ABSTRACT

Force-velocity profiling (FVP) during linear sprinting is emerging in elite soccer to assess sprint acceleration performance and mitigate hamstring muscle injury (HMI) risk. Acceleration-speed profiling (ASP) has been introduced as an FVP alternative, using GPS already employed in elite soccer for load monitoring, but interchangeability between these approaches is unclear. Profiling methods must be valid and reliable to assess FVP or ASP, helping practitioners orient training and rehabilitation, potentially mitigate injury risk, and improve sprint acceleration. This review provides a critical overview of FVP and ASP techniques, profile changes, and the potential association with HMI risk in elite soccer. FVP from linear sprint testing remains the reference for evaluating sprint performance, but ASP in-situ, using GPS data from routine play, offers an ecologically valid alternative, challenging the need for structured sprint protocols (invisible monitoring). The practical benefits of ASP in-situ allow profiling to be conducted passively, provided adequate validity and reliability is obtained. Practitioners can combine FVP and ASP to monitor sprint variables in elite soccer, including maximal horizontal force (F0), running velocity (V0), and profile orientation (FVslope). This guides adjustments in training loads and interventions to enhance performance, reduce injury incidence, and support return-to-play protocols, contributing to injury management.

**Keywords**: sprint performance; injury management; validity; reliability; soccer; GPS.

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INTRODUCTION

Sprinting is a key aspect of elite soccer performance, proving integral to positive outcomes such as goal scoring and defensive actions (34), with increased frequency in the men’s English Premier League in recent years (2). Understanding sprint mechanical variables is crucial for evaluating sprint acceleration performance (87) and assessing potential hamstring injury risk (31,57). Hamstring muscle injuries (HMIs) are the most common injuries sustained in elite soccer with an average 22% of players suffering at least one per season, and recurrence rates nearing one-third (56). Since 2001, HMI incidence has risen by 4% annually, with reinjury rates between 14% and 63% in the same playing season following initial injury, resulting in significant layoff periods (94). HMIs typically occur during non-contact or indirect contact mechanisms when sprinting, inducing high negative work demands on the posterior thigh during the late swing phase or early touch down (5). Sprinting has been identified as a key mechanism of injury, with most HMIs in elite male soccer sustained during linear acceleration efforts and high-speed upright running, and increased HMI incidence when reaching > 80% of individual maximal speed thresholds (1,102). The force-velocity profile (FVP) encapsulates the linear relationship between horizontal force and velocity obtained during human movement (91), and is used to evaluate sprint kinematics and performance in elite soccer (12,43,50). Studies have linked reductions in the force component of profiling with retrospective HMI (62,65,67) and potential prospective HMI risk (31,32,49), highlighting the importance of force-velocity profiling in both performance and injury contexts.

Traditionally, force-velocity profiling was limited to laboratory environments and relied on force platforms or instrumented treadmills which directly measured horizontal antero-posterior and vertical ground reaction force components, alongside horizontal forward velocity (74). Although highly accurate, these processes are costly, time-consuming, and in specific reference to instrumented treadmills, can alter natural sprinting technique due to loss of balance induced by incorrect setting of the constant motor torque (76). Previously, several field-based reference methods, namely those measuring displacement (i.e., timing photocells) or instantaneous velocity (i.e., radar/laser systems), as a function of time were employed for force-velocity profiling (42). More recently, the Simple Method of force-velocity profiling (91) has gained popularity, utilising an inverse dynamics approach to indirectly analyse the kinematics and kinetics of the athlete's centre of mass (COM) during linear sprinting (85). This method has been reported as an accurate, reliable, valid, and practical approach for determining sprint force-velocity profiles in field conditions, addressing the aforementioned limitations of traditional methods (75,91). Additionally, smartphone applications (MySprint), and global positioning systems (GPS), which integrate this method, are being used for force-velocity profiling due to enhanced accessibility in applied soccer settings (27,69).

Ensuring intra- and inter-tester reliability is crucial for force-velocity profiling, as potential measurement inaccuracies are magnified when determining integrative indexes including theoretical maximal horizontal force (F0), theoretical maximal running velocity (V0), maximal running velocity (Vmax), and the overall orientation of the profile (FVslope) (92), ultimately contributing to the linear relationship between horizontal force and velocity. Assessing intra-tester reliability fulfils adequate reporting of potential sources of error, and examining inter-tester reliability provides an indication as to whether different observers can determine force-velocity profiles, with both aspects essential for practitioners working in the elite soccer environment. The MySprint app (89) and GPS (23) have been concurrently validated for force-velocity profiling, using radar devices as the reference method. Whilst inter-trial reliability of force-velocity profiling has been reported as good (coefficient of variation = 0.25–6.76%, standard error of measurement = 1.4–4.94%) (91), these studies used timing photocells to derive split times and it is unclear if these were single or dual-beam. Single-beam timing photocells are subject to false triggers in determining when the body COM passes through the ‘gate’, reducing the accuracy and reliability of derived split times and subsequent sprint mechanical variables (77). Differences in instrument error across profiling techniques likely causes variation in sprint mechanical variables, and subsequently the influence of individual differences on these variations can vary with equipment type (92). Evaluating the validity and reliability ensures that athletic performance data can be relied upon and supports meaningful decision making, whilst delineating the optimal force-velocity profiling approach in different contexts could guide soccer practitioners’ implementation in applied settings (49). This would direct the orientation of training and rehabilitation programmes, indicate and mitigate potential injury risk, and improve sprint acceleration and overall soccer performance (24,32,49,56,72).

Force-velocity profiling approaches, including those integrating the Simple Method, are typically based on a single linear sprint test, with a two- or 3-point staggered stance, which requires extensive preparation including programming into the training schedule, warm-up procedure, and equipment setup. Although linear sprints transpire in soccer, this approach can fail to fully reflect soccer-specific actions which often include accelerations and curvilinear sprints occurring from different initiation positions (72). An alternative is the acceleration-speed profile, which characterises an individual's maximal forward acceleration capability over the range of their running velocity spectrum, providing conceptually similar insights to the linear sprint force-velocity profile (75,91). The relative force (N/kg) derived from the MySprint app or GPS data using the Simple Method is equivalent to the acceleration (m/s²) calculated from GPS data using the in-situ method (72). The use of GPS for acceleration-speed profiling in situ allows for contextual data collection incorporating soccer-specific actions, such as non-linear sprints from varying initial speeds, to be gathered passively during training and matches (21,22,82). Functions of the force-velocity profile elucidating injury risk could be applicable to the acceleration-speed profile, with discrepancies in relevant profiling variables and deviations from individual or squad norms potentially indicating increased HMI risk (3,24,72). Comparing force-velocity and acceleration-speed profiling could determine if they can be used interchangeably to assess sprint performance and HMI risk, shifting towards non-invasive, accessible, and efficient athlete profiling, of critical importance in elite soccer.

Aim

This review aims to provide the background, evolution, and critical overview of force-velocity and acceleration-speed profiling techniques, including examination of the validity and reliability of different profiling approaches. Sprint mechanical variables deriving from force-velocity and acceleration-speed profiling will be discussed, providing a basis for insights into changes in relevant profiles, and potential association with HMI risk. This critical insight will contribute to robust evidence-based practical recommendations, supporting the practitioner to implement complementary injury prevention and performance enhancement practices in elite soccer.

METHODS

This review followed the Scale for the quality Assessment of Narrative Review Articles (SANRA) guidelines (8). Google Scholar was used to conduct the literature search with the initial strategy focused on the following broad terms: “sprint force-velocity” OR “acceleration-speed profiling in-situ” AND “performance augmentation” OR “hamstring injury risk”. To address more specific elements of the review’s aims, additional targeted queries were used: 1) “the ‘simple method’ of sprint force-velocity profiling”; 2) “force-velocity profiling” AND “error” OR “measurement error”; 3) “MySprint app force-velocity profiling”; 4) “2D vs 3D biomechanics analysis”; 5) “validity and reliability of force-velocity profiling techniques” (“MySprint app” OR “GPS” OR “LPS”); 6) “acceleration-speed profiling in-situ” vs “force-velocity profiling” AND “ecological validity”; 7) “acceleration-speed profiling in-situ” AND “validity” OR “reliability” OR “minimum data requirement”; 8) “changes in acceleration-speed profiles in-situ” AND “demands of training” OR “match play”. The term “elite soccer” was appended to refine the results to the elite soccer environment, in line with this review’s focus. Article publication dates ranged from 1998 to March 2025. An extensive search of selected articles’ bibliographies was conducted to retrieve further relevant papers. No restrictions were placed on study design, with inclusion primarily based on relevance to this narrative review’s objectives.

Force-velocity profiles encapsulate sprint mechanics in elite soccer

Maximal acceleration performance depends on an individual's ability to generate and apply high magnitudes of horizontal force rapidly over short time intervals (i.e., impulse), with vertical ground reaction force application capabilities the predominant modulator of performance in the upright sprinting phase towards maximal velocity (70). Key physical factors including sprint speed, forward acceleration, and power output are crucial for elite soccer performance, with high-speed running actions inextricably linked to beneficial outcomes including goal-scoring scenarios and defensive actions (34). Understanding and quantifying sprint mechanical variables is essential for the evaluation of sprint acceleration performance (87). The integrative macroscopic force-velocity profile represents the linear relationship between horizontal force and velocity obtained during sprinting. The Simple Method for determining force-velocity relationships (91) analyses the kinematics and kinetics of the athlete's COM during acceleration using an inverse dynamics approach (85), modelling variables as step-averaged values over time. This biomechanical model estimates ground reaction forces in the sagittal plane during a single sprint, enabling the calculation of force and power-velocity relationships and related sprint mechanics. Figure 1 illustrates changes in force, velocity, and power during a typical 30-m sprint, with sprint mechanical outputs derived from the Simple Method (91).

**\*Insert Figure 1\***

Force-velocity profiles indirectly capture the neuromuscular behaviour of the lower limbs during sprinting, thus offering an estimated quantitative measure of an athlete's ability to generate force in the horizontal direction (32). The hamstrings significantly contribute to horizontal ground reaction force production, playing a crucial role in sprint acceleration (71). Training interventions aimed at enhancing maximal horizontal force (F0) and velocity (V0) have shown strong correlations with improved sprint acceleration performance (7). Assessing the sprint force-velocity profile facilitates the identification of individual profile imbalances, with larger disparities between horizontal force and velocity elucidated by the overall orientation of the profile (FVslope) potentially indicating higher risk of sustaining HMI, subsequently informing targeted training interventions to correct these discrepancies and enhance sprint acceleration performance (45,90). These profiling techniques provide valuable insights into the sprint capabilities of both individual athletes and entire teams, guiding training and rehabilitation, indicating potential injury risk, and augmenting sprint performance in elite soccer (32,49).

Critically analysing the Simple Method of sprint force-velocity profiling

Sprint mechanical variables derived from force-velocity profiling offer an indirect prospective representation of the behaviour of the lower limb neuromuscular system during sprint accelerations. These outputs reflect a complex integration of various mechanisms contributing to total external force production during limb extensions, influenced by segmental dynamics, morphology, neurology, and muscle mechanics, which have been assumed to follow the inverse relationship between force and velocity (14). However, the propagation of this force-velocity relationship from a single isolated muscle fibre concentric action and application to multi-joint dynamic activities (i.e., sprinting), can be questioned due to the complexity of human movement. This can be further queried as during maximal velocity sprinting the athlete generates some of the highest external forces observed over the entire sprint duration, and higher than other slower movements i.e., jumping, squatting, and walking, opposing the inverse force-velocity relationship (79). It has been debated whether theoretical maximal horizontal force (F0) and running velocity (V0) are interchangeable to adjust the slope of the force-velocity profile (FVslope), as these parameters are physiologically independent (35). However, an alternative view suggests that F0 and V0 are independently modifiable, thus modulating the overall FVslope (90). The Simple Method for force-velocity profiling (91) is based on three key assumptions:

1. The athlete's mass is assumed to be concentrated at the COM, neglecting limb motion effects on running energetics (85).
2. Vertical acceleration of the COM is considered nearly zero during the sprint acceleration phase (91).
3. Horizontal aerodynamic drag is estimated using stature, body mass, and a fixed drag coefficient.

The Simple Method for force-velocity profiling uses step-averaged values (contact and flight time) rather than support phase-averaged values (contact time), which better captures the mechanics of the overall sprint acceleration rather than just the mechanical capabilities of the lower limb neuromuscular system during each contact phase (91). This model accounts for large oscillations in instantaneous acceleration: during the flight phase, air resistance is the only horizontal force acting on the COM of the athlete, resulting in negative acceleration, whilst ground contact features negative acceleration during braking, and positive acceleration during propulsion (81). However, actual external force output when sprinting is non-linear with frequent positive-negative oscillations, whereas the model produces a smooth positive curve, and the lack of external force application during the flight phase raises questions about the use of step-averaged values due to mismatching between modelled and actual acceleration and force (25). Stature and mass significantly influence the Simple Method equations, with shorter athletes often showing higher initial horizontal force (103). This could result in misleading force-velocity profiles, suggesting imbalances that do not accurately reflect the athlete's true capabilities, potentially resulting in erroneous evaluations (90). These limitations stem from the method's indirect nature, highlighting the assumptions and estimates involved. Nonetheless, the Simple Method has advantages, particularly regarding accessibility and practical implementation, marking an evolution in sprint profiling.

The Simple Method of determining force-velocity relationships displays low coefficient of variation (CV) values for intra- and inter-individual comparisons of sprint mechanical variables (0.25 – 6.76%) (91). Profiling techniques based on this Simple Method (Radar device, MySprint app, and GPS unit) can reliably detect meaningful changes, and due to the limited variation of such techniques, any changes in sprint mechanical outputs are more likely due to intra or inter-individual differences rather than error (91). However, inherent differences in instrument error between profiling techniques will likely induce alterations in CV values between them. Studies have reported changes in sprint mechanical variables for the same athlete between repeated trials enacted on the same day and trials conducted throughout the season (49). This reiterates differences in relevant variables due to intra-individual differences or error, with the magnitude of error and the degree to which intra-individual differences contribute to variation changing between profiling techniques (92).

Evolution of profiling techniques and error consideration

Sprint performance has traditionally been evaluated using reference methods, namely those measuring time to displace a specific distance (timing photocells) or instantaneous velocity (radar/laser systems) (42). The biomechanical factors influencing sprint performance have been assessed using force platforms or instrumented treadmills, which measure horizontal antero-posterior and vertical ground reaction forces alongside horizontal velocity over the entire sprint acceleration (74). However, these methods, whilst highly accurate, can limit natural overground running (i.e., force platform targeting), are expensive, generally restricted to laboratory environments, and time-intensive, reducing widespread practical use and large mass profiling of soccer teams (76). The Simple Method offers an accurate, reliable, valid, and precise alternative for determining sprint force-velocity profiles in practical field conditions, addressing the aforementioned limitations associated with traditional methods (75,91). This approach has made force-velocity profiling more accessible, further supported by smartphone applications such as MySprint which integrate the Simple Method for practical, on-field use (69). It is important to note that sprint analyses of this type can fail to provide insight into the actual kinetic strategy employed by the athlete to achieve sprint performance and mechanical output variables. Therefore, the phase-specific information derived from these techniques may not account for the sprint acceleration performance in its entirety, potentially limiting the indication of specific sprint strategy deficits, and application of these methods for practical use.

Studies on sprint force-velocity profiling emphasise the importance of intra-tester reliability, standardisation, and familiarisation to ensure methodological rigor by addressing potential sources of error. Heterogeneity including age, sex, and playing level influence profiling outcomes, necessitating consistency in these variables across studies to enable meaningful comparisons (32). Standardising protocols, including testing surface i.e., natural grass or artificial turf (26), specific warm-up procedures (65), and consistent sprint start positions (67), improves the reliability and validity of profiling, particularly for sprint mechanical outputs derived from integrative indexes estimated from split times as measurement inaccuracies can be amplified. Critical examination and reporting of all potential sources of error distinguishes the reliability of the profiling concept, methodology, and input data. Reliability issues in vertical force-velocity profiling stem from inconsistent procedures, including mixed movement constraints, participant unfamiliarity, variable testing volumes, and inconsistent starting positions (92). Such issues, alongside biological variations, can skew input data and affect reliability, potentially leading to misinterpretations. The neuromuscular, physiological, and biomechanical factors influencing vertical force-velocity profiles in jump testing are complex, comparable to those in horizontal force-velocity profiles from sprint testing, suggesting that reliability considerations can be applied across both profiling types. Several studies herein incorporate the intraclass correlation coefficient (ICC) and the coefficient of variation (CV) which are generally interpreted as follows for the former: < 0.5 = poor; 0.5 – 0.75 = moderate; 0.75 – 0.9 = good; and > 0.90 = excellent (53), and good when < 5–10% for the latter (19).

MySprint app force-velocity profiling

Anaerobic performance testing in elite male soccer players shows that maximal sprint velocity typically peaks between 20–40-m, at speeds of 8.8–9.0 m/s (44), although these values have been reported to reach in excess of 9.5 m/s (43,49). This indicates that force-velocity profiling protocols should be conducted ~40 meters to capture maximal performance and ensure valid and reliable sprint mechanical variables. The original MySprint app was designed to determine sprint mechanical outputs and force-velocity profiles from 40-m sprints whereas the latest versions (2.0.1 and 2.5) analyse sprint mechanical outputs and force-velocity profiles based on 30-m sprints. To adapt to this, practitioners can use the MySprint app to calculate split times and then input these values into a force-velocity profile calculation spreadsheet (73), or alternatively, the 30-m sprint data can be used to generate a force-velocity profile to be extrapolated to 40-m or maximal velocity time/distance point to obtain relevant output data.

Inter-tester reliability is crucial in elite soccer due to the requirement for multiple practitioners to collect and evaluate extensive data often across multiple testing days. Studies examining the intra-tester reliability of the current MySprint app for 30-m maximal sprint tests have found good-to-excellent agreement levels (ICC = 0.862–0.984) (69), with low measurement dispersion (CV = 1.3%) indicating high test-retest reliability (97). However, differences in accounting for parallax error, such as the use of vertical marker poles at varying distances, likely influenced the accuracy of sprint split time and mechanical variable calculations across studies (95). The MySprint app's recommendation for 30-m sprint analysis is a perpendicular camera distance of 10-m from the sprint midpoint, whereas the original app suggested 18-m for 40-m sprint assessments (89). The difference in camera placement could impact the consistency and comparability of results, especially between studies that involve unrepresentative populations (97). Figure 2 details an example equipment setup to record 30-m maximal sprints, and figure 3 provides a photo sequence of the corresponding video frames used for analysis from an example sprint, using the MySprint app. This can prove useful for the practitioner as misidentification of the start, and frame in which the players hip COM is aligned with (crosses) each of the six vertical marker poles, has been reported to induce error and alter the resultant sprint mechanical variables (69).

**\*Insert figure 2\***

**\*Insert figure 3\***

The MySprint app relies on two-dimensional (2D) video analysis, limiting accuracy, validity, and reliability due to issues with data digitisation, image quality, and capture speed as lower frame rates introduce sampling errors and make it harder to identify key sprint phases (11). In contrast, three-dimensional (3D) motion capture is the ‘gold standard’, providing precise kinematic analysis across sagittal, coronal, and transverse planes (88), potentially quantifying horizontal COM velocity with extensive marker sets, though at significantly higher costs (64). Whilst 2D video analysis is more accessible, it fails to capture the full complexity of maximal sprint acceleration which involves triaxial force applications (vertical, anterior-posterior, medio-lateral), joint kinetics, kinematics, and coordination (88). Despite these limitations, 2D systems including MySprint have been used to validate and explore force-velocity profiling in relation to training interventions, performance, and injury, thereby promoting the implementation of these methods to assess sagittal plane kinematic variables during sprint acceleration in these contexts (13,65,89). Overall, methods integrating 3D or multi-planar data still offer a more comprehensive assessment of sprint mechanics and technique in elite soccer.

Validity and reliability of force-velocity profiling techniques

The relevant force-velocity profiling techniques (MySprint app and GPS) require validation against a criterion ‘reference’ device so they can be used as a cost effective and field-based method to assess athletes’ sprint acceleration performance. When determining force-velocity profiles, GPS (Catapult, Vector S7) is valid and reliable against radar devices (23), and MySprint is valid against radar devices and timing photocells (89). In the study validating the MySprint app, Pearson’s product–moment correlation coefficient (*r* = 0.974–0.999) and standard error of estimate (0.001–0.19) demonstrated validity against the radar device. ICC (0.979 – 1.000, for all sprint mechanical variables) and CV (0.14%) were used to report the excellent reliability between the force-velocity profiling techniques whilst Bland–Altman plots illustrated high inter-trial and inter-tester reliability (89). However, examining for agreement between measurement techniques using ICCs has previously been critiqued, with recommendations to instead utilise ordinary least products regression, as it detects and distinguishes between fixed and proportional bias between methods, or Bland-Altman analysis (60). Working on this premise, Bland-Altman plots have been utilised to display differences (level of agreement) in computed force-velocity profiling variables between a motorised linear encoder, laser, radar, GPS, and timing gates (39).

Force-velocity profiling deriving from single linear sprint testing informs on players’ acceleration capacities at different velocities but lacks adequate competitive stimuli, which stimulate maximal sprint performance during match play (22). Additionally, straight-line sprints can fail to represent soccer-specific sprinting actions, which are rarely linear due to the relationship between external stimuli and perception-action (P-A) coupling (22). P-A coupling refers to the constant exchange of information between the environment and the selected movement responses. Affordances, defined as potential opportunities for action, underpin the relationship between decision making and the action performed and are mediated by the task nature, individual characteristics, and the performance environment, with this interplay determining the type of sprinting occurring (36). Competitive stimuli are particularly relevant to elite soccer players who often possess enhanced competitiveness, thus insinuating its importance as a trait to target when seeking maximal performance in sprinting tasks (36).

Critically analysing GPS force-velocity profiling (maximal sprint testing protocols)

GPS units can often be unreliable due to "noise" in data, especially at high speeds (93), and may lack accuracy and sensitivity in capturing acceleration at low speeds (< 2 m/s) and between different units (18). Consistent use of the same GPS unit by individuals during testing can help reduce inter-unit variation. Force-velocity profiles derived from GPS data rely on linear fitting, which is affected by signal quality that varies due to environmental factors (e.g., weather, stadium conditions), hardware specifics (e.g., sampling rate and positioning type), and analysis software features (61). GPS reliability is time and task-dependent, with short high-intensity activities, such as maximal acceleration or high-velocity runs, proving the least reliable (6). However, these studies focused on units sampling at 1–5 Hz, indicating that higher sampling rates (≥ 10 Hz) significantly improve measurement reliability.

Despite drawbacks, studies have compared GPS against radar for assessing force-velocity profiles from isolated linear sprint tests. An early study found that GPS from Gpsports (SPI proX–5Hz) yielded inaccurate sprint mechanical variables during maximal sprint accelerations (percentage error −5.1–2.9%, typical error 5.1-19.2%), advising against its use for force-velocity profiling (78). In contrast, recent findings indicate that 10Hz GPS units from STATSports (Apex V3.0) and Catapult (Vector S7) achieve moderate-to-good accuracy (< 2% bias, ICC: 0.84 – 0.99) compared to a radar gun when measuring sprint mechanical variables derived from 40 and 50-m maximal sprints (23,27). Contrariety may stem from differing GPS sampling rates: the earlier study used 5Hz and 20Hz units (78), whilst the more recent used 10Hz (23,27), demonstrating improved accuracy with higher sampling rates (≥ 10Hz). Excluding 5Hz data, both studies show moderate-to-good validity and reliability, supporting GPS as a valid and reliable force-velocity profiling tool when assessing maximal linear sprints (23,39,55). Whilst the validity, reliability, and accuracy of GPS devices tends to improve with increasing sampling rates, there are potential trade-offs above 10Hz, where further increases may only yield negligible benefits and could introduce additional error in certain contexts (30).

Local positioning systems (LPS), while not commonly used in elite soccer, have been evaluated for their suitability in sprint force-velocity profiling alongside the more widely adopted GPS systems. One such study compared 20 Hz LPS (Kinexon Precision Technologies, Munich, Germany) with 10 Hz (MinimaxX S4, Catapult Innovations, Melbourne, Australia) and 18 Hz (GPEXE Pro, Exelio SRL, Udine, Italy) GPS devices in the measurement of sprint mechanical variables in youth basketball (47). Validity was determined using typical error of estimate: 20Hz LPS (Vmax = 2.1% and F0 = 9.2%), 18Hz GPS (Vmax = 4.5% and F0 = 14.3%), and 10Hz GPS (Vmax = 4.1% and F0 = 23.1%). Reliability was calculated using CV: 20Hz LPS (Vmax = 1.6% and F0 = 7.3%), 18Hz GPS (Vmax = 3.1% and F0 = 7.5%), and 10Hz GPS (Vmax = 3.3% and F0 = 20.9%). Overall, the LPS demonstrated superior validity and reliability (lowest error/CV), but both the 20Hz LPS and 18Hz GPS exhibited a higher incidence of measurement outliers compared to the 10Hz GPS, likely due to increased sampling rates inducing error, potentially limiting their practical application. The testing protocol employed a circuit (walking, jumping, jogging, and sprinting in straight lines or with changes of direction), contrasting with previous studies investigating GPS force-velocity profiling which typically utilise isolated maximal straight-line sprint efforts over fixed distances of 30–40-m (23,27,55), likely altering sprint mechanical variables alongside validity and reliability measures between studies.

GPS acceleration-speed profiling in-situ

The recent integration of GPS (72) and light detection and ranging (LiDAR) technology, such as Sportlight® (Oxford, UK), has broadened the options for acceleration-speed profiling and athlete tracking (9,99). Root mean square error was used to validate the Sportlight® system’s measurement of velocity and acceleration during soccer-specific tasks, displaying low values for velocity (0.08 – 0.12 m/s) but slightly higher values for acceleration (0.36 – 0.6 m/s2) (9). Therefore, root mean square error can be applied to predict the accuracy and subsequent validity of acceleration-speed profiling models. While force-velocity and acceleration-speed profiling techniques may appear to yield comparable sprint mechanical outputs, subtle differences in underlying calculations should be acknowledged to ensure methodological rigor and standardisation (92). The acceleration-speed profile represents an athlete’s maximal forward acceleration capability across their running velocity spectrum, meaning conceptually, the information provided by the acceleration-speed profile closely represents the linear sprint force-velocity profile (75,91).

Acceleration-speed profiling in-situ vs force-velocity profiling

Recent studies report good levels of agreement between GPS force-velocity (F0 and V0) and acceleration-speed (A0 and S0) profiling techniques in the measurement of F0 or A0 (ICC = 0.48 – 0.90), and V0 or S0 (ICC = 0.80 – 0.97) deriving from 40-m maximal sprint testing protocols (29). The acceleration-speed profiles derived using the Tukey boxplot outlier removal technique demonstrated good agreement with isolated maximal sprint test metrics (percentage mean difference -0.98–2.17%, typical error 0.14–0.17%). This study involved elite female soccer players, meaning results may not translate to elite male players, in concordance with previous work elucidating the differences in force-velocity and acceleration-speed profiling variables between sexes (3,29,43), highlighting that further research amongst the elite male soccer player demographic may be required. The same variables were consistent between 30-m maximal sprint testing and in-situ monitoring of a 45-minute training session: F0 or A0 (strong correlation, r = 0.65), and V0 or S0 (strong correlation, r = 0.56), further reporting no significant difference in Vmax and S0 with low absolute bias, but variation in F0 and A0 with moderate absolute bias (systematic error 0.17–0.68, random error 0.846–1.081) (52).

However, some of these correlation effects are relatively low when concerning the level of agreement between force-velocity and acceleration-speed profiling techniques i.e., r = 0.48–0.65, while ICC has been reported unsuitable to establish agreement, with other statistical tests including Lin’s Concordance Correlation Coefficient or Ordinary least products regression test recommended (60). Also, soccer-specific context was limited, as training data does not fully represent match conditions, with a more recent study suggesting larger-sided games in training better reflect match demands (24). Another study compared maximal sprint testing GPS data against the acceleration-speed profiles in situ computed from cumulated GPS data of five training sessions and a match, demonstrating high levels of agreement in sprint mechanical variables (bias -0.299–0.190, relative systematic error −4.52 ± 7.95%) (3). Despite limitations, these results suggest that acceleration-speed profiles generated in-situ during training and competitive games are comparable to force-velocity profiles from isolated linear sprint tests thus challenging the need for time-consuming testing protocols, and marking the beginning of an era where relevant profiles can be passively collected from GPS data during routine training and competitive play (68,72)

Linear sprint testing renders a controlled and standardised measure of an athletes sprint mechanical capabilities, with previous research reporting that 40-m sprint testing could provide a better indication of ‘maximal’ performance as players elicited higher peak velocities than during competitive games and various sided-games during training sessions (GPS data collected in-situ) (54). The most important aspect to consider when applying isolated sprint testing is that it should be implemented with intent and incorporate elements of competition to stimulate maximal effort, performance, and resultant sprint mechanical variables (36). For example, instant feedback from GPS units using the ‘live monitoring’ functions now widely available can be integrated to create leaderboards and communicated directly to the athletes being tested. Comparability facilitates inter and intra-athlete comparisons using force-velocity and acceleration-speed profiling interchangeably (3). This is further supported by fundamental biomechanical principles (Equations 1 and 2) which demonstrate how relative force (N/kg) derived from maximal sprint testing (calculated using the Simple Method (91), is equivalent to acceleration (m/s2) derived from the in-situ data (calculated using the ‘in-situ method’ (72).

**Equation 1**:

**Equation 2**:

Where (N = kg x m/s2) becomes (m/s2 = N/kg).

Ecological validity of acceleration-speed profiling in-situ

Acceleration-speed profiling in situ deriving from more contextual soccer-specific data, can be passively collected during play using GPS units or the Sportlight® system (Oxford, UK) (72). Recording both linear and curved sprints ensures this method closely reflects soccer-specific actions (21). Curved and linear sprints have been classified as distinct motor tasks, perhaps requiring independent assessment with testing methodologies incorporating both isolated and in-situ profiling techniques (37). In professional soccer, ~30% of game-related actions involve movement in arced, backward, lateral, and diagonal directions, with ~85% of maximum-velocity actions being curvilinear sprints, highlighting non-linear sprint ability as crucial for performance (38). Although this type of profiling integrates sprints of many varieties, distinguishing between types of acceleration can be difficult, as sprints of this type involve horizontal, resultant, tangential, and centripetal acceleration components specific to their unique kinetic and kinematic demands (37).

Around 98% of maximal acceleration efforts in competitive games start from low to moderate velocities (≤ 4.17 m/s), making acceleration-speed profiling in situ more reflective of soccer-specific actions than force-velocity profiling from standstill (101). However, possible GPS reliability issues may hinder its use, as these problems are exacerbated by the cut-off speeds (high-intensity accelerations at < 3 m/s (18,93)), non-linear nature (84), and maximal acceleration or high-velocity running involved in this profiling technique (6). See the ‘Critically analysing GPS profiling techniques’ section for extensive evaluation of inherent GPS reliability concerns alongside further explanation of contextual factors which contribute to altered sprint mechanical variables and subsequent force-velocity or acceleration-speed profiles. Enhancing ecological validity by incorporating more contextual data may increase variability in sprint mechanical variables between training and competition. This reiterates the question of the minimum amount of in-situ data required for valid and reliable acceleration-speed profiles.

Critically analysing GPS acceleration-speed profiling in-situ

The original individual acceleration-speed profile in-situ concept (72) relies on several weeks of cumulated training data, incorporating methodological prerequisites including an adequate spread of raw points across the speed and acceleration spectrum, and consistent linear regression (24). Whilst the exact minimum amount of data needed for reliable in-situ profiling is unknown, recent observations point to > 45-90 minutes of game data (72) or 5 to 9 days of tracking data (3,28), highlighting discrepancies in minimum monitoring duration proposed between different studies. One study reported ~45 minutes in-situ data was insufficient to determine A0 but provided reliable insight for S0 (52). However, this study utilised 18Hz GPS, contrary to the 10Hz units commonly used by elite clubs, potentially limiting the application in this environment. The minimum amount of GPS data required and associated ‘saturation point’ to determine a reliable acceleration-speed profile in-situ is beyond 160 minutes of playing time (4 x 40-minute game halves worth of data), which can be spread over more than two matches if needed (63). However, acceleration-speed profiles in-situ are known to fluctuate between different competitive games (68), with training sessions often displaying sub-maximal values unless specific sprint drills are incorporated into sessions (24), potentially altering the minimum bout duration and overall playing time required to reach this ‘saturation point’. 160 minutes playing time corresponded to a substantial loss of significance (*p* > 0.98) highlighting the threshold beyond which adding new game time data did not result in significant changes to the values of A0 and S0, alongside demonstrating lower values of intra-individual variation (1.52 and 1.20% for A0 and S0, respectively) (63). Despite pivotal findings, none of these studies included elite male soccer players, likely preventing generalisability to this population.

Reliability of the acceleration-speed profile in-situ is most dependent upon spread of data points i.e., 20-95% of maximum speed included, and is improved when a high percentage of maximum speed i.e., ≥ 95%, is reached (24). The use of different acceleration-speed profiling in-situ techniques between sessions i.e., GPS from different manufacturers or other technology such as Second Spectrum®, could alter the spread of acceleration-speed points, and the percentage of maximum speed reached (> 95%) due to inherent methodological and measurement differences, potentially altering profiles between training and competition. Defining the minimum amount of GPS data required for valid and reliable acceleration-speed profiling in-situ could streamline data collection, making the method more accessible to coaches and practitioners. The primary advantages of using GPS units for acceleration-speed profiling in-situ are that elite clubs already possess the equipment, staff members are familiar with relevant technology, and moving towards non-invasive, accessible, and efficient athlete monitoring aligns with the demands of the elite sport environment. Though GPS reliability concerns persist, they are perhaps outweighed by the accessibility and practical benefits.

Relevant sprint mechanical output variables

Force-velocity profiling methods provide a multitude of sprint mechanical output variables, but the focus will be on the following: F0 (N/kg), V0 (m/s), Vmax (m/s), and FVslope (see Table 1), as these are the primary contributors to horizontal force production capacity and best encapsulate the overall horizontal force-velocity profile (75), proving highly relevant in both performance and injury contexts (32,49,56). Acceleration-speed profiling methods provide several sprint mechanical output variables (i.e., A0 (m/s2) and S0 (m/s) (see Table 2)), which correspond to the force-velocity profiling variables of F0 (N/kg) and V0 (m/s), respectively. Equations 1 and 2 detail how the variables obtained from different profiling techniques are equivalent and can be standardised thus enabling comparison of relevant data between force-velocity and acceleration-speed profiling methods (52,75,91). This is of particular importance when examining for potential differences in sprint mechanical output variables between training and games, or any situation where different profiling techniques (force-velocity and acceleration-speed) might be utilised interchangeably to provide relevant data. Tables 2 and 3 provide definitions, practical interpretation, and normative values for the main variables associated with force-velocity and acceleration-speed profiling in sprinting, outlined in this section.

**\*Insert table 1\***

**\*Insert table 2\***

GPS acceleration-speed profiling in-situ methodology

Individual GPS units continuously record during team training sessions and games, generating raw speed-time data. Linear interpolation is used to provide ‘missing’ speed data points based on the 10 Hz GPS data already assembled. Raw speed data is smoothed using signal filtering algorithms which incorporate ‘missing data’ from the GPS output, similar to ‘low-pass’ filtering techniques utilised in other acceleration-speed profiling studies (24,72). Acceleration values at each point are calculated as the rate of change of the filtered speed, according to acceleration being defined as the change in velocity over a given change in time. Maximal speed-acceleration values are derived from the five maximal values of acceleration performed for each 0.2 m/s speed subinterval (3 m/s to maximal speed). A 3 m/s threshold is used as maximal values of acceleration are rarely observed below this point, consistent with the notion that at the very first steps of a standing start the COM velocity raises quickly above 3 m/s within the first step (75). Two maximal acceleration values at each speed subinterval can be used for analysis (24,72), whereas a larger number of values could provide more valid insight into the acceleration values observed at each speed throughout the spectrum. A linear regression line is fitted to these points and residuals analysed, with outlier points removed, yielding an accurate regression line to delineate the individual acceleration-speed profile in-situ from which several main variables are derived: A0 (theoretical maximal acceleration in m/s2) and S0 (theoretical maximal running speed in m/s), as intercepts of the y-axis and the x-axis, respectively, and the ASslope (overall orientation of the A-S profile), computed as - A0 / S0.

Figure 4 presents an acceleration-speed profile for a typical elite soccer player, derived from the original in-situ method (72). This profile illustrates the athlete’s maximal forward acceleration capability over the range of their running velocity spectrum, generated from cumulated soccer practice data collected over a given time. Due to GPS inaccuracies in capturing high-intensity accelerations at low speeds, alongside data filtering and smoothing, a “blank area” appears on the profile, less populated with raw data points, as marked with a red outline in figure 4. This warrants caution as the highest acceleration values enacted at the start of the sprint and during initial acceleration are not incorporated completely into the computations, meaning the method relies more heavily on linear fitting to estimate these values, potentially inducing variation in subsequent sprint mechanical output variables.

**\*Insert figure 4\***

Changes in profiles between training and competitive games

Potential contributing factors

Considering potential drawbacks, it is valuable to examine for differences in the acceleration-speed profile in-situ between training sessions and competitive games (match-day, MD) to understand variations in sprint mechanical variables and resultant profiles. Previous work typically used the training session 4 days before match-day (MD-4), as this session often elicits the highest training load demands with metrics closely aligning to MD values (96). Running metrics vary between training and competition, with position-specific tactical demands and formation changes significantly impacting acceleration, deceleration, and high-intensity running requirements during matches (10). Training often lacks adequate competitive stimuli which act to maximise sprinting performance, potentially explaining divergence in running metrics between training and competitive games (22). Factors including weekly schedule, training mode, competition level, tactical formations, and individual playing style modulate training and match loads (100). Soccer-specific fatigue is moderated by these factors, impairing maximal force production and velocity capabilities during matches (80). All these elements could alter the spread of acceleration-speed points, and the maximum speed reached (> 95%), potentially changing profiles between training and competition (24).

Acceleration-speed profile within training and competitive games

Longitudinal observations of elite soccer players' acceleration-speed profiles revealed variations in sprint mechanical variables across training days and playing positions (4). Match-day (MD) was the most demanding for acceleration-speed profiling, consistent with prior research on workload (83). However, these findings are context-specific and should not be generalised to other elite teams, as physical demands influence profiling variables (100). A study on individual acceleration-speed profiling in-situ found that key variables (A0 and S0) remained stable regardless of match data inclusion in GPS acceleration-speed data, though the use of a friendly match limits ecological validity (24). Seasonal variations in acceleration-speed profiles have been observed, with A0 showing more sensitivity to change than S0, concomitant with seasonal trends in force-velocity profiles (59). This research has limitations regarding the sample demographic as men’s Russian Premier League teams are understudied questioning generalisability, and the shortened COVID-19 season possibly omitting late-season profile variations previously reported to occur in force-velocity profiles (49). Only one study has compared acceleration-speed profiles in-situ between training and competitive games, finding higher A0 values in games and peak S0 values in both games and training sessions incorporating specific sprint drills (68). This study, the first to examine acceleration-speed profile differences in professional rugby players, highlights the need for similar research in elite soccer. Understanding profile imbalances between training and competitive games could guide targeted training interventions to reduce injury risk and enhance performance (4,58,68).

Hamstring injuries and profiling in elite soccer

Risk factors and propagation

Numerous potential risk factors, including sprinting kinematics, contribute to hamstring strain injury (HSI), a primary mechanism of hamstring muscle injuries (HMI) (40). In professional soccer, HMIs typically occur during non-contact or indirect contact, such as sprinting or lunging, which involve rapid, negative work requirements during the late swing phase or early touch down (5). High-speed running actions account for approximately 70% of HMIs in elite soccer (34). The eccentric brake-driven model suggests hamstrings decelerate knee extension and increase tolerance to high loads during the late-swing sprint phase of sprinting, which makes them vulnerable to injury as the muscle-tendon unit (MTU) lengthens (46). Hamstring MTU function in sprinting involves complex interactions between musculoskeletal kinematics and kinetics, muscle activation patterns, neuromechanical regulation of tensions and stiffness, and loads applied by the environment (51). Sprint mechanics directly influence HSI risk through kinematic and kinetic factors that regulate strain magnitude thus contributing to HMI risk (15). Hamstrings may experience high strain due to anterior pelvic tilt in the initial sprint steps, inducing greater hip flexion angles, resulting in longer biceps femoris muscle-tendon lengths and faster lengthening velocities, contributing to increased HSI occurrence during acceleration efforts (5,41). Research on kinematic parameters links anterior pelvic tilt and forward trunk lean, with HSI risk (66), subsequently contributing to HMI development.

Profiling and retrospective HMI risk

Upon return to play after HMI, players have demonstrated decreased F0 (horizontal force production) with no change in V0 (maximal sprinting velocity), resulting in impaired acceleration capability, potentially undermining overall sprint performance (65). One study observed improvements in horizontal force production and acceleration two months post-return to play (67), whilst another reported lower horizontal force after injury (62). These findings should be interpreted cautiously as the first study only included two participants (one male professional soccer player), and used a 50-m maximal sprint protocol, limiting comparability with other studies that typically use 30 or 40-m sprint protocols (32,49,56,89). The other studies used semi-professional players, reducing the applicability of findings to elite soccer players, as sprint mechanical variables vary by practice level (43,50). Research into seasonal changes in force-velocity profiles among elite male soccer players has revealed significant fluctuations in F0, V0, and FVslope across the season, with reductions in F0 (more than V0) noted towards the end of the competitive season (49). Similar alterations in acceleration-speed profiles have been observed throughout the season, with A0 showing more sensitivity to change than S0 (59). This indicates an impairment of the hamstring muscles to efficiently manage force production which could exacerbate the imbalance between horizontal force and velocity, modifying the tolerance of and mechanisms by which speed is developed and maintained during sprinting, thus contributing to increased HMI risk (32). However, the timing of force-velocity profiling within each general “testing time-point” was not specified, leaving intra-period variation unexamined, and force-velocity or acceleration-speed profiling only analysed data from a single team respectively, potentially limiting generalisability.

Profiling and prospective HMI risk

Few studies have quantified prospective HMI risk alongside fluctuations in sprint mechanical variables from force-velocity profiling, due to the multifactorial nature of HMI (56). One study found that a 1 N.kg drop in F0 increased general HMI risk by 2.67 times (32), whilst another reported that players displaying F0 reductions between screenings had 2.78 times higher odds of sustaining general HMI (exact mechanisms of HMI not available for either study) (31). The number of measurements and testing execution was different throughout the season depending on the teams and players sampled which limits the application of conclusions. Furthermore, sprint acceleration was assessed only in linear sprinting, though HMI can arise from varied actions like direction changes, tackling, or overstretching (34). This simple approach does not assess specific muscle contributions to acceleration, omits sprint technique, and overlooks other risk factors such as neuromuscular inhibition and altered lumbo-pelvic control (66), positioning it as a sprint-specific component within a broader injury risk assessment. Also, previous HMI timing was not considered, despite it being known to mitigate horizontal force production and re-injury rates (65). The Sprint Mechanics Assessment Score (S-MAS) has emerged as a tool for evaluating HMI risk by assessing sprint mechanics through 12 kinematic parameters to derive an overall sprint movement quality score and holistic measure of sprint mechanics (17). This tool integrates factors reported to be most closely associated with HMI using anecdotal evidence from practitioners and quantitative research, providing a comprehensive sprint mechanics overview, although valid and reliable assessment likely requires extensive training and expertise in biomechanics. A recent prospective cohort study integrated this technique, recruiting 126 professional male soccer players from the English soccer league, reporting a 33% increase in the risk of a new HSI with every one-point increase in S-MAS (16).

The extent to which isolated hamstring exercises replicate hamstring function during sprinting remains under debate. Frequently used hamstring strengthening exercises including the Nordic hamstring exercise, explosive lying kick, and upright hip extension exhibit lower levels of muscle activation compared to sprinting (98). However, it should be noted that the purpose of these exercises is to strengthen the muscle tissue (i.e., material strength), induce structural changes, and improve force production, all of which can contribute to reduced injury risk (15). Nordic hamstring exercises target HMI risk factors, substantially increasing eccentric strength and muscle fascicle length, thus supporting their implementation as part of a holistic HMI prevention strategy (48). In contrast, maximal sprinting elicits higher hamstring muscle activation (86), improving eccentric strength and promoting favourable changes in muscle architecture, highlighting the importance of incorporating task-specific maximal sprinting activity into HMI management programs (33). This is reinforced by a systematically lower incidence of match hamstring injuries in elite soccer when > 95% maximal sprint speed exposures were programmed into training but warrants caution as overexposure can act to increase HMI risk (20). By routinely incorporating force-velocity profiling within a comprehensive hamstring injury management framework, practitioners can address challenges including long-term compliance (56).

Monitoring players’ force-velocity and acceleration-speed profiles is vital for injury prevention and tailored return-to-play protocols (24,72). Discrepancies in profiling variables relative to individual or team norms may also signal elevated injury risk (31). Prospective HMI risk can be ‘flagged’ by plotting player’s acceleration-speed profile variables (A0 and S0) in relation to individual or squad averages for relevant metrics, dividing the resultant scatter plot into four ‘risk quadrants’. Deviation from individual or squad averages and larger imbalances between these metrics could indicate higher HMI risk. The conditioning status of the team should be cited when using squad averages to determine plot axes, as it can significantly influence sprint mechanical variables (A0/S0) and potentially lead to misleading risk levels. For instance, if the squad is poorly conditioned due to inadequate training prescription, a player may appear at ‘low risk' relative to the group but still face a higher HMI risk when assessed against arbitrary thresholds. However, the lack of established risk thresholds linking changes in sprint mechanical outputs to HMI occurrence underscores the urgent need for further research in this area (31,32). Figure 5 provides a simplified example of this quadrant chart, showing how different plot areas could correspond to varying levels of prospective HMI risk.

**\*Insert figure 5\***

## CONCLUSION

Force-velocity and acceleration-speed profiling are essential tools for assessing sprint mechanics, optimising training, and managing hamstring injury risk in elite soccer. Force-velocity profiling remains an option to evaluate sprint performance but can be limited by practical testing implementation challenges and may lack ecological validity. Alternatively, GPS-based acceleration-speed profiling in-situ offers a contextualised assessment of sprint mechanics incorporating soccer-specific actions, addressing the complexities of curvilinear sprints and more closely representing the diverse movements players engage in during play. However, the degree to which profiling in-situ represents ‘maximal’ performance is unclear with isolated linear sprint testing often eliciting superior acceleration and velocity values. Working on this premise, both profiling types require adequate acknowledgement of relevant limitations, to provide the most valid and reliable profiling technique which can be implemented to assess and monitor elite soccer players’ individual force-velocity or acceleration-speed profiles. This will allow practitioners to orient training and rehabilitation programmes, indicate and mitigate injury risk, and improve sprint acceleration and overall soccer performance.

Recent research suggests that acceleration-speed profiles generated in-situ during play are comparable to force-velocity profiles derived from isolated linear sprint tests (3,29,52), potentially questioning the need for isolated sprint testing protocols. The accessibility and practical benefits of acceleration-speed profiling in-situ designates the beginning of an era where profiling can be conducted passively, using GPS data collected during routine play. Plotting players’ acceleration-speed profiling in-situ metrics relative to individual or squad norms on a quadrant-based scatter plot can aid visualisation of imbalances in profiling variables. The practitioner can then ‘flag’ players potentially at heightened risk of sustaining a hamstring injury, facilitating tailored training interventions targeting individual weaknesses in sprint mechanics to mitigate associated injury risk. These methodologies contribute to a more comprehensive profiling approach, aligning with the growing emphasis on preventative individualised injury management practices. Due to the lack of research base regarding acceleration-speed profiling in-situ, a combination of both force-velocity and acceleration-speed profiling is currently recommended to support injury prevention and performance enhancement practices in elite soccer. Future research should focus on acceleration-speed profiling in-situ in elite soccer, assessing the validity and reliability of different profiling techniques, indicating the minimum amount of data required for valid and reliable profile determination, determining potential hamstring injury risk based on changes in profiles, and evaluating the efficacy of hamstring injury risk reduction protocols to alter injury risk. Although difficult in the elite soccer environment these studies should seek to address inherent GPS reliability concerns whilst incorporating larger, more representative samples and longitudinal assessments, to corroborate and contrast the studies discussed in this review.

PRACTICAL APPLICATIONS

* **Force-velocity vs. acceleration-speed profiling in-situ**: The force-velocity profile can be similarly characterised by the acceleration-speed profile meaning conceptually, the information provided by the acceleration-speed profile closely represents the linear sprint force-velocity profile. The primary benefits of using GPS data for acceleration-speed profiling in-situ surround enhanced ecological validity and non-invasive monitoring during routine play, improving the accessibility of this approach compared to isolated linear sprint testing protocols, especially in the elite soccer environment. Therefore, the practitioner could use these different profiling approaches interchangeably, provided that adequate validity and reliability analyses are conducted, as research concerning the validity and reliability of the acceleration-speed profiling in-situ method is currently limited.
* **Profiling Implications**: By integrating longitudinal force-velocity and acceleration-speed profiling approaches, the practitioner can track changes in relevant sprint mechanical variables, for example, throughout the competitive season. Specific and individualised training programmes can be prescribed to address any sprint mechanical deficits, to ultimately improve sprint and overall soccer performance. Potential hamstring muscle injury risk can be indicated by monitoring discrepancies in players’ sprint metrics relative to individual or squad norms. This enables proactive adjustments in training loads and targeted interventions to reduce the likelihood of injury, alongside effective, context-specific return-to-play protocols, contributing to more comprehensive injury management.

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Author contributions

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Conflicts of interest

N/A.

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SUPPLEMENTAL DIGITAL CONTENT

SDC 1.mov

FIGURE LEGEND

Figure 1: Changes in horizontal force, velocity, and power output over a 30m maximal sprint for a typical subject (using sprint acceleration force-velocity-power profiling spreadsheet (73)).

Figure 2: 30-m maximal sprint testing protocol equipment setup. Arrows at finish denote direction players should be instructed to return to the start – passing behind the camera to avoid confounding.

Figure 3: Example photo sequence of frame selection used for MySprint app analysis

Figure 4: Individual acceleration-speed profile in-situ obtained from the data of 8 training sessions over 2 consecutive weeks in a professional soccer player. Theoretical maximal acceleration (A0 = 7.88 m/s2) and speed (S0 = 9.19 m/s). Data below the 3 m/s threshold were shaded. Red outline denotes the ‘blank area’ less populated with raw data points, corresponding to high intensity accelerations at low speeds (Adapted from (72)).

Figure 5: Acceleration-speed profiling in-situ quadrant chart with highlighted risk areas or ‘flags’. Axis crossover determined by individual or squad averages. Area of ‘high HMI risk’ based on previous research investigating the association between reduced F0/A0 and increased V0/S0 with hamstring injury incidence (31,32).

TABLE LEGEND

Table 1: Definition, practical interpretation, and normative values of the main variables when using force-velocity profiling in sprinting.

Table 2: Definition, practical interpretation, and normative values of the main variables when using acceleration-speed profiling in-situ. Acceleration-speed variables vary due to contextual (cumulated vs isolated and training vs match data etc.) and technical factors (specific GPS unit worn etc.), thus warranting caution when comparing the range of values reported between studies.

**Figure 1.**

A diagram of a phone tripod

Description automatically generated

**Figure 2.**

**A screenshot of a video

Description automatically generatedA screenshot of a video game

Description automatically generatedA screenshot of a video game

Description automatically generated**

**Figure 3.**

A graph of a graph

Description automatically generated with medium confidence

**Figure 4.**

A yellow and red squares with black text

Description automatically generated

**Figure 5.**

**Table 1.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Definition** | **Interpretation** | **Normative Values (**Elite male soccer players**)** |
| F0 (N/kg) | Theoretical maximal horizontal force production (per unit body mass) | Maximal force output in the horizontal direction corresponding to initial push-off. Higher value = higher sprint specific horizontal force production. | **6.63 – 9.0 N/kg**  (3,43,50) |
| V0 (m/s) | Theoretical maximal running velocity | Maximal sprint-running velocity the athlete would reach if mechanical resistances against movement are null. Also represents capability to produce horizontal force at very high running velocities. | **8.64 – 10.33 m/s**  (3,43,50) |
| Vmax (m/s) | Maximal running velocity | Maximal running velocity in the horizontal direction during sprinting. | **8.66 – 9.83 m/s**  (3,12) |
| FVslope | Overall orientation of the FV profile  Computed as: FVslope = - F0 / V0 | Provides an understanding of the relationship between F0 and V0 over the entire sprint acceleration distance. | **-0.92 0.07**  (43) |

**Table 2.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Definition** | **Interpretation** | **Normative Values (**Elite male and female soccer players**)** |
| A0 (m/s2) | Theoretical maximal acceleration | Maximal sprint-acceleration capacity. Higher value = higher sprint specific acceleration. Equivalent to F0 (N/kg). | **5.14 – 9.22 m/s2**  (4,24,59,72) |
| S0 (m/s) | Theoretical maximal running speed | Maximal sprint-running speed the athlete would reach if mechanical resistances against movement are null. Also represents capability to produce horizontal force at very high running velocities. Equivalent to V0 (m/s). | **6.23 – 12.09 m/s**  (4,24,59,72) |
| ASslope | Overall orientation of the AS profile  Computed as: ASslope = - A0 / S0 | Provides an understanding of the relationship between A0 and S0 over the entire sprint acceleration distance. | N/A |