport and medical staffs about players physical fitness without requiring specific testing and the associated reluctance. Assessing athletes' physical profile and capacity directly from real practice data (i.e. not isolated, laboratory-based or non-specific testing) has been done with race and training power output data "passive" collection in cycling, based on the "power record profile" concept (Pinot and Grappe, 2015, 2011) from which the method we propose here is inspired. In team sports, beyond the power output, the force-velocity profile informs on the acceleration capacities of the players at different velocities, which can be also characterized by the acceleration-speed (AS) profile. In other words, the AS profile represents the maximal forward acceleration capability of a player (resulting from propulsive force in the direction of running, according to Newtonian laws of motion) over the range of their running velocity spectrum. Conceptually, the information provided by the *in-situ* AS profile is close to the sprint force-velocity profile explored during specific testing (linear sprint acceleration from zero to maximal running speed) (Morin et al., 2019; Samozino et al., 2016). The aim of this proof-of-concept study is to present a simple method to derive team sport players individual acceleration-speed profile from global positioning system (GPS) data collected over several training sessions.

2. Method

2.1. Participants, procedures and equipment

Sixteen male professional football players (mean $\pm$ SD age of 25.3 ± 3.8 yr; body mass 78.9 ± 4.3 kg; height 1.80 ± 0.1 m) gave their written informed consent to participate in this study. These football players were training and playing within the first team of an Italian first league professional club. Their training program during the data collection period (August 20, 2018 to September 23, 2018) included 5 football training sessions, 1 physical training gym session and 1 official football game per week. Official game data were not included in the analysis because the players did not carry their GPS units. In order to assess the reliability of

the AS profile between collection periods, data were analyzed for comparison over two 2-week phases: from August 20 to September 2 (Phase1) and from September 10 to September 23 (Phase2).

During each football training session, players were constantly monitored with the same GPS unit (GPEXE Pro2, Exelio SRL, Italy, firmware version 0.13) inserted into tightly fit vests, between the upper sides of scapula blades. Position and speed data were collected at a sampling rate of 18 Hz. The data of 13 players who completed at least 5 football training sessions (~90 min) during both Phase1 and Phase2 were retained for further analyses. This minimal amount of 5 training sessions represent a cumulative total of ~500.000 raw data points, which allowed the collection of enough raw acceleration-speed data points to cover the 0-to-maximal running speed range for each player.

Data collection for this retrospective analysis was performed within the typical training of the professional club, under usual technical and medical supervision. No specific intervention was therefore required for this study, which was performed according to Declaration of Helsinki.

2.2. Data analysis

The aim of the *in-situ* AS profile is to identify the linear relationship between a given running speed and the corresponding maximal acceleration generated in cumulated football practice data collected over a given period. More specifically, the GPS data collected over a defined time window yielded a cloud of acceleration-speed points (depending on the sampling frequency of the GPS devices used). A typical example of this scatter plot is presented in Fig. 1 (note that only positive acceleration values were displayed and retained for further analyses). This large set of raw data was first filtered with a custom Gaussian type procedure accounting for the time-averaged running acceleration. The individual AS profile was plotted based on the maximal acceleration the player could generate for every possible running speed over the measurement period, as follows. Within a running speed interval ranging between 3 m/s and the individual maximal speed, the two maximal values of acceleration performed for each 0.2 m/s subintervals (i.e. 3, 3.2, 3.4, 3.6 m/s and so on) were selected for further analysis. This 3 m/s threshold was chosen since maximal values of accelerations were rarely observed below this point (see Fig. 1), which is consistent with the fact that even at the very first steps of a standing or starting-block start, the center of mass velocity raises quickly above 3 m/s within the first step (e.g. Morin et al., 2019; Nagahara et al., 2014). A first linear regression was fitted to these speed-acceleration points (~70 data points depending on the individuals). Then, after fitting, the residuals were analyzed and outlier points were removed, in order to improve the linear regression fitting and the overall accuracy of the model variables. For each individual and phase tested, this procedure eventually provided ~50 data points (52 ± 5 , range 43-63) from which the AS profile was derived using the updated linear regression model (for description of the linear modeling of sprint force-velocity profile, see (Morin et al., 2019; Rabita et al., 2015; Samozino et al., 2016)).

Finally, three main variables were derived to characterize the players AS profile and potentially be the variables of interest for further studies: A_0 is the theoretical maximal acceleration (y-intercept of the AS linear relationship); S_0 is the theoretical maximal running speed (x-intercept of the AS relationship); AS_{slope} is the slope, i.e. overall orientation of the AS profile (computed as $AS_{\text{slope}} = -A_0/S_0$).

2.3. Statistics

All data are presented as mean $\pm$ standard deviation (SD). The quality of the linear fitting of the AS relationships was assessed with R^2 values. The inter-Phase reliability for each variable was quantified through

the change in the mean (systematic error) and the standard error of measurement (SEM, random error), both expressed in raw units and in percentage of mean values, between Phase1 and Phase2 data (Hopkins, 2000).

3. Results

All acceleration-speed individual profiles showed nearly perfect linear trends (all $R^2 > 0.984$, typical example in Fig. 1).

Figure 1. Typical example of an individual acceleration-speed profile obtained from the data of 8 training sessions spanned over 2 consecutive weeks in a professional football player. From the total >700.000 raw points, 51 points were selected (see methods) to compute the acceleration-speed linear profile. The dashed line shows the linear profile, from which theoretical maximal acceleration ($A_0 = 7.88 \text{ m/s}^2$ in this example) and speed ($S_0 = 9.19 \text{ m/s}$) were determined. Raw data below the 3 m/s speed threshold were partially masked for clarity.

The main variables computed and between-Phase reliability are presented in Table 1.

Table 1. Main variables of the individual acceleration-speed profile for the two training phases analyzed.

	Phase1	Phase2	Raw difference (Phase2 - Phase1)	Raw difference (% from Phase1)	Standard Error of Measurement (raw units)	Standard Error of Measurement (%)
S_0 (m/s)	9.21±0.43 (8.41; 9.92)	9.47±0.52 (8.68; 10.3)	0.26±0.43	2.86	0.30	3.31
A_0 (m/s²)	7.70±0.53 (6.55; 8.43)	7.20±0.40 (6.72; 7.84)	-0.50±0.59	-6.43	0.41	5.38
AS slope (1/s)	-0.839±0.086 (-0.976; -0.660)	-0.764±0.070 (-0.976; -0.660)	0.08±0.09	-9.03	0.06	7.64

4. Discussion

The main result of this study is that an almost perfectly linear acceleration-speed relationship was observed for all the professional football players, which confirms that an *in-situ* individual AS profile may be computed from football GPS data passively collected and processed as described above. The range of A_0 and S_0 show that

even in a highly trained population, who followed the same football training sessions, major inter-player differences were observed in acceleration-speed capacities.

This *in-situ* AS concept, which is easy to implement (no specific testing required, only GPS data passively collected throughout several training sessions), might lead to more specific and advanced assessment and monitoring of team sport players sprinting mechanical outputs. The potential applications are numerous, within the training, talent identification or injury management fields, as observed in recent studies using the concept of sprint acceleration force-velocity profiling (e.g. Haugen et al., 2020b; Jiménez-Reyes et al., 2018, 2020; Mendiguchia et al., 2014, 2016).

The reliability observed between Phase1 and Phase2 (random error <8%, Table 1) is very good and in line with reliability observed during standardized sprint testing (Haugen et al., 2020a; Samozino et al., 2016). Note that, unexpectedly, the systematic differences in the individual AS profile between phases 1 and 2 is not negligible. These differences require further investigations and may be partly due to the reproducibility of the method and procedures proposed, the devices used (although similar units were used by each player), but also the actual changes in maximal running acceleration and speed induced by the several weeks of football training and games that occurred between Phase1 and Phase2. Indeed, recent research has shown that sprint acceleration force and velocity outputs changed over the course of a season in professional football players (Jiménez-Reyes et al., 2020). These inter-Phase systematic differences obtained here could also have been influenced by actual changes in players AS profile and/or changes in coaching instructions and training content that may have differed (e.g. more maximal speed-oriented stimuli) between Phase1 and Phase2.

Although direct comparison with existing literature is not possible, there is a conceptual proximity between the *in-situ* AS profile presented here and the force-velocity profile obtained during single, isolated, linear sprint tests. Indeed, S_0 is the same mechanical concept as " V_0 ", and by Newtonian laws of motion, A_0 and F_0 are two expressions of the same capacity (maximal acceleration in the forward direction of motion expressed in m/s^2 or the corresponding ground reaction force antero-posterior component per unit body mass expressed in N/kg). The typical values found in this study are remarkably close to those previously reported by different research groups in professional male football players: S_0 of 9-10 m/s in the present study versus V_0 of 9.3 on average for (Jiménez-Reyes et al., 2020), 9.25 for (Jiménez-Reyes et al., 2018), or 9.2 for (Haugen et al., 2020b, 2019); A_0 of 7.2-7.7 m/s^2 in the present study versus F_0 of 7.11 N/kg on average for (Jiménez-Reyes et al., 2020), 7.35 for (Jiménez-Reyes et al., 2018), or 8.4-8.5 for (Haugen et al., 2020b, 2019).

One limitation of this work is that official game data could not be pooled with training GPS data due to different systems used, thus questioning the extent to which individual AS profiles would differ by adding official game data. In addition, it is important to note that the quality of the linear fitting used to determine the AS profile highly depends on the quality of the sampled GPS signal, which depends on environmental, hardware and software characteristics, and may influence the application of the proposed method to different contexts. This is a track for future research on the topic, that could include (i) a comparison with "classical" isolated sprint testing AS or force-velocity profile, or other types of football players' effort assessment, (ii) the changes in AS profile over a full season or before-after injury, (iii) the effects of tactical coaching choices and associated training content orientation (e.g. small-sided games, acceleration or speed-oriented training, tactical periodization), (iv) the effects of strength and conditioning blocks (e.g. do the effects of heavy resistance training on F_0 (Morin et al., 2017) transfer to football-specific A_0 ?).

More broadly, the main topic that should be addressed is the direct comparison of linear test force-velocity outcomes with those derived from the in-situ method proposed here, and the extent to which these pieces of information are interchangeable. Also, in order to narrow the time-focus down, research should clarify the minimal amount of data (i.e. training sessions and days/weeks of data collection) needed to provide reliable AS profiles. Finally, future works should test the possible use of this approach in other team sports, provided accurate individual acceleration and speed data are collected during practice.

In conclusion, keeping in mind the limitations and need for future works, the *in-situ* acceleration-speed profiling presented here allows to individually characterize the limits of team sport players acceleration and running speed capacities, in real football context (with or without ball, opponents, teammates, accelerations in different directions), from football practice GPS data: "testing the players without testing them".

Conflict of interest statement

Authors Cristian Osgnach and Pietro E di Prampero are scientific consultants for Exelio SRL, the company which provided the GPS units used in this study.

Other authors have no conflict of interest to declare.

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