Maximal locomotor function in elite football: protocols and metrics for acceleration, speed, deceleration, and change of direction using a motorized resistance device

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Locomotor Performance | Acceleration | Sprinting | Deceleration | Change of Direction (COD) | 15-0-5 Test | 1080 Sprint | Elite Football | Performance Testing | Reliability Analysis | Athlete Monitoring | 1080 Football Protocol

Headline

In elite football, assessing physical capacities such as sprinting speed, acceleration, deceleration, and change of direction (COD) is crucial for optimizing player performance and health (Asimakidis 2024). More precisely, this testing is believed to be important to profile individual player strengths and weaknesses, benchmark performances, and establish baseline values for injury recovery and rehabilitation. This testing is essential for tracking progress and refining training interventions. It also supports the calibration of GPS-based analyses (i.e., relative speed thresholds) by providing accurate benchmarks for maximal sprint speeds, accelerations, and decelerations, which are crucial for optimizing both between- and within-player analyses of training and game demands. Moreover, it plays a key role in injury mitigation, ensuring players meet the necessary speed and deceleration demands during training, particularly when approaching 90–95% of their individual maximal capacities (Buchheit 2024b, Della Villa 2020, Harper 2024, Rekik 2023).

Various technologies are available to measure player performance during these specific tests. Motorized resistance devices, such as the 1080 Sprint, provide continuous measurements throughout the entire performance spectrum (i.e. sprint, change of direction), and are now considered the optimal choice due to their superior precision and reliability (Eriksrud 2022 & 2024, Westheim 2023). In contrast, relying solely on timing systems or GPS offers limited accuracy (Buchheit 2014, Roe 2016).

Aim

This study aims to introduce and validate a comprehensive testing protocol, using the 1080 Sprint, to evaluate critical physical capacities in elite football players. The tests include a 40-m straight-line sprint and the 15-0-5 COD test (Buchheit 2024c), which we believe are critical for assessing sprinting, acceleration, deceleration, and COD capacities in elite football players. The objective is then to identify metrics that offer the most distinct insights into various physical qualities and are easy to use in football (soccer). In addition, these tests will provide metrics that are familiar and practical for coaches and practitioners in field settings.

The rationale for test selection

The rationale for these tests is based on both extensive research and practical feedback from elite football practitioners, highlighting their relevance to player performance and injury prevention. A user survey conducted among 1080 Sprint users in elite football underscored the importance of these two tests in evaluating player performance (Buchheit 2024a). Additionally, Asimakidis et al. (2024) reinforced this through a survey of 102 elite football practitioners, further validating the critical role of maximal speed and COD assessments in performance analysis.

Locomotor demands in football necessitate accurate assessments of sprinting capacity, particularly maximal sprint speed (MSS) (Buchheit 2024b, Gómez-Piqueras 2024). Buchheit (2012) emphasized that efforts $\geq$ 40 meters are likely necessary for football players to reach their true MSS, which provides essential data for performance training, injury prevention strategies (Buchheit 2021, 2023, Colby 2018, Gómez-Piqueras 2024), and performance analysis, including GPS calibration (Gómez-Piqueras 2024). Regarding injury risk, Della Villa et al. (2020) highlighted the strong association between ACL injuries and deceleration, making the assessment of deceleration and COD crucial. The 15-0-5 test, in particular, offers a practical way to evaluate deceleration from high running speeds, making it valuable for injury prevention. In fact, Buchheit et al. (2024c) demonstrated that the 15-0-5 test closely mirrors the peak speed demands of football pressing actions during match play. Players achieved average peak speeds of 25-26 $km \cdot h^{-1}$, validating the 15-0-5 as an effective tool for both screening and training. The test also captures deceleration demands, simulating the critical speed and agility movements observed in gameplay (Silva 2025). This makes the 15-0-5 a robust test for assessing the complex physical demands of football.

Methodology

While previous studies have examined the reliability of some metrics in common COD tests like the 15-0-5 (Eriksrud 2022 & 2024, Westheim 2023), not all metrics have been fully analyzed—particularly the specific metrics that are most relevant to football. The novelty of the present study lies in assessing the reliability of these specific metrics, which are widely used in football, such as acceleration (m·s^{-2}), deceleration (m·s^{-2}), and time to reach 25 km/h—key thresholds employed in GPS-based training and match analyses (Gualtieri 2023). Data were captured at 333 Hz and filtered using a 1.3Hz Butterworth 4th order filter before calculating the outcome metrics described below. These metrics were then examined using correlation analysis to distinguish unique variables from those that overlap, followed by a reliability analysis to assess consistency across trials. Additionally, we compared the 15-0-5 test with other COD tests like the m5-0-5 and 10-0-5 to provide further insight into the variability of deceleration and reacceleration demands, building a comprehensive protocol that reflects real-world football requirements.

Subjects

Data from the Westheim (2023) study were re-analyzed for the present study. A total of 16 male (age, 23.0 ± 3.7 years; body mass, 77.3 ± 6.8 kg; height, 179.9 ± 3.7 cm) and five female participants (age, 20.0 ± 0.0 years; body mass, 68.6 ± 3.7 kg; height, 171.4 ± 9.5 cm) with experience in soccer (n = 8), handball (n = 8), and floorball (n = 5) completed the study. Nineteen of the 21 participants completed all four test sessions, whereas one male and one female participant completed only two and three test sessions, respectively (due to the COVID-19 pandemic). Inclusion criteria were familiarity with ball sports COD movements and no musculoskeletal injury or illness at the time of testing that would prevent maximum effort for all test sessions. This study was approved by the Local Ethical Committee and the National Data Protection Agency for Research (reference number: 148213) and conducted following the Declaration of Helsinki. Before participation, all participants provided written informed consent after being given detailed verbal and written explanations of the purpose, procedures, and risks associated with their participation.

Protocols

The performance assessments were conducted using the 1080 Sprint (1080 Motion AB, Lindingoe, Sweden), focusing on two primary families of tests: a 40-meter straight-line sprint and a series of COD tests (m5-0-5, 10-0-5, and 15-0-5, Link to VIDEO) (Eriksrud 2022 & 2024, Westheim 2023). The goal was to evaluate key metrics related to sprinting, acceleration, deceleration, and COD while balancing the depth of data collection with practical applicability. Simpler, more intuitive metrics were prioritized unless complexity added necessary value.

1. 40-m straight-line sprint

In this test, athletes were instructed to sprint 40 meters at maximum effort from a stationary start. The 1080 setup used 3 kg resistance during the test, though we recommend 5% of body weight for more accurate comparisons between subjects. While 3 kg provides good measurement stability—equivalent to 5% of body mass for a 60 kg subject—it may not be ideal for larger athletes, which is a limitation of the present study; resistance setting No Flying Weight (NFW), resisted speed 14 m·s^{-1}, assisted speed 2 m·s^{-1} using the auto distance function (measurement starts at a speed trigger of 0.2 ·s^{-1} and ends at a set distance. Metrics analyzed include (Figure 1b):

- **Time (s)**: The total time to complete the 40-m sprint.
- **Top Speed (m·s^{-1})**: The highest speed reached during the sprint.
- **0-5 m Time (s)**: Time to cover the first 5 meters to quantify early acceleration.
- **Tau Acceleration (s)**: Time to reach 63% of maximum speed. A relative acceleration measurement used in modeling of linear sprint performance.
- **Time to 25.2 km·h^{-1} (s)**: Time required to reach a common (GPS) football sprint threshold speed.
- **Max Acceleration (m·s^{-2})**: 0.5-s time interval with the greatest average acceleration.

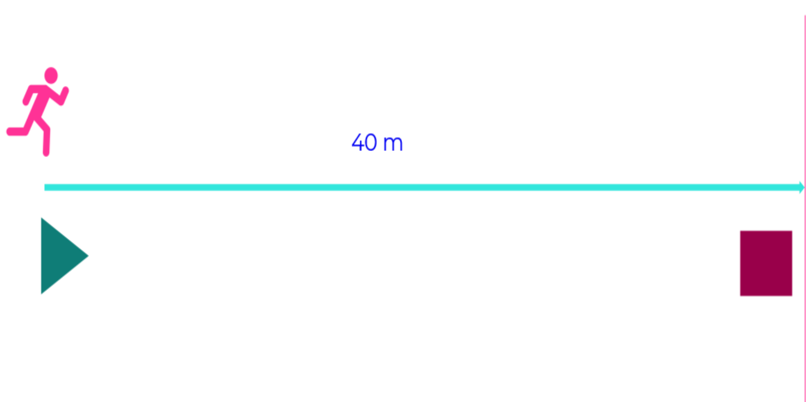

Fig. 1a. Set up for the 40-m sprint.

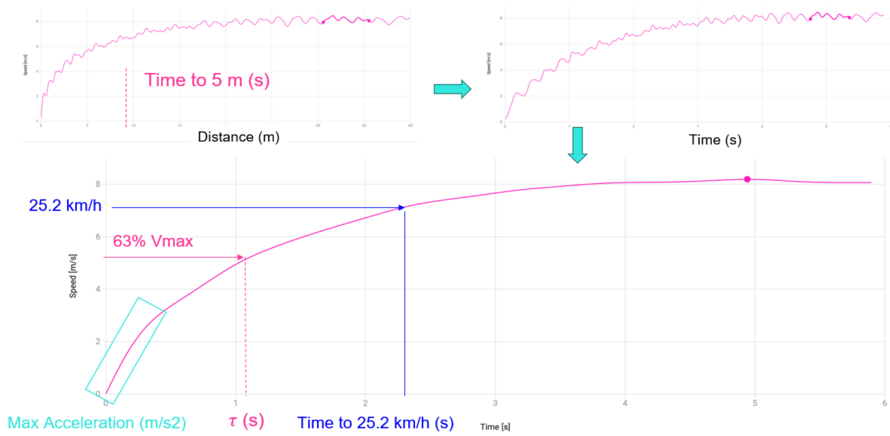

Fig. 1b. Key metrics obtained during the 40-meter sprint test.

2. Change of Direction (COD) Tests

Three COD tests were conducted: m5-0-5, 10-0-5, and 15-0-5. Specifically, cones were placed at the starting point (5, 10, and 15 m) with another cone at the turning line. Then the subjects were instructed to complete the test as fast as possible from the starting line back to the cones at the 5-m mark with a 180-degree turn at the turning line. An assisted start was used, which is where the athlete first sprints toward the machine (assisted sprint) before turning around and sprinting back (resisted sprint) to the 5 m mark. A valid trial was full effort, turning foot hitting the 15 cm turning line, and full sprint past the 5 m cones (Figure 2a). The settings for 1080 Sprint were as follows: assisted and resisted load: 5% BW, resistance setting: No Flying Weight (NFW), assisted and resisted speed:14 m·s^{-1}.

Metrics analyzed include (Figure 2b) :

- **Total Time (s)**: Time to complete the COD test.
- **0-5 m Time (s)**: Time to complete the first 5 meters of the sprint (only calculated for the 10 and 15-0-5 tests).
- **Top Speed 1a (m·s^{-1})**: The highest speed reached during phase 1a.
- **Tau Acceleration 1a (s)**: Time to reach 63% of Top Speed during phase 1a.
- **Max Acceleration 1a (m·s^{-2})**: 0.5s time interval with the greatest average acceleration during phase 1b
- **Deceleration Time (s)**: Time spent from Top Speed to COD
- **Tau Deceleration 1a (s)**: Time from 63% of Top Speed to COD.
- **Max Deceleration (m·s^{-2})**: 0.5-s time interval with the greatest average deceleration during phase 1a.
- **Max Acceleration 1b (m·s^{-2})**: 0.5-s time interval with the greatest average acceleration during phase 1b.

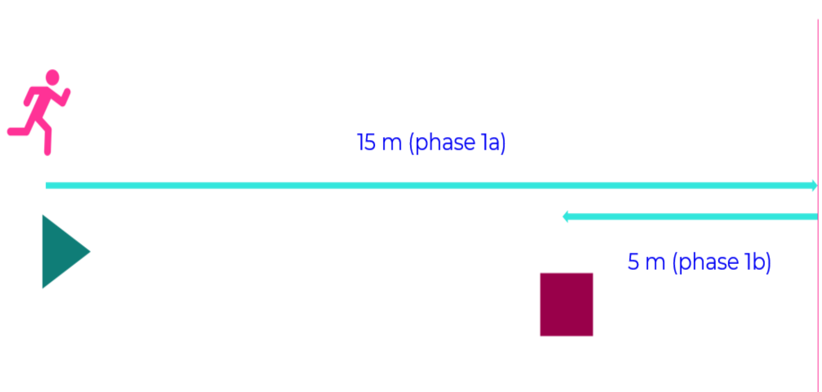

Fig. 2a. Set up for the 15-0-5 COD test (the setup is similar for the m5-0-5 and 10-0-5 tests, with the running distance before the COD set to 5 and 10 meters, respectively).

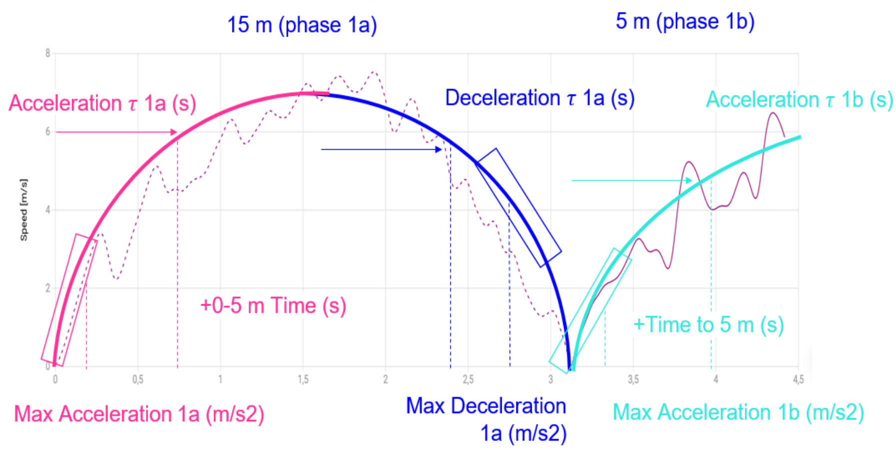

Fig. 2b. Key metrics obtained during changes of direction (COD) tests - example here for the 15-0-5.

Metric selection rationale and explanation of terms

When assessing player performance using the 1080 Sprint, it is essential to strike a balance between data richness (Westheim 2023) and practical application. The principle of Occam's razor suggests that simpler metrics are preferable unless added complexity brings significant insights. Below is a detailed rationale for each of the metrics included in this analysis, along with their respective pros and cons. Note also that Top Speed refers to the highest speed reached during a specific exercise. It is the maximum speed observed during the test, though not necessarily the absolute maximum capacity of the player. For a non-loaded 40-meter sprint, Top Speed likely represents MSS, which is the player's true maximal sprinting capacity (Buchheit 2012).

Table 1. Rationale, pros, and cons for the main metrics analyzed. * for COD tests only.

Metric	Definition	Pros	Cons
Total Time (s)	Time taken to complete the entire 40-m run or the COD tests (5-0-5, 10-0-5, or 15-0-5).	Simple and comprehensive, which combines acceleration, deceleration, and re-acceleration for COD tests.	Lacks specificity, especially in COD tests, as it does not break down the different phases (acceleration, deceleration, re-acceleration).
Top Speed ($m \cdot s^{-1}$)	The highest speed reached during a specific test.	Simple and commonly used across disciplines. The 40-meter sprint likely captures MSS while this may depend on the load when using the 1080 Sprint.	If resistance/load is used, there will be a bias or shift when compared to other technologies (Fornasier-Santos 2022).
0-5 m Time (s)	Time taken to reach 5 meters from a stationary start.	A simple and intuitive measure of initial acceleration.	Provide a limited view of the entire acceleration as it only captures the early phase of the sprint.
Max Acceleration ($m \cdot s^{-2}$)	0.5-s interval with the greatest average acceleration.	Familiar to users of GPS-based systems.	Dependent on measurement window (time). A short and long time window yields higher and smaller values respectively. Comparisons between methods may be difficult.
Time to 25.2 $km \cdot h^{-1}$ (s)	Time to reach a sprint speed of 25.2 $km \cdot h^{-1}$ (7 $m \cdot s^{-1}$), commonly used in football for training and game-speed analysis.	Relevant to football-specific sprint thresholds observed during practice and competition.	Arbitrary threshold, which may represent $70-85\%$ of players' MSS.

Tau (s) Acceleration	Time required to reach 63% of maximum speed.	An overall measure of acceleration. Commonly used in sprint profile calculations.	Relative measure that is dependent on Top Speed. Not an absolute acceleration measure.
Max Deceleration ($m \cdot s^{-2}$)	0.5-s interval with the greatest average deceleration.*	Critical for assessing deceleration and subphases of COD.	As with acceleration dependent on the measurement window (time), potentially complicating comparisons between different methods.
Deceleration Time (s)	Time from Top Speed to COD.*	Simple and comprehensive	This may reflect the athlete's general approach to braking rather than their maximal deceleration capacity
Tau (s) Deceleration	Time from 63% of Top Speed to COD.*	Measure of deceleration that targets the later portions of the deceleration phase.	Relative measure that is dependent on the Top Speed. Not an absolute deceleration measure

Statistical Analyses

All analyses were performed with a specifically designed spreadsheet (Hopkins 2015). Correlation analyses were performed using Pearson correlation coefficients with 95% confidence intervals. The strength of associations was evaluated using Hopkins' scale as follows: trivial (0.00-0.09), small (0.10-0.29), moderate (0.30-0.49), large (0.50-0.69), very large (0.70-0.89), nearly perfect (0.90-0.99), and perfect (1.00) (Hopkins 2009).

Then, relative reliability for all metrics was explored using an Intraclass Correlation Coefficient (ICC) with 95% confidence intervals. The magnitude of the ICC was assessed using the following thresholds: > 0.99, extremely high; 0.99–0.90, very high; 0.90–0.75, high; 0.75–0.50, moderate; 0.50–0.20, low; < 0.20, very low (Hopkins 2009). As measures of absolute reliability, we calculated the typical error of measurement (TE, in the unit of the metric), which was then expressed as a coefficient of variation (%). To better understand the TE's magnitude, we standardized it using Cohen's "d" effect size principles, with magnitudes rated according to Hopkins' scale: trivial (0.00-0.19), small (0.20-0.49), moderate (0.50-0.79), large (0.80-1.19), and very large (>1.20) (Hopkins 2009).

Finally, to assess the usefulness of each test, we compared the TE with thresholds of small (SWC) and moderate (MWC) worthwhile changes or differences (based on 0.2 and 0.6 of between-player SD). When the TE was smaller than these magnitude thresholds, the test metric was rated as "good" to assess changes/differences of that given magnitude. If the TE was similar to these thresholds, the test metric was rated as "okay." If the TE exceeded these thresholds, the test metric was rated as "poor," indicating that only larger changes/differences would be detectable (Hopkins 2004).

Results

Within-test correlation analysis

In the linear 40-m sprint test, variables like Top Speed and Time to 25.2 $km \cdot h^{-1}$ were highly correlated (r = -0.90), indicating that they measure similar sprinting capacities (Figures 3 and 5). On the other hand, variables such as Max Accel were less correlated with the Top Speed metric, suggesting that they capture unique aspects of the sprinting ability, particularly the athlete's acceleration and short-distance performance.

In the 15-0-5 test (focusing on right turns for simplicity), several variables exhibited at least large correlations, indicating redundancy. For example, variables related to deceleration, such as Deceleration Time (Figures 4 and 5) and Max Decel, were very largely correlated with each other (r = -0.77). These variables likely capture similar aspects of the athlete's ability to decelerate during direction changes. However, Max Decel had only a large correlation with Top Speed (r = -0.68); correlations were trivial to small with other variables, suggesting that it captures a unique aspect of the locomotor function, that may not be represented by other metrics (Figures 4 and 5). Interestingly too, Max Accel during the second phase (1b) was not much correlated with metrics during the first phase (1a) such as Max Accel (r = -0.11) or Max Decel metrics (r = 0.30) (Figure 5).

Similarities Between the 15-0-5 and Linear Sprint Tests

When comparing the 15-0-5 test and the linear sprint test, we observed that Top Speed in the linear sprint test (Figures 4 and 5) was very largely correlated with Top Speed during phase 1a of the 15-0-5 test (r = 0.90), indicating that both tests measure similar aspects of speed, though in different contexts (linear versus directional). However, the deceleration metrics in the 1505 test did not correlate largely with any of the linear sprint metrics, suggesting that deceleration is a unique skill set not captured by linear sprint tests.

Reliability analysis

Reliability of the 40-m sprint

Reliability statistics for the 40-m sprint are provided in Table 2. The two variables with the best level of reliability were Time and Top speed, with very high ICCs $\geq$0.98 and trivial TEs of 1.2%. Since these TEs were both lower than the SWC of these variables, the usefulness of detecting small changes/differences was rated as "Good" (Table 2).

The magnitude of the TE of all acceleration measures was small, with a tendency for the Time to 25.2 $km \cdot h^{-1}$ (CV 6.3%, Standardized TE of 0.25) to be slightly better than that of the 0-5 m (3.3%, 0.38), Tau Accel (5.4%, 0.45) and Max Accel (10.3%, 0.47). The usefulness of the four metrics was good in detecting moderate changes/differences (MWC) (Table 1).

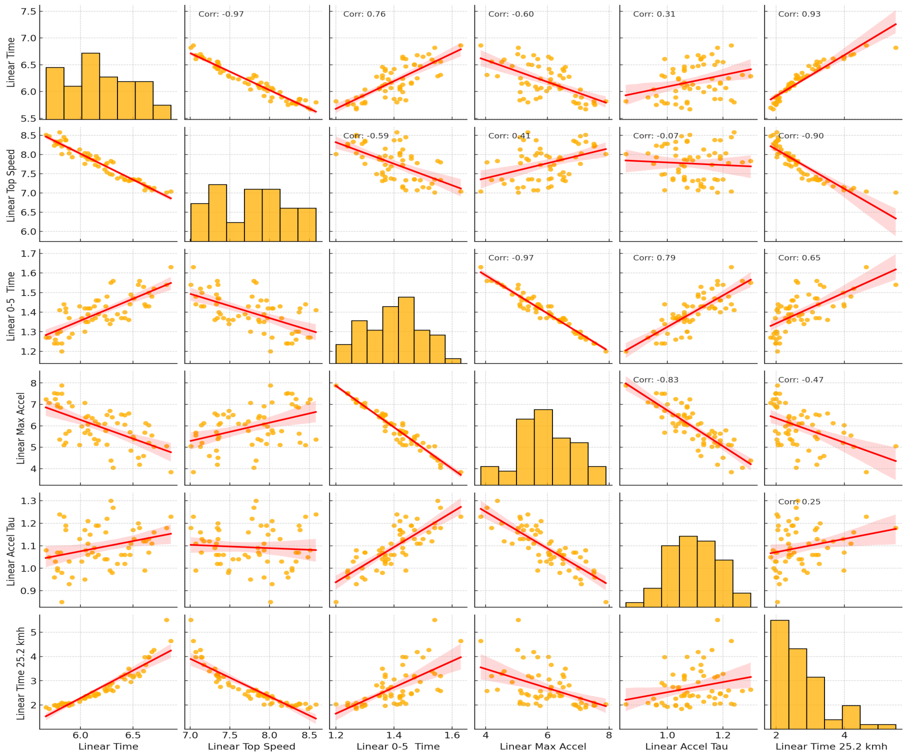

Fig. 3. Pairwise plot matrix with all the metrics collected during the 40-m sprint.

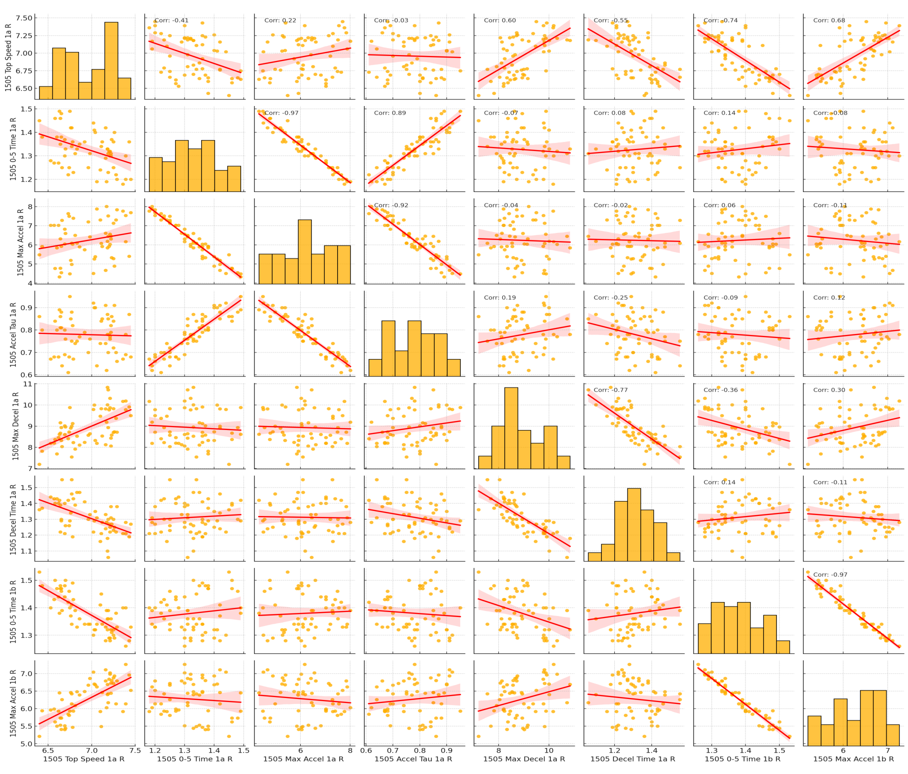

Fig. 4. Pairwise plot matrix for selected metrics collected during the 15-0-5 test (data limited to right turns for clarity).

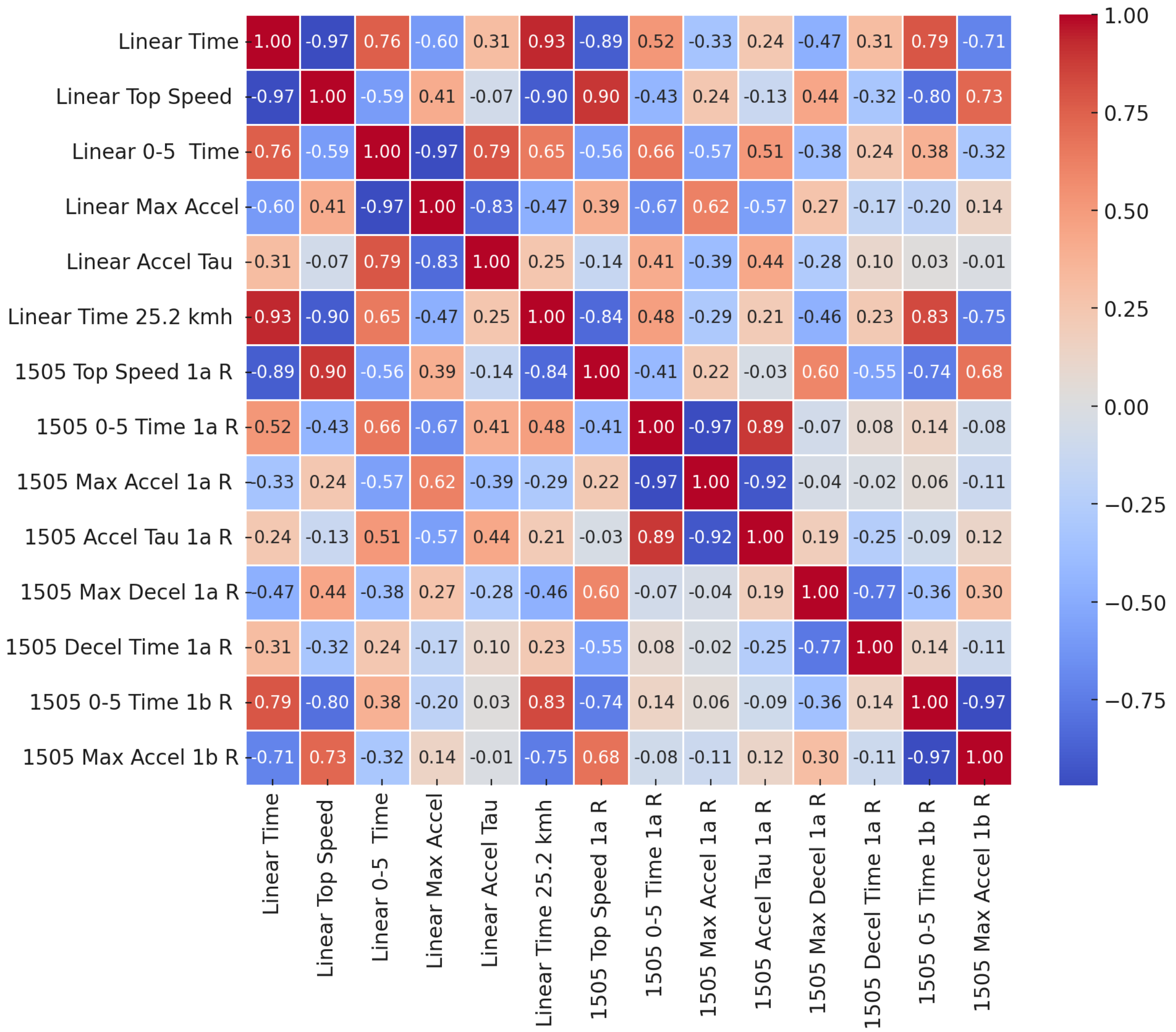

Fig. 5. Correlation matrix heatmap that includes both the metrics from the linear sprint metrics and the right-turn 15-0-5 test metrics. The heatmap provides a comprehensive view of the correlations between these variables, with color coding to indicate the strength and direction of the correlations.

Reliability of the m5-0-5

The reliability of all metrics during the m5-0-5 are shown in Tables 3a and 3b for right and left turns, respectively. Overall, most of the ICC were at least high (0.90–0.75), except for a few variables for which it was only moderate (e.g., Top Speed 1a, Tau Accel 1b). The magnitude of the TEs was small to moderate for all metrics, and the usefulness of all the metrics was good in detecting moderate changes/differences (MWC) (Tables 3a and 3b). The variables with the best reliability were Total Time, Phase 1b time, and Top Speed 1b, with very high ICC and small Standardized TE of 0.25-0.29.

When looking specifically at specific groups of measures, Max Accel tented to be slightly more reliable than Tau Accel (small Standardized TEs of 0.37 vs 0.42, when turning on both sides). The tendency for Max Accel to be more reliable than Tau Accel was more pronounced for phase 1b (i.e., small vs moderate Standardized TEs). Similar results were obtained for deceleration metrics, with Max Decel being more reliable than Tau Decel (i.e., small vs moderate Standardized TEs). Max Decel was also more reliable than Decel Time (Standardized TE: 0.49-0.54). Despite different CVs between Max Accel and Max Decel metrics (e.g., Max Accel 1a: 9% vs. Max Decel: 3-4%), the Standardized TEs were all small and highly similar (0.37 vs. 0.30-0.43).

Table 2. Test-retest reliability of 40-m sprint performance metrics of four test sessions.

	Outcome	ICC (95% CI)	CV (95% CI)	TE (95% CI)	Standardized TE	SWC	MWC
Time (s)	6,47±0,63	0.98 (0.97; 0.99)	1.2 (1.0; 1.5)	0.07 (0.06; 0.09)	0.12 (0.10; 0.16)	0.13 (0.10; 0.18)	0.38 (0.10; 0.18)
Top Speed ($m{\cdot}s^{-1}$)	7,43±0,79	0.99 (0.98; 1.00)	1.2 (1.0; 1.5)	0.09 (0.07; 0.11)	0.10 (0.09; 0.13)	0.16 (0.12; 0.23)	0.48 (0.36; 0.69)
0-5 m (s)	1.44±0.12	0.87 (0.76; 0.94)	3.3 (2.8; 4.3)	0.05 (0.04; 0.06)	0.38 (0.32; 0.49)	0.03 (0.02; 0.04)	0.08 (0.06; 0.11)
Max Accel ($m{\cdot}s^{-2}$)	5.70±1.08	0.78 (0.61; 0.90)	10.3 (8.4; 13.4)	0.54 (0.44; 0.68)	0.47 (0.39; 0.60)	0.22 (0.17; 0.32)	0.66 (0.50; 0.96)
Tau (s) Accel	1.08±0.12	0.82 (0.67; 0.91)	5.4 (4.5; 7.0)	0.06 (0.05; 0.07)	0.45 (0.37; 0.57)	0.02 (0.02; 0.04)	0.07 (0.06; 0.11)
Time to 25.2 $km{\cdot}h^{-1}$ (s)	2.67±0.68	0.93 (0.85; 0.97)	6.3 (5.1; 8.6)	0.20 (0.16; 0.26)	0.25 (0.20; 0.34)	0.14 (0.10; 0.22)	0.42 (0.31; 0.66)

Definition and description of all outcome variables are presented in Table 1. ICC Intra-class correlation coefficient; CI Confidence interval; CV coefficient of variation; TE typical error; SWC smallest worthwhile change; MDC moderate worthwhile change; Tau acceleration time constant/time to 63% of top speed; Max Accel 0.5-s interval with the greatest average acceleration; Green: very high ICC and trivial Standardized TE; Yellow: high ICC and small Standardized TE; Blue: magnitude of clear change/difference.

Table 3a. Test-retest reliability of m5-0-5 performance outcome measurements of four test sessions with a left turn

	Outcome	ICC (95% CI)	CV (95% CI)	TE (95% CI)	Standardized TE (95% CI)	SWC	MWC
Total Time (s)	3.04±0.22	0.92 (0.85; 0.97)	2.1 (1.8; 2.7)	0.06 (0.05; 0.08)	0.29 (0.24; 0.38)	0.04 (0.03; 0.06)	0.13 (0.10; 0.19)
Time 1a (s)	1.69±0.13	0.86 (0.74; 0.94)	3.1 (2.6; 4.0)	0.05 (0.04; 0.07)	0.39 (0.32; 0.50)	0.03 (0.02; 0.04)	0.08 (0.06; 0.12)
Top Speed 1a ($m{\cdot}s^{-1}$)	4.38±0.34	0.61 (0.38; 0.80)	4.2 (3.5; 5.5)	0.21 (0.18; 0.27)	0.61 (0.50; 0.78)	0.07 (0.05; 0.10)	0.20 (0.15; 0.29)
Tau Accel 1a (s)	0.43±0.12	0.85 (0.72; 0.93)	12.8 (10.5; 16.8)	0.05 (0.04; 0.06)	0.42 (0.35; 0.54)	0.02 (0.02; 0.04)	0.07 (0.06; 0.11)
Max Accel 1a ($m{\cdot}s^{-2}$)	6.28±1.36	0.87 (0.75; 0.94)	9.0 (7.4; 11.8)	0.52 (0.43; 0.66)	0.37 (0.31; 0.48)	0.27 (0.21; 0.40)	0.82 (0.62; 1.19)
Decel Time (s)	0.74±0.09	0.74 (0.55; 0.88)	6.6 (5.4; 8.6)	0.05 (0.04; 0.06)	0.54 (0.45; 0.70)	0.02 (0.01; 0.02)	0.05 (0.04; 0.07)
Tau Decel 1a (s)	0.28±0.05	0.75 (0.56; 0.88)	9.6 (7.9; 12.5)	0.03 (0.02; 0.03)	0.56 (0.46; 0.72)	0.01 (0.01; 0.01)	0.03 (0.02; 0.04)
Max Decel ($m{\cdot}s^{-2}$)	7.95±0.80	0.87 (0.75; 0.94)	4.1 (3.4; 5.3)	0.31 (0.25; 0.39)	0.43 (0.36; 0.55)	0.16 (0.12; 0.23)	0.48 (0.37; 0.70)
Phase 1b Time (s)	1.35±0.11	0.93 (0.87; 0.97)	2.2 (1.8; 2.8)	0.03 (0.02; 0.04)	0.28 (0.23; 0.36)	0.02 (0.02; 0.03)	0.06 (0.05; 0.09)
Top Speed 1b ($m.s^{-1}$)	4.70±0.26	0.94 (0.89; 0.97)	1.4 (1.2; 1.8)	0.06 (0.05; 0.08)	0.25 (0.21; 0.32)	0.05 (0.04; 0.07)	0.15 (0.12; 0.22)
Tau Accel 1b (s)	0.47±0.06	0.52 (0.27; 0.75)	9.1 (7.5; 11.99	0.04 (0.03; 0.05)	0.72 (0.60; 0.92)	0.01 (0.01; 0.02)	0.03 (0.03; 0.05)
Max Accel 1b ($m{\cdot}s^{-2}$)	6.21±0.66	0.87 (0.75; 0.94)	4.4 (3.6; 5.7)	0.25 (0.21; 0.32)	0.39 (0.32; 0.50)	0.13 (0.10; 0.19)	0.40 (0.30; 0.58)

Definition and description of all outcome variables are presented in Table 1. ICC Intra-class correlation coefficient; CI Confidence interval; CV coefficient of variation; TE typical error; SWC smallest worthwhile change; MDC moderate worthwhile change; Tau acceleration time constant/time to 63% of top speed; Max Accel 0.5-s interval with the greatest average acceleration; Max Decel 0.5-s interval with the greatest average deceleration; Green: very high ICC and trivial Standardized TE; Yellow: high ICC and small Standardized TE; Orange: moderate ICC and moderate Standardized TE; Blue: magnitude of clear change/difference.

Table 3b. Test-retest reliability of m5-0-5 performance outcome measurements of four test sessions with a left turn

	Outcome	ICC (95% CI)	CV (95% CI)	TE (95% CI)	Standardized TE (95% CI)	SWC	MWC
Total Time (s)	3.04±0.22	0.92 (0.85; 0.97)	2.1 (1.8; 2.7)	0.06 (0.05; 0.08)	0.30 (0.25; 0.38)	0.04 (0.03; 0.06)	0.13 (0.10; 0.19)
Time 1a (s)	1.67±0.13	0.89 (0.79; 0.95)	2.9 (2.4; 3.8)	0.05 (0.04; 0.06)	0.36 (0.30; 0.46)	0.03 (0.02; 0.04)	0.08 (0.06; 0.12)
Top Speed 1a ($m.s^{-1}$)	4.46±0.22	0.91 (0.82; 0.96)	1.6 (1.3; 2.0)	0.07 (0.06; 0.09)	0.32 (0.26; 0.41)	0.04 (0.03; 0.06)	0.13 (0.10; 0.19)
Tau Accel 1a (s)	0.43±0.12	0.87 (0.75; 0.94)	12.6 (10.3; 16.5)	0.05 (0.04; 0.06)	0.41 (0.34; 0.53)	0.02 (0.02; 0.03)	0.07 (0.05; 0.10)
Max Accel 1a ($m.s^{-2}$)	6.35±1.29	0.88 (0.77; 0.95)	8.6 (7.1; 11.1)	0.47 (0.39; 0.60)	0.37 (0.31; 0.48)	0.26 (0.20; 0.38)	0.77 (0.59; 1.13)
Decel Time (s)	0.73±0.08	0.79 (0.63;0.90)	5.9 (4.9; 7.6)	0.04 (0.03; 0.05)	0.49 (80.40; 0.53)	0.02 (0.01; 0.02)	0.05 (0.04; 0.07)
Tau Decel 1a (s)	0.27±0.04	0.67 (0.45; 0.83)	8.2 (6.7; 10.6)	0.02 (0.02; 0.03)	0.60 (0.50; 0.77)	0.01 (0.01; 0.01)	0.02 (0.02; 0.03)
Max Decel ($m.s^{-2}$)	8.10±0.76	0.92 (0.84; 0.96)	2.8 (2.3; 3.7)	0.23 (0.19; 0.29)	0.30 (0.25; 0.38)	0.15 (0.11; 0.22)	0.45 (0.34; 0.66)
Phase 1b Time (s)	1.36±0.11	0.92 (0.85; 0.97)	2.3 (1.9; 3.0)	0.03 (0.03; 0.04)	0.28 (0.24; 0.37)	0.02 (0.02; 0.03)	0.07 (0.05; 0.10)
Top Speed 1b ($m.s^{-1}$)	4.69±0.27	0.93 (0.87; 0.97)	1.7 (1.4; 2.1)	0.08 (0.06; 0.10)	0.27 (0.23; 0.35)	0.05 (0.04; 0.08)	0.16 (0.12; 0.24)
Tau Accel 1b (s)	0.47±0.05	0.67 (0.45; 0.84)	6.8 (5.6; 8.8)	0.03 (0.03; 0.04)	0.58 (0.48; 0.75)	0.01 (0.01; 0.02)	0.03 (0.02; 0.05)
Max Accel 1b ($m.s^{-2}$)	6.16±0.66	0.91 (0.83; 0.96)	3.4 (2.8; 4.4)	0.21 (0.17; 0.27)	0.30 (0.25; 0.39)	0.13 (0.10; 0.19)	0.40 (0.30; 0.58)

Definition and description of all outcome variables are presented in Table 1. ICC Intra-class correlation coefficient; CI Confidence interval; CV coefficient of variation; TE typical error; SWC smallest worthwhile change; MDC moderate worthwhile change; Tau acceleration time constant/time to 63% of top speed; Max Accel 0.5-s interval with the greatest average acceleration; Max Decel 0.5-s interval with the greatest average deceleration; Green: very high ICC and trivial Standardized TE; Yellow: high ICC and small Standardized TE; Orange: moderate ICC and moderate Standardized TE; Blue: magnitude of clear change/difference.

Reliability of the 10-0-5

The reliability of all metrics during the 10-0-5 are shown in Tables 4a and 4b for right and left turns, respectively. Overall, most of the ICC were at least high (0.90–0.75). The magnitude of the TEs was small for all metrics (except moderate for Tau Decel for right turn), and the usefulness of all the metrics was good for detecting moderate changes/differences (MWC) (Tables 4a and 4b). The variable with the best reliability was Top Speed 1a, with very high ICC and small Standardized TEs. Similarly to m5-0-5, Max Accel (phase 1a and 1b) and Max Decel metrics were more reliable than Tau Accel and Tau Decel (i.e., small vs moderate Standardized TEs). Interestingly, 0-5 m Time tended to present slightly lower TEs than the other acceleration metrics.

Reliability of the 15-0-5

The reliability of all metrics during the 15-0-5 are shown in Tables 5a and 5b for right and left turns, respectively. Overall, most of the ICC were at least high (0.90–0.75), except for Tau Decel, which was moderate. The magnitude of the TEs was moderate for all metrics (except small for Top Speed 1a time and large for Tau Decel), and the usefulness of all the metrics was good for detecting moderate changes/differences (MWC) (Tables 5a and 5b). The variable with the best reliability was Top Speed 1a, with very high ICC and small Standardized TEs.

Similarly to the other tests, Max Accel and Max Decel metrics were more reliable than Tau Accel and Tau Decel (i.e., moderate vs large Standardized TEs). Interestingly, 0-5 m Time tended to present slightly lower TEs than the other acceleration metrics (especially during the re-acceleration phase, i.e., phase 1b).

Between-tests difference in reliability

Across the various tests, top speed was consistently the most reliable metric across the different tests, with the longer the sprint phase, the better the reliability (i.e., Standardized TE of 0.5, 0.5, 0.20 and 0.1 for 5-,10-,15-, and 40-m sprints, respectively (Tables 2 to 5).

In contrast, with the exception of Tau Decel during the 15-0-5 that showed large Standardized TEs, all the other acceleration and deceleration metrics displayed small-to-moderate reliability (Standardized TE 0.47-0.59 and ICC 0.78-0.87 for Acceleration, and 0.31-0.43 and ICC: 0.80 -0.88 for Deceleration metrics), with Max Accel and Max Decel showing consistently slightly better reliability than Tau-related variables (i.e., often small vs moderate) (Tables 2 to 5).

Interestingly, 0-5 m Time tended to also present slightly lower TEs than the other acceleration metrics (especially during the re-acceleration phase during the 15-0-5). Overall, the different COD tests followed similar reliability patterns, with minor variations in ICCs, Standardized TEs, and rating of usefulness (i.e., most of them rated as “Good” for MWC for all the different metrics).

Table 4a. Test-retest reliability 10-0-5 performance outcome measurements of four test sessions with a left turn

	Outcome	ICC (95% CI)	CV (95% CI)	TE (95% CI)	Standardized TE (95% CI)	SWC	MWC
Time 1a (s)	2.57±0.16	0.90 (0.81; 0.95)	2.2 (1.8; 2.8)	0.05 (0.05; 0.07)	0.34 (0.28; 0.43)	0.03 (0.02; 0.05)	0.10 (0.07; 0.14)
Top Speed 1a ($m.s^{-1}$)	5.96±0.36	0.94 (0.89; 0.98)	1.5 (1.3; 2.0)	0.09 (0.07; 0.11)	0.25 (0.21; 0.32)	0.07 (0.05; 0.10)	0.21 (0.16; 0.31)
0-5 m 1a (s)	1.35±0.12	0.90 (0.80; 0.95)	2.9 (2.4; 3.7)	0.04 (0.03; 0.05)	0.34 (0.28; 0.43)	0.03 (0.02; 0.04)	0.07 (0.05; 0.10)
Tau Accel 1a (s)	0.65±0.11	0.84 (0.71; 0.93)	7.5 (6.2; 9.7)	0.05 (0.04; 0.06)	0.43 (0.36; 0.55)	0.02 (0.02; 0.03)	0.07 (0.05; 0.10)
Max Accel 1a ($m.s^{-2}$)	6.07±1.19	0.86 (0.73; 0.94)	8.5 (7.0; 11.1)	0.47 (0.39; 0.60)	0.37 (0.31; 0.48)	0.24 (80.18; 0.35)	0.71 (0.54; 1.04)
Decel Time (s)	1.10±0.08	0.77 (0.59; 0.89)	3.5 (2.9; 4.6)	0.04 (0.03; 0.05)	0.49 (0.41; 0.63)	0.02 (0.01; 0.02)	0.05 (0.04; 0.07)
Tau Decel 1a (s)	0.41±0.06	0.81 (0.66; 0.91)	7.2 (6.0; 9.3)	0.03 (0.02; 0.04)	0.47 (0.39; 0.60)	0.01 (0.01; 0.02)	0.04 (0.03; 0.05)
Max Decel ($m.s^{-2}$)	8.48±0.95	0.88 (0.78; 0.95)	4.1 (3.4; 5.3)	0.34 (0.28; 0.44)	0.35 (0.29; 0.45)	0.19 (0.14; 0.28)	0.57 (0.43; 0.83)
0-5 m 1b (s)	1.41±0.11	0.89 (0.78; 0.95)	2.6 (2.2; 3.3)	0.04 (0.03; 0.05)	0.35 (0.29; 0.45)	0.02 (0.02; 0.03)	0.06 (0.05 0.09)
Max Accel 1b ($m.s^{-2}$)	6.12±0.66	0.79 (0.62; 0.90)	5.3 (4.4; 6.8)	0.32 (0.26; 0.40)	0.47 (0.39; 0.60)	0.13 (0.10; 0.19)	0.40 (0.30; 0.58)

Definition and description of all outcome variables are presented in Table 1. ICC Intra-class correlation coefficient; CI Confidence interval; CV coefficient of variation; TE typical error; SWC smallest worthwhile change; MDC moderate worthwhile change; Tau acceleration time constant/time to 63% of top speed; Max Accel 0.5-s interval with the greatest average acceleration; Max Decel 0.5-s interval with the greatest average deceleration; Green: very high ICC and trivial Standardized TE; Yellow: high ICC and small Standardized TE; Orange: moderate ICC and moderate Standardized TE; Blue: magnitude of clear change/difference.

Table 4b. Test-retest reliability of 10-0-5 performance outcome measurements of four test sessions with a right turn

	Outcome	ICC (95% CI)	CV (95% CI)	TE (95% CI)	Standardized TE (95% CI)	SWC	MWC
Time 1a (s)	2.55±0.16	0.87 (0.76; 0.94)	2.4 (82.0; 3.1)	0.06 (80.05; 0.08)	0.38 (0.32; 0.49)	0.03 (0.02; 0.05)	0.10 (0.07; 0.14)
Top Speed 1a ($m.s^{-1}$)	5.95±0.37	0.93 (0.86; 0.97)	1.7 (1.4; 2.2)	0.10 (0.09; 0.13)	0.27 (0.22; 0.34)	0.07 (0.06; 0.11)	0.22 (0.17; 0.33)
0-5 m 1a (s)	1.34±0.12	0.90 (0.80; 0.95)	3.0 (2.4; 3.7)	0.04 (0.03; 0.05)	0.35 (0.28; 0.43)	0.02 (0.02; 0.03)	0.07 (0.05; 0.10)
Tau Accel 1a (s)	0.64±0.12	0.81 (0.66; 0.91)	8.7 (7.2; 11.3)	0.05 (0.04; 0.07)	0.46 (0.38; 0.59)	0.02 (0.02; 0.03)	0.07 (0.05; 0.10)
Max Accel 1a ($m.s^{-2}$)	6.13±1.22	0.82 (0.68; 0.92)	10.0 (8.2; 12.9)	0.53 (0.44; 0.68)	0.44 (0.37; 0.57)	0.24 (0.18; 0.36)	0.73 (0.55; 1.07)
Decel Time (s)	1.09±0.07	0.80 (0.63; 0.90)	3.2 (2.7; 4.2)	0.04 (0.03; 0.04)	0.47 (0.39; 0.60)	0.01 (0.01; 0.02)	0.04 (0.03; 0.07)
Tau Decel 1a (s)	0.39±0.06	0.57 (0.33; 0.78)	10.0 (8.3; 13.0)	0.0 4 (0.03; 0.05)	0.67 (0.55; 0.85)	0.01 (0.01; 0.02)	0.03 (0.03; 0.05)
Max Decel ($m.s^{-2}$)	8.65±0.85	0.77 (0.60; 0.89)	5.0 (4.1; 6.4)	0.42 (0.35; 0.54)	0.49 (0.40; 0.62)	0.17 (0.13; 0.25)	0.51 (0.39; 0.74)
0-5 m 1b (s)	1.41±0.10	0.90 (0.80; 0.95)	2.4 (2.0; 3.0)	0.04 (0.03; 0.05)	0.34 (0.28; 0.43)	0.02 (0.02; 0.03)	0.06 (0.05; 0.0)
Max Accel 1b ($m.s^{-2}$)	6.06±0.67	0.86 (0.74; 0.94)	4.4 (3.6; 5.6)	0.26 (0.22; 0.34)	0.38 (0.31;0.48)	0.13 (0.10; 0.19)	0.40 (0.30; 0.58)

Definition and description of all outcome variables are presented in Table 1. ICC Intra-class correlation coefficient; CI Confidence interval; CV coefficient of variation; TE typical error; SWC smallest worthwhile change; MDC moderate worthwhile change; Tau acceleration time constant/time to 63% of top speed; Max Accel 0.5-s interval with the greatest average acceleration; Max Decel 0.5-s interval with the greatest average deceleration; Green: very high ICC and trivial Standardized TE; Yellow: high ICC and small Standardized TE; Orange: moderate ICC and moderate Standardized TE; Blue: magnitude of clear change/difference.

Table 5a. Test-retest reliability of 10-0-5 performance outcome measurements of four test sessions with a right turn

	Outcome	ICC (95% CI)	CV (95% CI)	TE (95% CI)	Standardized TE (95% CI)	SWC	MWC
Time 1a (s)	3.31±0.21	0.91 (0.82; 0.96)	1.9 (1.6; 2.5)	0.07 (0.05; 0.08)	0.31 (0.26; 0.40)	0.04 (0.03; 0.06)	0.12 (0.09; 0.18)
Top Speed 1a (m/s)	6.77±0.46	0.96 (0.92; 0.98)	1.5 (1.2; 1.9)	0.10 (0.08; 0.12)	0.21 (0.17; 0.26)	0.09 (0.07; 0.14)	0.28 (0.21; 0.41)
0-5 m 1a (s)	1.36±0.12	0.84 (0.71; 0.93)	3.6 (3.0; 4.6)	0.04 (0.03; 0.05)	0.43 (0.35; 0.53)	0.02 (0.02; 0.03)	0.07 (0.05; 0.10)
Tau Accel 1a (s)	0.79±0.11	0.77 (0.59; 0.89)	7.6 (6.3; 9.8)	0.06 (0.05; 0.07)	0.52 (0.43; 0.66)	0.02 (0.02; 0.03)	0.07 (0.05; 0.10)
Max Accel 1a (m/s^2)	6.04±1.23	0.79 (0.62; 0.90)	10.5 (8.6; 13.5)	0.59 (0.49; 0.75)	0.45 (0.37; 0.57)	0.25 (0.19; 0.36)	0.74 (0.56; 1.08)
Decel Time (s)	1.32±0.09	0.80 (0.65; 0.91)	3.4 (2.8; 4.4)	0.04 (0.04; 0.05)	0.47 (0.39; 0.60)	0.02 (0.01; 0.03)	0.06 (0.04; 0.08)
Tau Decel 1a (s)	0.50±0.07	0.69 (0.48; 0.85)	8.3 (6.8; 10.7)	0.04 (0.03; 0.05)	0.57 (0.47; 0.73)	0.01 (0.01; 0.02)	0.04 (0.03; 0.06)
Max Decel (m/s^2)	8.54±0.94	0.81 (0.66; 0.91)	5.0 (4.2; 6.5)	0.43 (0.35; 0.54)	0.44 (0.37; 0.56)	0.19 (0.14; 0.28)	0.57 (0.43; 0.83)
0-5 m 1b (s)	1.42±0.10	0.94 (0.88; 0.97)	1.9 (1.6; 2.4)	0.03 (0.02; 0.04)	0.26 (0.22; 0.33)	0.03 (0.02; 0.04)	0.06 (0.05; 0.09)
Max Accel 1b (m/s^2)	6.06±0.62	0.88 (0.77; 0.94)	4.0 (3.3; 5.0)	0.23 (0.19; 0.29)	0.37 (0.31; 0.47)	0.12 (0.09; 0.18)	0.37 (0.28; 0.55)

Definition and description of all outcome variables are presented in Table 1. ICC Intra-class correlation coefficient; CI Confidence interval; CV coefficient of variation; TE typical error; SWC smallest worthwhile change; MDC moderate worthwhile change; Tau acceleration time constant/time to 63% of top speed; Max Accel 0.5-s interval with the greatest average acceleration; Max Decel 0.5-s interval with the greatest average deceleration; Green: very high ICC and trivial Standardized TE; Yellow: high ICC and small Standardized TE; Orange: moderate ICC and moderate Standardized TE; Blue: magnitude of clear change/difference.

Table 5b. Test-retest reliability of 15-0-5 performance outcome measurements of four test sessions with right turn

	Outcome	ICC (95% CI)	CV (95% CI)	TE (95% CI)	Standardized TE (95% CI)	SWC	MWC
Time 1a (s)	3.31±0.20	0.93 (0.86; 0.97)	1.7 (1.4; 2.2)	0.06 (0.05; 0.07)	0.28 (0.24; 0.36)	0.04 (0.03; 0.06)	0.12 (0.09; 0.18)
Top Speed 1a (m/s)	6.78±0.46	0.96 (0.93; 0.98)	1.4 (0.8; 1.8)	0.09 (0.08; 0.12)	0.20 (0.17; 0.25)	0.09 (0.07; 0.13)	0.28 (0.21; 0.40)
0-5 m 1a (s)	1.35±0.11	0.89 (0.79; 0.95)	2.9 (2.4; 3.7)	0.04 (0.03; 0.05)	0.35 (0.29; 0.45)	0.02 (0.02; 0.03)	0.07 (0.05; 0.10)
Tau Accel 1a (s)	0.79±0.10	0.82 (0.68; 0.92)	5.9 (4.8; 7.5)	0.04 (0.04; 0.06)	0.45 (0.37; 0.57)	0.02 (0.02; 0.03)	0.06 (0.05; 0.09)
Max Accel 1a (m/s^2)	6.08±1.15	0.87 (0.75; 0.94)	7.6 (6.2; 9.7)	0.44 (0.36; 0.56)	0.36 (0.30; 0.45)	0.23 (0.17; 0.33)	0.69 (0.52; 1.00)
Decel Time (s)	1.33±0.10	0.77 (0.59; 0.89)	3.9 (3.2; 4.9)	0.05 (0.04; 0.06)	0.50 (0.41; 0.63)	0.02 (0.02; 0.03)	0.06 (0.05; 0.09)
Tau Decel 1a (s)	0.49±0.06	0.71 (0.50; 0.86)	7.3 (6.0; 9.4)	0.03 (0.03; 0.04)	0.55 (0.46; 0.70)	0.01 (0.01; 0.02)	0.04 (0.03; 0.05)
Max Decel (m/s^2)	8.66±0.91	0.83 (0.69; 0.92)	4.6 (3.8; 5.9)	0.39 (0.32; 0.50)	0.43 (0.36; 0.55)	0.18 (0.14; 0.26)	0.54 (0.41; 0.79)
0-5 m 1b (s)	1.42±0.11	0.96 (0.93; 0.98)	1.5 (1.3; 2.0)	0.02 (0.02; 0.03)	0.20 (0.17; 0.26)	0.02 (0.02; 0.03)	0.06 (0.05; 0.09)
Max Accel 1b (m/s^2)	6.03±0.69	0.91 (0.83; 0.96)	3.7 (3.0; 4.7)	0.21 (0.18; 0.27)	0.30 (0.25; 0.38)	0.14 (0.11; 0.20)	0.42 (0.32; 0.61)

Definition and description of all outcome variables are presented in Table 1. ICC Intra-class correlation coefficient; CI Confidence interval; CV coefficient of variation; TE typical error; SWC smallest worthwhile change; MDC moderate worthwhile change; Tau acceleration time constant/time to 63% of top speed; Max Accel 0.5-s interval with the greatest average acceleration; Max Decel 0.5-s interval with the greatest average deceleration; Green: very high ICC and trivial Standardized TE; Yellow: high ICC and small Standardized TE; Orange: moderate ICC and moderate Standardized TE; Blue: magnitude of clear change/difference.

Comparison between the metrics

While Top Speed was largely slower during the 15-0-5 than during the 40-m Sprint (i.e., 91%), acceleration was slightly greater during the first phase of the COD test (i.e., Max Acceleration 106%, 0-5 m time 94% during phase 1a) (Table 6 and Figure 6). Re-acceleration during the second phase of the 15-0-5 (phase 1b) was however slower than during the first phase, and similar to that during the linear sprint (Table 6 and Figure 6).

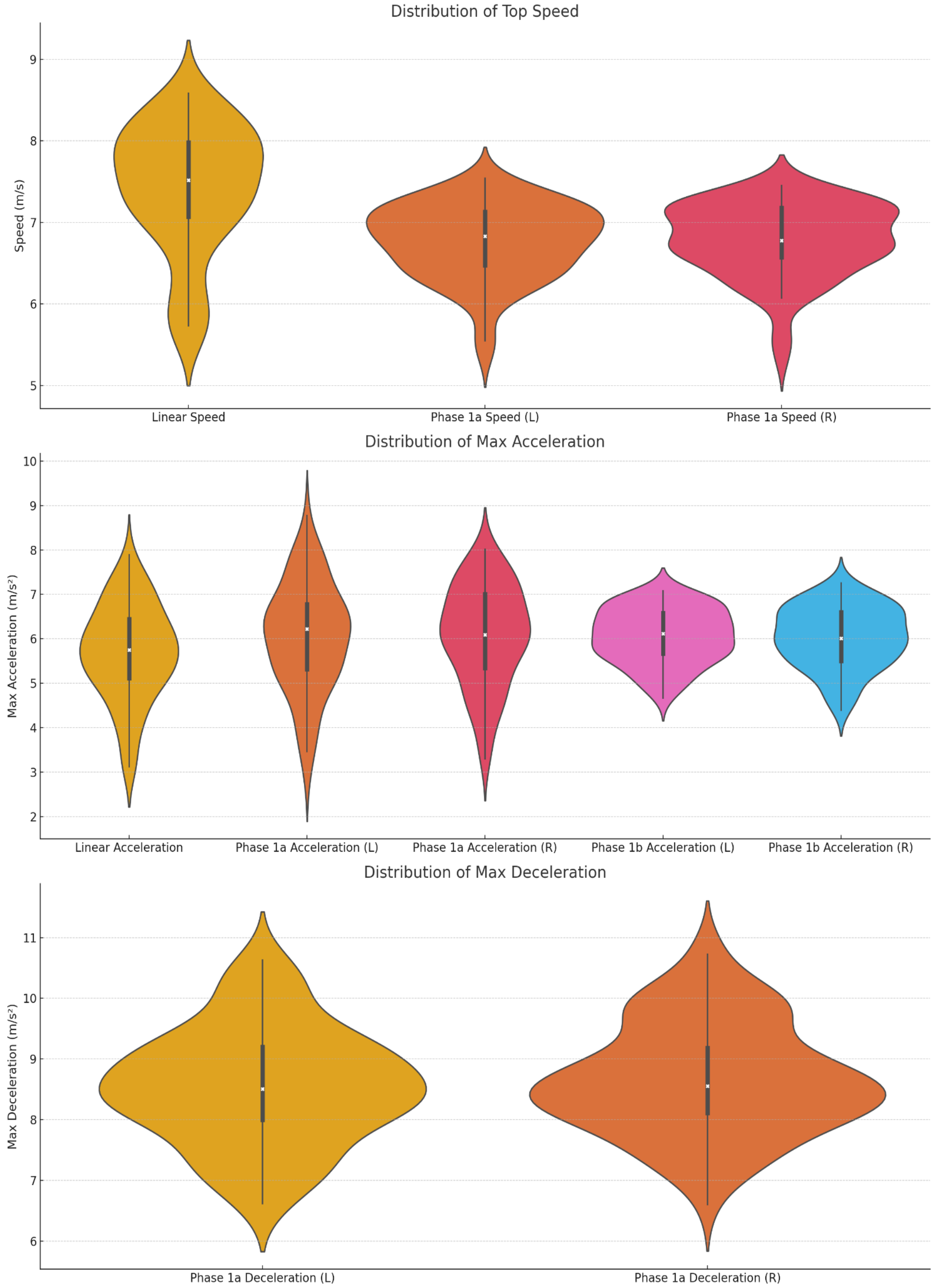

Fig. 6. Violin plot and overall distribution of performance for the main metrics identified.

Table 6. Mean values (SD) for the selected main metrics during both tests.

Metrics	Test	Values (SD)	ES vs 40-m Sprint	% of Linear 40-m Sprint Tests (SD)
Top Speed (m·s^{-1})	40-m Sprint	7.43 (0.8)		
	15-0-5 Phase 1a (L)	6.77 (0.5)	-0.92	91.1 (6.1)
	15-0-5 Phase 1a (R)	6.78 (0.5)	-0.92	91.3 (6.1)
0-5m (s)	40-m Sprint	1.40 (0.26)		
	15-0-5 Phase 1a (L)	1.36 (0.12)	-0.22	94.1 (5.5)
	15-0-5 Phase 1a (R)	1.35 (0.11)	-0.21	93.9 (5.6)
	15-0-5 Phase 1b (L)	1.42 (0.10)	0.11	99.2 (8.2)
	15-0-5 Phase 1b (R)	1.42 (0.11)	0.12	99.5 (7.6)
Tau Acceleration (s)	440-m Sprint	1.05 (0.21)		
	15-0-5 Phase 1a (L)	0.77 (0.16)	-1.56	73 (9.1)
	15-0-5 Phase 1a (R)	0.77 (0.16)	-1.56	73 (9.2)
Max Acceleration (m·s^{-2})	40-m Sprint	5.7 (1.1)		
	15-0-5 Phase 1a (L)	6.0 (1.2)	0.25	106 (0)
	15-0-5 Phase 1a (R)	6.1 (1.1)	0.33	106.6 (0)
	15-0-5 Phase 1b (L)	6.1 (0.6)	0.33	106.4 (0)
	15-0-5 Phase 1b (R)	6 (0.7)	0.25	105.8 (0)
Max Deceleration (m·s^{-2})	15-0-5 Phase 1a (L)	8.5 (0.9)		
	15-0-5 Phase 1a (R)	8.7 (0.9)		

Discussion

This study provides a comprehensive analysis of various metrics that offer insights into top speed, acceleration, deceleration, and change of direction (COD) abilities using a newly proposed test battery (Buchheit 2024a & 2024c). The key tests include the 40-meter straight-line sprint and COD tests, with particular emphasis on the 15-0-5, which we consider the most suitable complement to the 40-meter sprint for evaluating these specific capacities in relation to the demands of football (Buchheit 2024b & 2024c, Della Villa 2020, Gómez-Piqueras 2024, Rekik 2023). This approach allows for a more detailed understanding of the physical qualities required for both linear and non-linear high-intensity actions in elite football (Buchheit 2024c). One of the key contributions of this study is the use of simple metrics such as the time to cover the first 5 m (i.e., 0-5 m time) and maximal acceleration and deceleration measured over 0.5-s intervals (Max Accel and Max Decel). This method aligns with how these metrics are typically calculated in the field using tracking systems like GPS or semi-automatic video systems (Buchheit & Simpson 2017). Consequently, our findings are highly applicable to real-world settings, making them valuable for coaches and sports scientists aiming to assess player performance under game-like conditions.

Our results show that simpler variables often offer the most useful insights. Given the large correlations between some metrics (Figures 3, 4, and 5), it was evident that certain variables were redundant. Based on their reliability, uniqueness (i.e., lower correlation with other metrics), usefulness (i.e., ability to track small-to-moderate changes or differences), and practical utility (e.g., using a common language with GPS-based analyses), we suggest focusing on only a few key metrics for each test.

For the 40-meter sprint, the most informative metrics are Top Speed, the 0-5 m Time, and Max Accel (Table 6 and Figure 6). The case of Time to 25.2 km·h^{-1} is interesting, as it relates to commonly used speed thresholds in GPS analyses (Table 1). However, its very large correlation with overall sprint time (r = 0.93) and Top Speed (r = 0.90) (Figures 3 and 5) makes it somewhat redundant as an overall measure of performance, while not providing specific insights into the typical benchmarks related to maximal acceleration capacity (r = -0.47 vs Max Accel).

For the COD tests, using the same reasoning and considering correlations between metrics, reliability, usefulness, and practical utility, we eventually recommend focusing on Top Speed during the phase before the turn (i.e., phase 1a), 0-5 m Time and Max Accel both before and after the COD (i.e., phases 1a and 1b), and Max Decel during the first phase (i.e., phase 1a) (Table 6 and Figure 6). Interestingly, the 0-5 m Time showed lower TEs than Max Accel during the re-acceleration phase 1b (Tables 5a and 5b). Deciding whether to prioritize this metric over Max Accel likely depends on the practitioners, who must weigh the benefit of improved reliability against the consistency of using similar metrics and units throughout the testing battery (e.g., for alignment with Max Decel).

Notably, the percentage of Top Speed reached in the present study was higher than previously reported, i.e., 91% (Table 6) vs. 80% of MSS (Buchheit 2024c). This difference is likely related to the fact that, in the previous study, linear Top Speed data was collected with GPS during non-resisted sprints performed ahead of the study (i.e., allowing the proper assessment of MSS), while only the 15-0-5 was performed with a motorized resisted device with a 3 kg resistance (Buchheit 2024c). In contrast, in the present study, we assessed players using the 1080 for all tests with a 3 kg resistance. Despite the limitation of comparing different populations (a mix of team sport players vs. highly-trained football/soccer players), this difference in % reached is likely directly related to difference in 40-m Top Speed (present study) or pure MSS (Buchheit 2024) used as reference: 7.4 m·s^{-1} or 26.7 km·h^{-1} (Table 6) vs 8.6 m·s^{-1} or 31.2 km·h^{-1} (Buchheit 2024), for more similar 15-0-5 Top Speeds of 6.6 m·s^{-1} or 23.8 km·h^{-1} (Table 6) vs 7.1 m·s^{-1} or 25.4 km·h^{-1} (Buchheit 2024). Interestingly also, the Max Decel values observed here (-8 m·s^{-2}, Table 6) were higher than those we reported previously (i.e., -6 m·s^{-2}) (Buchheit 2024). While the time window of analysis was similar (i.e., 0.5 s), differences in technology (GPS vs. 1080) and population may explain this difference.

Change of direction ability

When analyzing COD ability in detail, there were a few interesting considerations. Max Decel, believed to be a crucial aspect of COD ability (Harper 2024), was largely correlated with Top Speed before the break (r = -0.68, Figure 4). This relation with Top Speed is expected since the greater the speed to brake from, the greater the brake. However, correlations between Max Decel and other metrics were all trivial to small (Figures 4 and 5), confirming that it captures a unique aspect of the locomotor function, that may not be represented by other metrics (Harper 2024). Interestingly too, Max Accel during the second phase (1b) was not much correlated with metrics during the first phase (1a) such as Max Accel (r = -0.11) or Max Decel (r = 0.30) (Figure 5), suggesting also that re-acceleration capacity after a turn is a specific locomotor capacity (Sheppard 2006).

Application to current football practices

Ideally, maximal sprints over 40 m should be prioritized over shorter sprints to ensure that the true player's MSS is reached (Buchheit 2012, Table 6 and Figure 6). However, in elite football, full efforts over 40 m are not commonly practiced, which could be a limitation in implementing the suggested 40-m sprint. In practice, the most common prescription for reaching MSS in training is to implement >20-m sprints with a flying start, which, while perceived as less demanding by players and staff, still allow players to reach the required maximal velocity effectively (Kyprianou 2022). In this context, only Top Speed can be assessed. The initial portion of the sprint does not accurately reflect players' maximal acceleration, and further analysis such as proper F/V profiling (Cross 2017) is obviously excluded, which is another discussion beyond the scope of this paper, but readers are referred to Episode 115 of the Training Science podcast with JB Morin). However, the 15-0-5 can be performed as a full-effort test due to the shorter distances involved (Buchheit 2024c). The good news is that, given that Max Accel during the first phase of the 15-0-5 was even higher than during the linear 40-meter Sprint (i.e., 106%, Tables 6 and Figure 6), and that both were highly correlated (r = 0.85, Figure 5), overall player profiling could still be completed using a flying 20-30 m sprint and the 15-0-5. While performing the 40-m sprint with full effort is the preferred option, using only the Max Accel metric from the 15-0-5 as the reference measure of maximal acceleration capacity would allow practitioners to simplify the testing battery and reduce the burden on players and staff.

Re-acceleration during the second phase of the 15-0-5 (phase 1b) was slower than in the first phase and comparable to the linear sprint (Figure 6). This could be due to the difficulty of starting from a lateral position while also adjusting for the momentum generated in the first phase of the test. The reason why Max Accel was slightly higher during the 15-0-5 than during the 40-m sprint (Tables 6 and Figure 6) may be related to a pacing strategy, where players adapt their acceleration strategy to the distance/time available, with shorter distances/times requiring greater acceleration early in the run. This difference in strategies is confirmed by the significantly shorter Tau Acceleration for the COD tests (77% of that during the linear 40-m test, Table 6).

If the earlier suggested alternative of using a 20-30 m flying sprint combined with the 15-0-5 is still considered too much given the time constraints in elite football, the congested fixture schedule, and a culture that may be resistant to extensive testing, the 15-0-5 alone is an excellent option if only one test can be performed. Although it cannot capture true maximal sprinting speed (MSS) due to the short distance (Buchheit 2012), the fact that Top Speed in the 15-0-5 is very strongly correlated with Top Speed in the 40-meter sprint test (r = 0.90, Figures 4 and 5), along with the reality that true MSS may not be reached with resistance applied during the 40-m sprint, suggests that the 15-0-5 alone can almost be considered sufficient for player profiling. The exact impact of a low resistance as used here (i.e., 3 kg) on Top Speed and how it compares with the true MSS still requires further investigation.

By prioritizing the metrics suggested in Table 6, practitioners can streamline their assessments and focus on the most valuable data, ultimately enhancing both performance monitoring and training interventions. These findings provide a clear framework for future applications in elite football, particularly in field-based performance testing using widely available technology such as the 1080.

Key Findings

- Based on their reliability, uniqueness (lower correlation with other metrics), usefulness (i.e., ability to track small-to-moderate changes or differences), and practical utility (e.g., using a common language with GPS-based analyses), we suggest focusing on key metrics for each test:
- For the 40-m sprint, Top Speed (trivial CV of 1.2%, ability to track small changes/differences), the 0-5 m Time (small CV of 3%, ability to track moderate changes/differences), and Max Accel (small CV of 10%, ability to track moderate changes/differences).
- For the 15-0-5, Top Speed before the COD (small CV of 1.5%, ability to track moderate changes/differences), 0-5 m Time (small CVs of 2-3%, ability to track small-to-moderate changes/differences) or Max Accel (small CV of 4-10%, ability to track moderate changes/differences) both before and after the COD, and Max Decel during phase 1a (small of CV of 5%, ability to track moderate changes/differences).
- Present data confirm that deceleration metrics capture a unique aspect of the locomotor function, that may not be represented by other metrics (i.e., only trivial to small correlations with other metrics, except Top Speed preceding the braking phase).
- Max Accel during the second phase (1b) was poorly correlated with metrics during the first phase, suggesting also that re-acceleration capacity after a turn is another specific locomotor capacity.
- The fact that Top Speed in the 15-0-5 is very strongly correlated with Top Speed in the 40-m sprint test (r = 0.90), along with the reality that true MSS may not always be reached with resistance applied during the 40-meter sprint, suggests that the 15-0-5 alone could almost be considered sufficient for player profiling when using a motorized resistance device.

Conflict of Interest Statement

This study received partial funding from the 1080 company. MB has served as a consultant for 1080, and OE holds shares in the company.

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