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**1 Testing the peak running speed in analytical and contextual-based scenarios:  
2 applied research in young adult soccer players**

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26 **Abstract**

27 The primary aim was to compare the peak running speed (PRS) attained in the 40-m linear  
28 sprint test, in an analytical-based soccer drill, in the 5-0-5 test, and a training match  
29 scenario. The secondary aim of the study was to evaluate the differences between the  
30 three assessment sessions and identify how the tests can vary from session to session.  
31 Additionally, we aimed to investigate the within-test variability to understand how  
32 consistent the performance is within each test format across the different sessions. Forty  
33 male under-19 players competing at the national level participated in this study. A training  
34 session was observed for each of the three study weeks in which the following  
35 tests/scenarios were monitored using a GPS. The 40-m linear sprint test and the  
36 analytical-based soccer drill presented the smallest within-subject coefficients of  
37 variation between the sessions. A large correlation ( $r=0.742$ ) was found between the PRS  
38 during the 40-m linear sprint test and the analytical-based soccer drill. The 40-m linear  
39 sprint test was the best method of those examined for measuring PRS. The analytical  
40 drill provides a reliable method for measuring PRS, although it differs from the 40-meter  
41 linear sprint test.

42 **Keywords:** football; athletic performance; running; speed tests.

43

44 **Testing the peak running speed in analytical and contextual-based scenarios:**  
45 **applied research in young adult soccer players**

46

47 **Introduction**

48 A substantial amount of time is spent executing low-to-moderate effort activities in  
49 soccer match play, however, near-to-maximum and maximum intensity actions, such as  
50 sprinting, are an essential element of successful performance (16,45). Previous research  
51 revealed that straight-line sprinting is the most frequent action that precedes a goal-  
52 scoring opportunity in open play, thus underlining the influence of such an activity on  
53 successful performance within games (17).

54 The prevalence of sprinting has increased in some competitive leagues such as the  
55 English Premier League, with some reports indicating an increase of around 50% between  
56 the 2006-07 and 2012-12 seasons (10). Depending on contextual factors and playing  
57 position, professional soccer players may accumulate up to ~350 meters per match as has  
58 been shown for the fullback position in previous research (10). In the UEFA Europa  
59 League, the average number of sprints per game is  $11.2 \pm 5.3$  per player and in most cases,  
60 these sprints are shorter than five seconds in duration (4). In relation to the peak speed  
61 attained in such sprints, a recent study revealed that highly ranked German professional  
62 players can achieve velocities of between 9.2 and 9.4 m/s (33.1 to 33.8 km/h) (13).

63 Because sprinting is a key performance indicator in soccer, testing batteries  
64 recommended for soccer typically include sprinting tests to determine players' ability in  
65 this domain (7,46,48). Across different distances, the typical test distances used for soccer  
66 players are between 30 and 40 m. However, some authors suggest that 20 and 30 m  
67 appears to be long enough distance to guarantee a reliable estimate of peak running speed  
68 (PRS) (9). Usually, the sprint test employed is linear in direction, a characteristic that

69 offers very good intra-day and inter-day reliability (3). Although sprint time is a fairly  
70 easy metric to evaluate (since common apparatus such as photocells and smartphones can  
71 measure it), another important piece of information to extract from a sprint test is the PRS  
72 which can be used to standardize sprint training and determine the anaerobic speed  
73 reserve (8,25). Despite this, PRS is more complicated to measure as it requires either a  
74 gold-standard radar gun, a Global Positioning System (GPS) (6,43) or photocells with a  
75 split at each 5-m interval (49).

76         Considering that undertaking physical fitness tests is usually challenging in  
77 professional football due to scheduling and time constraints, some approaches argue that  
78 PRS can be measured in other scenarios, such as during matches or drill-based games  
79 (e.g., small and large-sided games). Despite these assertions, recent comparisons between  
80 small-sided games, soccer matches, and 40-m linear sprint tests, reveal that only the latter  
81 can accurately estimate PRS (29). This is underlined by the fact that the inherent  
82 variability and dynamic conditions of match play may not present players with  
83 opportunities to perform linear sprints at PRS (29). Additionally, the different positional  
84 demands of soccer may enable only some players to achieve PRS in a match scenario.  
85 The findings suggesting the non-possibility of a match being used as a scenario for  
86 estimating the PRS, although this is contradicted by a study that found PRS was higher  
87 in a match than it was in a 40-m linear sprint test (32).

88         Given the above-described dilemma, there may exist an intermediate test that  
89 incorporates the characteristics of both match play and the 40-m linear sprint test, thus  
90 allowing coaches to test PRS more regularly while integrating some specificity to the task  
91 at hand. For example, technical drills involving the execution of crossing and shooting,  
92 often used in soccer training, may present players with the necessary space (between 30-  
93 and 40-m) to achieve PRS whilst also minimizing the potentially disruptive effects posed

94 by opponent players. Indeed, increasing the pitch size in environmental situations, such  
95 as large-sided games with large fields, may lead to more sprints in players (12). However,  
96 it is essential to consider the contextual effects on within and between-player variability  
97 (19), which can still persist even in such scenarios, similar to what occurs in a match.  
98 While it is important to use training drills that ensure the perception-action coupling and  
99 the dynamics of the game, ecological drills for assessment purposes may not guarantee  
100 that all players achieve the same maximum performance at the same time, thus increasing  
101 time consumption.

102 While linear sprinting may not be the most frequent action in a game, it is crucial  
103 to acknowledge that the mechanical load of such activity is of paramount importance in  
104 adjusting the training process. This includes preventing injuries and preparing players for  
105 the occurrence of such activities during the game (31). Moreover, despite most sprinting  
106 actions occurring in curvilinear trajectories (20), linear sprinting is highly related to those  
107 actions and provides a practical means to measure PRS.

108 An additional alternative worth considering for PRS is the classical 5-0-5 change-  
109 of-direction test. This particular test evaluates change-of-direction performance, and it  
110 presents an opportunity to investigate whether the 15-meter linear sprint trajectory within  
111 the test can provide meaningful data for PRS evaluation in soccer players. Previous  
112 research has indicated a nearly perfect correlation between change-of-direction time and  
113 linear speed (44), which raises the possibility of exploring whether PRS can be reliably  
114 assessed during this test. If such a relationship is found to exist, it would offer the  
115 advantage of obtaining two crucial measures from a single test, simplifying the  
116 assessment process and saving valuable time during player evaluations.

117 Based on the above information, it is necessary to determine time-efficient,  
118 alternative approaches to measuring PRS that conform to the specific characteristics of a

119 soccer match. Although PRS can be monitored in official matches, not all players are  
120 selected to partake in these matches with a rotational squad system highly recommended,  
121 particularly during fixture congestion during the season (21). Moreover, within-player  
122 variability within matches is an essential factor that may influence the evaluation of PRS.  
123 Accordingly, building analytical drills to test PRS and conform to the specificity of a  
124 match may decrease such variability and provide coaches with an opportunity to deploy  
125 regularly in training sessions. Considering the pertinence of examining more ecological  
126 approaches to testing PRS, this study has two purposes: the primary aim is to compare  
127 the PRS attained in the 5-0-5 and 40-m linear sprint tests, an analytical-based soccer drill  
128 and during a training match scenario. A secondary aim is to evaluate the within-test  
129 variation of PRS over three consecutive weeks. This analysis will focus on assessing the  
130 variability within each test and comparing the results between different days and trials to  
131 understand if the observed differences are meaningful. The aim is to ensure that the test  
132 consistently provides similar information over time, allowing for reliable and meaningful  
133 data to be obtained. Based on our objectives, we hypothesize that the change-of-direction  
134 test will not yield the same PRS results as the linear speed test. Additionally, we speculate  
135 that there may be slight differences in PRS between the linear speed test and the  
136 analytical-based drill or the match scenario. Regarding the second aim of the study, we  
137 anticipate that the match scenario will exhibit higher within-player variability, while the  
138 linear speed test will show smaller variability within the participants.

139

## 140 **Methods**

### 141 *Experimental approach to the problem*

142 This applied research study adopted a repeated measures design conducted over  
143 three consecutive weeks of a soccer season. Forty players from two teams were tested to

144 evaluate their PRS in the 5-0-5, 40-m linear sprint, analytical-based soccer drill, and  
145 match scenarios. The players underwent measurements once per week for three  
146 consecutive weeks. This specific time frame was chosen to allow for repeated measures,  
147 which would enable the evaluation of within-player variability. Additionally, the duration  
148 of the study was kept as short as possible to accommodate the team's training schedule  
149 efficiently. The assessments always occurred during the equivalent training session and  
150 day of the week, aiming to preserve similarity of conditions. Over the observation period,  
151 the teams undertook four training sessions per week (Monday, Wednesday, Thursday and  
152 Friday) and had one official match (Sunday). The tests were implemented in session two  
153 of the training week (i.e., Wednesday), which occurred 72 h after the most recent match.  
154 This session corresponded to the first session after the players had recovered from the  
155 match. The research team suggested this timing to ensure that the players were in the most  
156 suitable condition for the test. On Monday (the day after the match), the training session  
157 was primarily dedicated to recovery, with a focus on low-to-moderate training intensity,  
158 and more emphasis on tactics and strategy. On Wednesday, the players began the session  
159 with the experimental approach and later transitioned to a match scenario. On Thursday  
160 and Friday, the players were typically engaged in aerobic-based and agility-based training  
161 sessions, respectively. The environmental conditions recorded on the testing days were  
162 as follows: an average temperature of  $16.0 \pm 1.7^\circ\text{C}$ , with a coefficient of variation of  
163 10.8%, and a relative humidity level of  $65.0 \pm 5.6\%$ , with a coefficient of variation of  
164 8.6%. The assessments occurred outdoors on dry synthetic turf and with no rain falling.

165

### 166 *Participants*

167 The sample size was determined using G\*Power software (version 3.1.9.6). To  
168 achieve a small effect size in Cohen's  $d$  of 0.41, a power of 0.8, and a significance level

169 of 0.05 (for the two dependent means while accounting for a two-tailed effect), a total  
170 sample size of 50 participants was recommended. The effect size was calculated based  
171 on the means and standard deviations of two trials of a 20-meter sprint test ( $2.50\pm 0.09$   
172 and  $2.52\pm 0.12$ ) for soccer players, as previously published. The correlation level was set  
173 at 0.93, determined using the intra-class correlation coefficient (ICC) reported in the  
174 referenced article (36).

175 Given the unavailability of literature reporting three sessions of sprint tests for  
176 reference in the ANOVA analysis, we employed match-to-match variation in peak speed  
177 as a reference point, which yielded a minimal partial eta squared of 0.14 (50). Utilizing  
178 this reference, for an ANOVA repeated measures test with within factors, an effect size  
179 of 0.4 (calculated from the eta squared), a power of 0.8, and three measurements,  
180 assuming a correlation of 0.5, we estimated a required sample size of 12.

181 Two teams were selected to participate in this study through convenience  
182 sampling, as the researchers aimed to integrate the experimental approaches into their  
183 regular routines. The teams were chosen because they exhibited similar patterns regarding  
184 the number of training sessions per day and the days when the experimental approach  
185 would be implemented. The only observed variation was in the training time, as one team  
186 started their sessions after the other team. Participants were enrolled by convenience  
187 sampling and were selected to the study based on the following eligibility criteria: (i) they  
188 do not miss any of the observations; (ii) they participate in all training sessions occurring  
189 during the three weeks corresponding to the period of the observation; (iii) they have not  
190 been injured in the previous four weeks before the study was initiated and were being  
191 injured during the period of the observation; and (iv) they play in an outfield position  
192 (i.e., no goalkeepers were included in this study). Out of the total of 45 players recruited,  
193 5 players were excluded from the analysis since they were acting as goalkeepers. Forty

194 male soccer players ( $18.5\pm 0.5$  years old;  $6.0\pm 1.5$  years of experience) from under-18 and  
195 under-19 soccer teams competing at the national level voluntarily participated. No  
196 dropouts or missing data were recorded in the study. The competitive level corresponded  
197 to tier 3 (highly trained/national level) of the Participant Classification Framework (33).  
198 The participants were informed about the study design, risks, and benefits prior to their  
199 participation. After verbal agreement, they signed a study consent form. The study  
200 followed the ethical standards for researching humans set out by the Declaration of  
201 Helsinki. The ethical committee of the University of XXXX, XXXX, XXXX approved  
202 the research.

203

#### 204 *Procedures*

205 For each day of the assessments, the following sequence was employed: (i)  
206 standardized warm-up protocol following the FIFA 11+ warm-up protocol (2) ; (ii) 5-0-  
207 5 test; (iii) 40-m linear sprint test; (iii) analytical-based soccer drill incorporating the skills  
208 of passing, crossing and shooting; and (iv) match scenario. The sequence was maintained  
209 consistently to ensure similar conditions, which was crucial for conducting the within-  
210 player analysis. There was a 5-minute rest period between each of these tests. Each test  
211 was executed twice, with a 3-minute rest period between each trial. This approach aimed  
212 to ensure consistent performance during the training session, as relying on only one  
213 attempt might not provide sufficient data to establish a reliable and representative  
214 measure of performance. The participant wore the team's official training uniform,  
215 consisting of a shirt and shorts, and used the same pair of soccer boots for the field tests.

216 The players used a Global Positioning System (GPS) Polar Team Pro (10 Hz,  
217 Finland) to measure PRS in each test. A body-worn sensor was positioned in the center  
218 of the chest and was held in place by an elastic band. To decrease inter-unit variability,

219 players wore the same units in each testing session. The GPS system was previously  
220 tested for its concurrent validity against radar guns and was also confirmed for its intra-  
221 and inter-unit reliability in measuring PRS (43). In this particular case, the GPS Polar  
222 Team Pro was compared with a radar gun, and the overall coefficient of correlation for  
223 maximum sprint speed was found to be extremely high ( $r = 0.938$ ,  $p < 0.001$ ) (43).  
224 Additionally, good inter-unit reliability between the Polar Team Pro GPS units was  
225 observed for maximum sprint speed, with low coefficients of variation (5%–6%) and low  
226 smallest worthwhile changes (0.4 for all systems) (43). To ensure optimal data collection,  
227 a standard protocol was followed in which all devices were powered on 15 to 30 minutes  
228 prior to commencing data collection. This timeframe allowed the devices to establish a  
229 connection with multiple satellites, synchronize their clocks with the satellite's atomic  
230 clock (30), and achieve a horizontal dilution of precision (HDOP) of less than 5, as  
231 indicated in the manufacturer's specifications. The player's data were objectively  
232 recorded using Polar Team Pro hardware and software. Afterward, the collected data were  
233 processed through the device's web platform and exported in accordance with RFC 4180  
234 standards, which specify a comma-separated values (CSV) text format.

235

#### 236 *40-m linear sprint test*

237 Players started in a staggered stance position. The players always started with the  
238 same preferred leg in front and after a count (i.e., '3, 2, 1, go'), they executed the sprint  
239 with maximal intent. For each session, the players performed two trials, interspaced by  
240 three minutes of rest. In each trial, the players wore the GPS unit to measure PRS. This  
241 PRS was used in further statistical analysis.

242

#### 243 *5-0-5 test*

244 The original version (42) of the 5-0-5 test was used. While it may not be expected  
245 to observe PRS as in the case of a linear sprint test, previous studies suggest that the  
246 results of change of direction tests are often highly correlated with linear sprint  
247 performance (44). Considering that soccer players typically achieve maximum speed  
248 earlier than sprint athletes (9), we aimed to investigate whether this change of direction  
249 test could provide similar information to a properly designed linear sprint test. By doing  
250 so, we aimed to exclude the possibility of obtaining redundant or duplicate information  
251 from both tests. The test consisted of sprinting a distance of 15 meters, before turning  
252 180° and performing a five-meter sprint to the finish line. The players started in a  
253 staggered stance with the same preferred leg in a forward position. Braking was also  
254 performed with the same preferred leg. Two trials were executed and were interspaced  
255 by a 3-minute rest period. The players wore a GPS unit during the trials. The PRS attained  
256 in each trial was collected and used in further statistical analysis.

257

### 258 *Analytical-Based Soccer Drill*

259 A standard crossing and shooting drill, typically performed as part of a regular  
260 training session, was also used to estimate RPS (Figure 1). Accordingly, players were  
261 familiarized with the utilized format. The drill began with players standing 40-m away  
262 from the goal. A row of three players was positioned with one of each on the left, at the  
263 center, and on right of the field. The player in the center had possession of the ball.  
264 Following the coach's instruction, this player performed a long pass aiming for the  
265 furthest 10-meter portion of the pitch (i.e., 30+ metres away) on the left or right sides.  
266 The player that was positioned on the side that this pass was directed to sprinted  
267 maximally in an attempt to collect the ball. Once the sprinting player gained possession  
268 of the ball, the original passing player from the center, and the player from the opposite

269 side to which the pass was directed, sprinted maximally to enter the goal area. The player  
270 who had received the original pass then ran with the ball before performing a cross pass  
271 to his teammates in the goal area, who would then attempt to shoot to the target. The  
272 target was the regularly-sized goal with a goalkeeper utilized as per a match scenario. The  
273 goalkeeper was instructed not to leave the goal and not to constrain the players in  
274 possession of the ball. Thus, goalkeepers were only allowed to perform a shot save in the  
275 line of goal.

276 The players were asked to sprint with maximal intent. The players rotated between  
277 the center (for passing and shooting) and each of the side positions (for crossing). They  
278 adopted the same positions and sequencing in all three of the observed training weeks.  
279 The players performed two trials and were monitored for PRS with the GPS unit. The  
280 trials were interspaced by ~3-minutes of active recovery (jogging back to the next  
281 position). The PRS attained in each trial was collected for statistical analysis.

282

283

284 < FIGURE 1 NEAR HERE

285

286

287 *Match Scenario*

288 Players were grouped into two teams. The traditional 11 vs. 11 format of play (10  
289 outfield players and a goalkeeper) was implemented in two repetitions of 5-minutes  
290 duration (interspaced by 3-minutes of rest). The soccer pitch was 105 × 68 meters. The  
291 players were grouped with their regular playing positions taken into consideration. The  
292 coach selected the teams based on his perception of players' individual abilities, aiming  
293 to provide two equally competitive sides. It is important to mention that each team

294 consisted of an equal distribution of typical starters and non-starters, carefully balanced  
295 across the defensive, midfield, and attacking zones. This composition was maintained  
296 consistently throughout the three observed sessions, ensuring the stability and consistency  
297 of the experimental setup. The players wore the GPS units to measure the PRS achieved  
298 during these match scenarios. The PRS attained during each repetition was collected and  
299 treated further for statistical analysis.

300

### 301 *Statistical procedures*

302 Preliminary inspection of the normality and homogeneity of the data was carried  
303 out using the Shapiro-Wilk and Levene's tests, respectively. Results indicated the  
304 accomplishment of assumptions of normality and homogeneity ( $p>0.05$ ). Within-session  
305 variability was tested using the data median across the three-week trial. The coefficient  
306 of variation (expressed as a percentage) and the intra-class correlation test (two-way  
307 random, absolute agreement, and average measures) was used to determine reliability.  
308 On the other hand, the paired t-test was used to evaluate potential variations in  
309 performance between Trial 1 and Trial 2. Cohen's  $d$  was used as the effect size measure  
310 and was calculated using the sample standard deviation of the mean difference adjusted  
311 by the correlation between measures. The effect size magnitude followed Cohen's own  
312 classifications (18): 0.0-0.2, trivial effect size; 0.41-1.14, recommended minimum effect  
313 size; 1.15-2.69, moderate effect size;  $>2.70$ , strong effect size. Furthermore, within-  
314 session comparisons were conducted by generating Bland-Altman plots for each test,  
315 incorporating 95% confidence intervals.

316 To calculate between-session variability, the coefficient of variation and the intra-  
317 class correlation (two-way random, absolute agreement, and average measures), the  
318 highest PRS in each session was used. Repeated measures ANOVA was used to compare

319 the variations between the observed training weeks with the Bonferroni adjustment used  
320 post-hoc analysis. Comparisons between the best scores in each test and drill scenario  
321 were performed using a repeated measures ANOVA. Finally, a Pearson's product-  
322 moment correlation test was performed to test the relationships between the PRS attained  
323 in each test and scenario. The correlation magnitude was classified as: 0.0-0.1, trivial;  
324 0.1-0.3, small; 0.3-0.5, medium; 0.5-1.0, large (14). All the statistical procedures were  
325 executed in the SPSS software (version 28.0.0.0, IBM, Chicago, USA) for a  $p < 0.05$ .

326

## 327 **Results**

328 Table 1 displays the within-session analysis, evaluating the variability of Trial 1  
329 and Trial 2 across three different training sessions. Trial 1 represents the results of the  
330 first repetition performed for each test, while Trial 2 shows the results of the second  
331 repetition for the same test. Table 1 presents the variability within-trial, the differences  
332 between means, and the intraclass correlation test. It was possible to observe that the  
333 variability between trials (within-session) was acceptable (below 3.3%) except for the  
334 match (8.0% coefficient of variation). Significant differences were also found between  
335 trials 1 and 2 in the match scenario (2.5 km/h of difference;  $p < 0.001$ ;  $d = 1.021$ ).  
336 Furthermore, Figure 2 presents the Bland-Altman plots, which illustrate the limits of  
337 agreement and facilitate the analysis of agreement between trials for each conducted test.  
338 Specifically, for the 5-0-5 test, the average difference was 0.3, with lower and upper 95%  
339 confidence interval limits of -2.5 and 2.0, respectively. In the case of the 40-meter test,  
340 the average difference was 0.1, with lower and upper 95% confidence interval limits of -  
341 2.0 and 2.1, respectively. For the analytical-based soccer drill, the average difference was  
342 -0.2, with lower and upper 95% confidence interval limits of -3.3 and 2.9, respectively.

343 Finally, in the match scenario, the average difference was 2.5, with lower and upper 95%  
344 confidence interval limits of -0.1 and 5.2, respectively.

345

346

347 <TABLE 1 NEAR HERE

348

349 <FIGURE 2 NEAR HERE

350

351

352 The between-session analysis can be found in table 2. The 40-m linear sprint test  
353 and the analytical-based soccer drill presented the smallest coefficient of variations  
354 within-subject between the sessions ( $3.3\pm 2.5$  and  $3.6\pm 2.3\%$ , respectively). Repeated  
355 measures ANOVA revealed significant differences in PRS between training sessions on  
356 the 5-0-5 test ( $p=0.007$ ;  $\eta_p^2=0.119$ ) and match scenario ( $p=0.005$ ;  $\eta_p^2=0.145$ ). No  
357 significant differences were found between sessions regarding the 40-m linear sprint test  
358 ( $p=0.337$ ;  $\eta_p^2=0.027$ ) and analytical-based soccer drill ( $p=0.186$ ;  $\eta_p^2=0.044$ ).

359 Overall (the three sessions pooled), the intra-class correlation test (for absolute  
360 agreement) revealed that the PRS attained in the 5-0-5 (ICC=0.536, [95%CI:  
361 0.236;0.735]), 40-m linear sprint test (ICC=0.693, [95%CI: 0.483;0.827]), and analytical-  
362 based soccer drill (ICC=0.593, [95%CI: 0.318;0.770]). Smaller ICC values were found  
363 for the match scenario (ICC=0.013, [95%CI: -0.538;0.413]).

364

365

366 <TABLE 2 NEAR HERE

367

368

369           Table 3 presents the comparisons of the best PRS attained during the three weeks  
370 for each of the tests and scenarios. The highest speed was found in the 40-m linear sprint  
371 test ( $30.6 \pm 1.5$  km/h), followed by the analytical-based soccer drill ( $30.1 \pm 1.1$  km/h). The  
372 repeated measures ANOVA executed to test the variations of the best values attained  
373 during the three weeks between tests and scenarios revealed significant differences  
374 between them ( $p < 0.001$ ;  $\eta_p^2 = 0.913$ ).

375

376

377 < TABLE 3 NEAR HERE

378

379

380           Pearson's product-moment correlation test was executed to test the relationships of  
381 the best PRS between tests and scenarios. Large correlations were found between the 40-  
382 m linear sprint test and the analytical-based soccer drill ( $r = 0.742$  [95%CI: 0.554; 0.853];  
383  $p < 0.001$ ). Moderate correlations were found between the 5-0-5 test and the 40-m linear  
384 sprint test ( $r = 0.442$  [95%CI: 0.146; 0.659];  $p = 0.004$ ), the 5-0-5 and the analytical-based  
385 soccer drill ( $r = 0.346$  [95%CI: 0.034; 0.591];  $p = 0.029$ ) and the analytical-based soccer  
386 drill and match scenario ( $r = 0.355$  [95%CI: 0.044; 0.597];  $p = 0.025$ ). The remaining  
387 relationships were trivial to small. Figure 3 presents the scatterplot of the best PRS  
388 attained during the three weeks for each test and scenario.

389

390

391 <FIGURE 3 NEAR HERE

392

393

## 394 **Discussion**

395         The primary aim of the current study was to compare the PRS attained in the 40-m  
396 linear sprint test with the 5-0-5 test, an analytical-based soccer drill, and match format  
397 scenarios. By analyzing the PRS results from these different test formats, we sought to  
398 gain insights into the relationships and potential differences between the tests, which  
399 could provide valuable information for coaches and practitioners in the field of soccer  
400 training and assessment. Additionally, we also aimed to analyze differences between  
401 training sessions and identify how the tests can vary from session to session, while also  
402 investigating the within-test variability.

403         The results of the study suggest that: (1) PRS presents low within-session and  
404 between-session variability in the 5-0-5 test and 40-m linear sprint tests as well as in a  
405 analytical-based soccer drill, but presents a high level of variability in match scenarios;  
406 (2) measured PRS is significantly greater in the 40-m linear sprint test than in the  
407 remaining tests and scenarios, although the percentage of difference in the analytical-  
408 based soccer drill is 1.6% and the magnitude of the effect size is small; (3) there is a  
409 significantly large correlation between PRS in the 40-m linear sprint test and the  
410 analytical-based soccer drill.

411         The variability of the four tests and scenarios applied was tested within- and  
412 between sessions. The coefficient of variation for within-session variability (two trials)  
413 revealed that the 5-0-5, 40-m linear sprint and analytical-based soccer drill had a within-  
414 subject coefficient of variation below 3.3% compared to 8.0% in match scenarios.  
415 Utilizing the Bland-Altman method to assess within-test agreement between trial 1 and  
416 trial 2 (Figure 2), our analysis reveals variations in agreement levels among the four tests  
417 examined. Specifically, the 5-0-5 and 40-m linear sprint tests exhibit lower levels of

418 agreement, with an average difference of approximately 0 and confidence intervals  
419 spanning approximately 2. In contrast, the analytical drill shows a similar average  
420 difference of approximately 0 but wider confidence intervals, ranging around 3. The  
421 match scenario, conversely, presents the most substantial average difference of  
422 approximately 2.5.

423         This significant mean difference may stem from several factors. Firstly, the intricate  
424 and dynamic nature of a soccer match (24), often influenced by various contextual and  
425 tactical factors, can lead to scenario-dependent variations in player movements and  
426 behaviors (23,39). Consequently, this complexity increases the likelihood of variability  
427 in test outcomes across similar scenarios. Additionally, the choice of measurement  
428 instruments may contribute, as GPS devices at peak speeds are known to exhibit lower  
429 reliability and greater variability (43). However, this particular issue was less pronounced  
430 in the remaining tests (5-0-5, 40-m, and analytical-based drill).

431         In light of these findings, it is important for coaches to recognize that the dynamic  
432 nature of soccer matches may not consistently provide ideal conditions for achieving  
433 consistent test outcomes (29). These outcomes are intricately linked to the ever-changing  
434 contextual and dynamic elements inherent in the inherently chaotic nature of dynamic  
435 systems (24).

436         Regarding between-session variability, it was found that only the 40-m linear sprint  
437 and the analytical-based soccer drill had a coefficient of variation of between 3.3 and  
438 3.6%, with the 5-0-5 tests demonstrating 5.6% and the match scenario 13.2%. These  
439 results suggest that the 40-m linear sprint test and the analytical-based soccer drill offer  
440 the smallest within- and between-session variability when measuring PRS. The results  
441 for the 40-m linear sprint were expected given that the coefficient of variation for this  
442 measure is typically < 3% (3). Additionally, the ICCs for within- and between-session

443 measures normally exceed 0.75 (22,35,41) an observation that was confirmed in our study  
444 with an ICC of 0.832 observed. However, despite this, the between-session ICC for this  
445 measure in our study was 0.693 indicating a lower degree of agreement over a more  
446 extended period of time during the season.

447         Interestingly, the analytical-based soccer drill presented small within- and between-  
448 session variability (ICC), which suggests that this exercise can provide coaches with good  
449 repeatability in a scenario which closely replicates the demands and characteristics of  
450 soccer play. That both the 40-m linear sprint and the analytical-based soccer drill  
451 presented lower variability and higher reliability can potentially be attributed to the linear  
452 nature of the exercises in terms of the running demands placed on the athlete. Previous  
453 studies (15,37,47) suggest that the measurement reliability of a sprint test is correlated to  
454 the distance that an individual traverses in a given test. Considering that the analytical-  
455 based soccer drill required participants to cover a 40-m distance, lower variability and  
456 greater reliability might reasonably have been expected in this test relative to the 5-0-5  
457 test. Although not presenting the same levels of reliability as the 40-m linear sprint, the  
458 analytical-based soccer drill does require participants to demonstrate soccer-specific  
459 skills in addition to sprinting, thus providing coaches with a viable and more sport-  
460 relevant alternative to precisely measure PRS. On the other hand, the ecological  
461 alternative of the match scenario revealed greater within and between-session variability  
462 and a poor level of reliability thus calling into question its usefulness as a measure of in-  
463 season PRS. The positional demands of a soccer match as well as the contextual factors  
464 associated with that match may mean that only some players are required to reach PRS  
465 on a repeated basis. This is confirmed by the greater between-match variability reported  
466 in previous studies (23,28) which can be attributed to the tactical and technical constraints  
467 and collective behaviors within a given match (5).

468 In addition to the match scenario being a less reliable method to determine PRS, it  
469 presents a 14.1% difference in PRS when compared to that captured in the 40-m linear  
470 sprint test and 12.6% when compared to that observed in the analytical-based soccer drill.  
471 While the PRS was 21.2 km/h in the 5-0-5 test and 26.3 km/h in the match scenario,  
472 players achieved velocities of 30.1 km/h in the analytical-based soccer drill and 30.6 km/h  
473 in the 40-m linear sprint. The magnitude of difference was large between the 5-0-5 test  
474 and match scenario compared to the analytical-based soccer drill and the 40-m linear  
475 sprint. However, the magnitude of difference between the analytical-based soccer drill  
476 and the 40-m linear sprint was small, although statistically significant.

477 A match scenario did not appear to offer the requisite conditions to detect PRS in a  
478 previous study that compared small-sided games, match scenarios and linear sprinting to  
479 determine maximum velocity (29). The explanation for such a result can be attributed to  
480 the limited space to execute longer sprints in a soccer match (40) restriction imposed by  
481 playing position constraints which prevent players from running over extended distances  
482 and reducing the possibility of achieving maximum speed. A previous study comparing  
483 the maximum velocity attained in a 40-m linear sprint and match scenarios revealed that  
484 none of the players achieved the maximum velocity in the match and that the playing  
485 position had a vital role in determining those that did (34).

486 While the match scenario may not guarantee the optimal conditions to achieve PRS  
487 as a linear speed test, coaches often raise concerns about the specificity of certain tests,  
488 leading to their limited use. To address this, we proposed an analytical-drill based task to  
489 offer coaches an alternative option that may not have as much within and between player  
490 variability in terms of PRS as a match scenario, but it can provide some degree of  
491 specificity compared to traditional linear speed tests. By having this option available,  
492 coaches may be more inclined to use the tests more frequently, allowing sports scientists

493 and strength and conditioning coaches to monitor the training stimulus provided to  
494 players and identify potential adaptations over longer periods of observation.  
495 Furthermore, this approach ensures that the tests can easily fit into the regular training  
496 schedule of the coach, facilitating its practical implementation.

497 In the current study, the 5-0-5 test also significantly underestimated PRS in  
498 comparison to the 40-m linear sprint and the analytical-based soccer drill. This is  
499 explainable due to the 5-0-5 test only allowing a player to run linearly for 15-m before  
500 decelerating and changing direction. Considering that soccer players often require  
501 distances of up to 30-m to achieve the maximum velocity (9), it could be argued that the  
502 5-0-5 test is not an appropriate way to measure PRS. However, it may offer an opportunity  
503 to measure accelerative abilities in soccer players.

504 The additional analysis of relationships between PRS in the various tests and  
505 scenarios also confirmed that only the 40-m linear sprint test and the analytical-based  
506 soccer drill shared a correlation of large magnitude ( $r=0.742$  [95%CI: 0.554; 0.853]).  
507 These results confirm that among the tests and scenarios utilized in this study, the  
508 analytic-based soccer drill holds meaningful relationships with the demands of the 40-m  
509 linear sprint test, which is considered the gold standard for measuring PRS. From a skill  
510 execution perspective, that the analytical-based soccer drill only implicated a pass, a cross  
511 and a shot without the impediment of opponents reduced the variability of a match  
512 scenario while adding some specificity to the task compared to the 40-m linear sprint.  
513 Although this analytical drill may not fully replicate the complexity of small-sided games  
514 or match scenarios, it is a common practice in shooting and finalization training. The  
515 main purpose of testing this drill was to provide coaches with a focused approach to  
516 improve shooting skills and finalization techniques while also exploring the possibility  
517 of measuring PRS.

518 This study does have some limitations worth noting. Firstly, the sample size, while  
519 consisting of forty participants, aligns with the typical sample sizes seen in recent sports  
520 science research focused on testing the reliability of sprint tests in soccer (20). However,  
521 it's important to highlight that the a priori sample size estimation suggested that the  
522 sample size fell below the required level. This discrepancy could potentially introduce  
523 bias into the final interpretation of the results, as previously discussed (1). Consequently,  
524 the statistical findings may be somewhat compromised, and generalizations should be  
525 made cautiously. Moreover, the match scenario was analyzed in training sessions and not  
526 in an official match which may constrain players' maximal efforts differently at various  
527 junctures, for example, late in the game when fatigue is present. Additionally, the duration  
528 of the match scenario was limited to two repetitions of 5 minutes each. While this allowed  
529 for controlled testing conditions, it may not provide the necessary ecological validity to  
530 fully capture the demands of an actual game and attain accurate PRS. Longer match  
531 scenarios or multiple repetitions may be necessary to better simulate real-game situations  
532 and gather more comprehensive data on players' performance.

533 Moreover, it is important to note that the tests and scenarios were conducted in a  
534 predetermined order rather than randomly (i.e., 5-0-5, 40-m linear sprint, analytical-based  
535 soccer drill, and match). This sequential approach introduces the possibility of  
536 interference from fatigue effects. For example, we cannot definitively ensure that match  
537 performance was not significantly influenced by the preceding test performances. It is  
538 worth mentioning that adopting a random order for the tests would have circumvented  
539 such an issue. However, it is also fair to acknowledge that soccer players frequently  
540 execute peak efforts in various periods throughout a 90-minute match. For instance, a  
541 recent study revealed that maximum speed actions are distributed across different  
542 intervals of the first and second halves, with around 22.7% occurring in the first 15

543 minutes and 21.9% between the 45th and 60th minutes (38). Additionally, 10 to 15% of  
544 maximum speed actions were observed in the second and third thirds of the match (38).  
545 This suggests that even after periods of recovery, players are still capable of delivering  
546 peak efforts over extended durations.

547 In our study, the match scenario was limited to 10 minutes, interspersed with 3  
548 minutes of rest (5+5 minutes in total). These timings align with when players often  
549 prepare to engage in peak-speed actions during actual game scenarios. It's worth  
550 mentioning that before the match scenario commenced, there was a 5-minute (i.e., 300-  
551 second) rest period. In real soccer matches, players, on average, recover for  $139\pm 43$   
552 seconds between high-intensity actions (11), which is notably less than the rest periods  
553 provided in our study design. It is also important to note that in maximal velocity training,  
554 recovery times between maximal sprints typically range from 4 to 15 minutes (26).  
555 However, these longer rest intervals are commonly recommended for elite sprinters, who  
556 engage in 30 to 40 sprints (26), a stark contrast to soccer players who perform shorter  
557 sprints covering less than 20 meters and achieve lower speeds compared to elite sprinters  
558 (27).

559 Therefore, while it is a recognized fact that randomizing the test order would be the  
560 ideal methodological design, we should also emphasize that the rest periods between tests  
561 may not necessarily compromise player performance. This potential bias should be  
562 acknowledged by coaches and the scientific community when interpreting the present  
563 results.

564 Additionally, the three-week period could be considered a limitation of the study,  
565 as a longer duration might provide more sensitivity to capture potential seasonal changes  
566 and accurately determine the actual changes in sprint ability. A more extended study  
567 period could help account for variations that occur over the course of a season, thus

568 providing a more comprehensive and robust assessment of the players' sprinting  
569 capabilities. Despite these limitations, the fact that the study has been conducted over  
570 three consecutive weeks and in a relatively large group of over forty players from two  
571 teams offers a solid practical application of the findings.

572         It is important to acknowledge that the current analytical-based soccer drill  
573 employed in this study may not fully replicate the environmental demands of actual game  
574 situations. This is because all players, regardless of their typical playing positions, are  
575 required to perform the same actions. Ideally, future drills should be designed to respect  
576 the playing positions and better approximate the training scenario to the reality of the  
577 game.

578         Since the current analytical-based drill lacks playing position-based training  
579 scenarios, coaches may find it less practical or relevant to incorporate it into their training  
580 routines. Thus, future studies should explore alternative skill-based scenarios that allow  
581 coaches to regularly assess players while maintaining specificity to the sport without  
582 introducing biases to the assessment. It is essential to respect the playing-position  
583 specificity to ensure the drill's effectiveness in evaluating players' skills and performance  
584 accurately.

585

## 586 **Practical applications**

587         While acknowledging the potential methodological biases previously discussed in  
588 this article, it is important to note that among the within-session comparisons, the PRS  
589 demonstrated the smallest mean difference (0.1; -2.0-2.1, 95% CI) in the 40-m linear  
590 sprint condition, according to the Bland-Altman analysis. Additionally, it exhibited the  
591 lowest coefficient of variation ( $2.1 \pm 1.5\%$ ) and did not show a significant difference in the

592 paired test ( $p=0.730$ ), accompanied by a trivial effect size in the pairwise comparison  
593 ( $d=0.038$ ).

594 Practically speaking, the 40-m linear sprint test emerged as the most reliable and  
595 stable condition for measuring PRS in the soccer players who participated in this study.  
596 In contrast, the analytical training drill scenario, involving passing, crossing, and  
597 shooting, exhibited an average difference of  $-0.2$  ( $-3.3$  and  $2.9$  95% CI), a coefficient of  
598 variation ( $3.0\pm 2.7\%$ ), no significant difference ( $p=0.215$ ), and a small effect size ( $d=-$   
599  $0.140$ ).

600 In practice, this implies that the 40-m linear sprint is the least variable condition  
601 identified in the current study. However, the analytical-based condition also demonstrated  
602 the potential for reproducibility, albeit without achieving the desired PRS, which is the  
603 primary objective when testing players.

604 Furthermore, when comparing the best PRS, the 40-m linear sprint test and the  
605 analytical drill-based test did not significantly differ from each other ( $p=0.029$ ).  
606 Nevertheless, there was a medium magnitude of difference ( $d=0.339$ ) and a mean  
607 percentage of difference of 1.6% between them. Based on these findings, it is not  
608 recommended to use these tests interchangeably, as they exhibit deviations that can  
609 ultimately influence coaches' assessments and interpretations.

610 Therefore, it is advisable for coaches not to generalize the results and, if feasible,  
611 to incorporate both tests into their assessments. Alternatively, they should be mindful that  
612 while these tests may share some similarities, they provide distinct information and  
613 insights regarding players' abilities. Recognizing these differences will empower coaches  
614 to make more informed decisions when evaluating player performance and designing  
615 tailored training programs.

616

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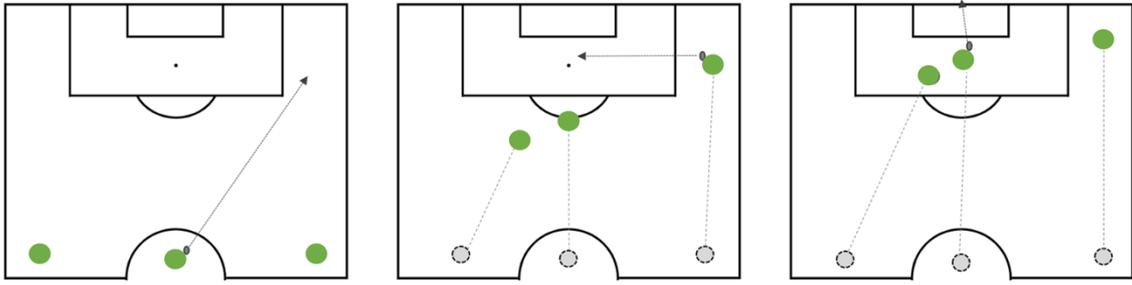


Figure 1. The sequence of actions during the analytical-based soccer drill.

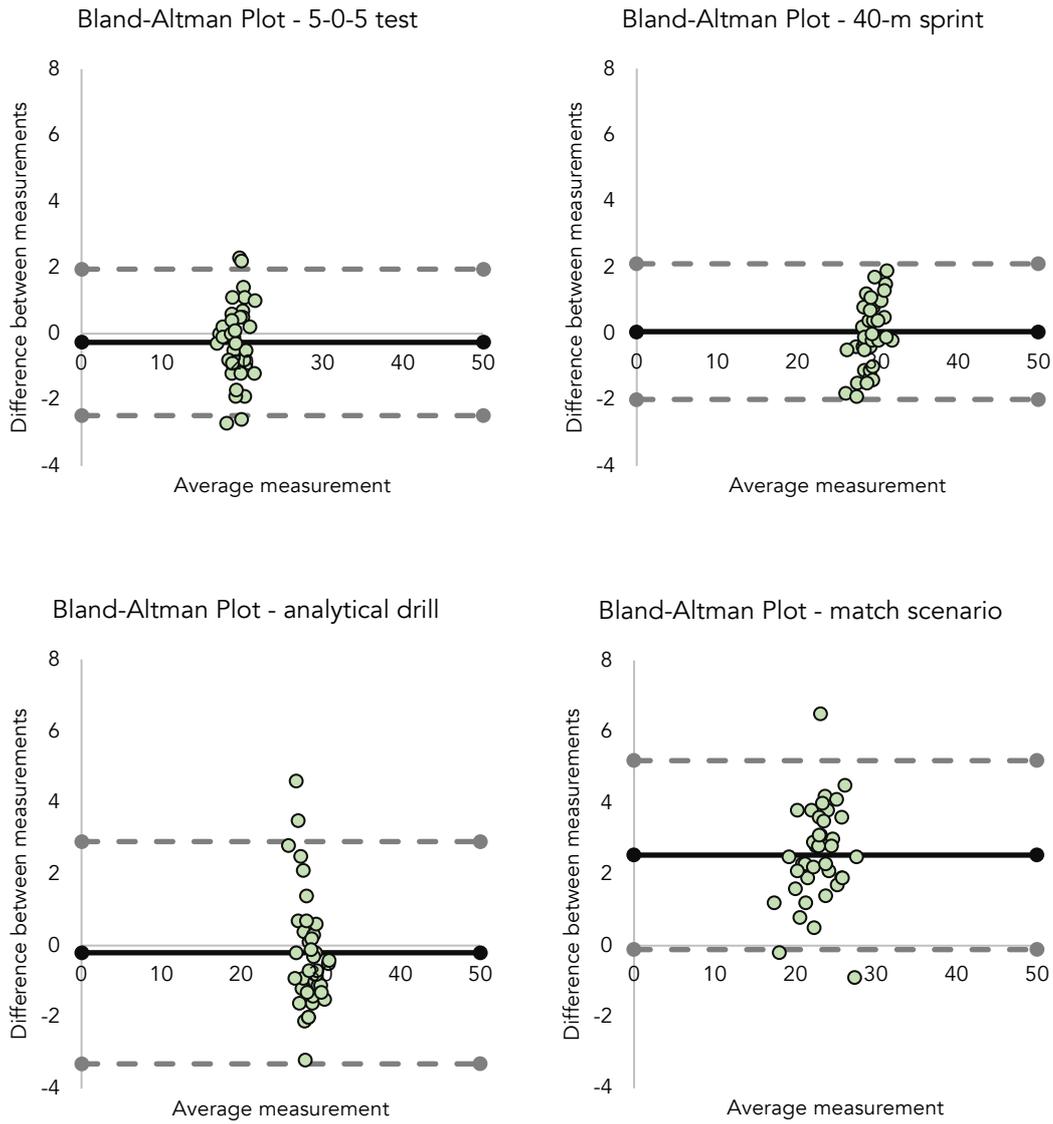


Figure 2. Bland-Altman plots depicting the limits of agreement (95% confidence interval) when comparing trial 1 and trial 2 for the four distinct tests analyzed in the study.

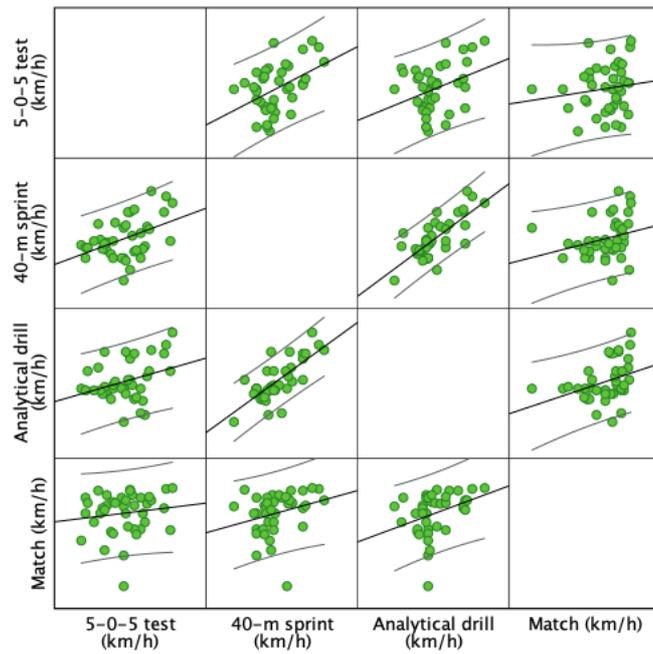


Figure 3. Scatterplot of the best PRS attained during the three weeks for each test and scenario.

Table 1. Within-session analysis (trial one vs. trial 2) for the four tests used to estimate running peak speed.

	T1	T2	%CV between trials	Difference (T1 vs. T2)	ICC* [95%CI]	p	d (T1-T2) [95%CI]
5-0-5 (km/h)	19.2±1.3	19.5±1.2	3.3±2.6	0.3 km/h   1.4%	0.727 [0.490;0.855]	0.150	-0.213 [-0.509; 0.084]
40-m sprint (km/h)	29.1±1.6	29.0±1.1	2.1±1.5	0.1 km/h   0.2%	0.832 [0.681;0.911]	0.730	0.038 [-0.185; 0.262]
Drill (km/h)	28.4±1.1	28.6±1.6	3.0±2.7	0.2 km/h   0.7%	0.523 [0.098;0.748]	0.215	-0.140 [-0.497; 0.217]
Match (km/h)	24.1±2.6	21.6±2.3	8.0±3.7	2.5 km/h   10.5%	0.710 [-0.193; 0.915]	<0.001	1.021 [0.730;1.313]

T: trial; d: Cohen-d value; CI: confidence interval; ICC: intraclass correlation test; \*two-way random; absolute agreement; average measures; drill: analytical-based soccer drill

Table 2. Between-session analysis for the four tests used to estimate running peak speed.

	W1	W2	W3	%CV between sessions	Pairwise Difference (%)	Pairwise comparison (ICC*)	Pairwise comparison (p-value)	Pairwise comparison (d)
5-0-5 (km/h)	19.6±1.5	20.1±1.4	20.5±1.4	5.6±2.9	W1 vs. W2: 2.6%	W1 vs. W2: 0.643	W1 vs. W2: 0.188	W1 vs. W2: 0.306
					W1 vs. W3: 4.6%	W1 vs. W3: 0.189	W1 vs. W3: 0.021*	W1 vs. W3: 0.596
					W2 vs. W3: 2.0%	W2 vs. W3: 0.434	W2 vs. W3: 0.340	W2 vs. W3: 0.306
40-m sprint (km/h)	29.7±1.7	29.4±1.4	29.8±1.8	3.3±2.5	W1 vs. W2: -1.0%	W1 vs. W2: 0.659	W1 vs. W2: 0.842	W1 vs. W2: 0.172
					W1 vs. W3: 0.3%	W1 vs. W3: 0.569	W1 vs. W3: >0.999	W1 vs. W3: -0.075
					W2 vs. W3: 1.4%	W2 vs. W3: 0.582	W2 vs. W3: 0.448	W2 vs. W3: -0.248
Drill (km/h)	28.9±2.1	29.3±1.0	29.3±1.1	3.6±2.3	W1 vs. W2: 1.4%	W1 vs. W2: 0.484	W1 vs. W2: 0.434	W1 vs. W2: -0.253
					W1 vs. W3: 1.4%	W1 vs. W3: 0.441	W1 vs. W3: 0.538	W1 vs. W3: -0.245
					W2 vs. W3: 0.0%	W2 vs. W3: 0.638	W2 vs. W3: >0.999	W2 vs. W3: 0.019
Match (km/h)	22.2±3.9	24.5±3.1	24.5±2.7	13.2±6.6	W1 vs. W2: 10.4%	W1 vs. W2: -0.299	W1 vs. W2: 0.028*	W1 vs. W2: -0.658
					W1 vs. W3: 10.4%	W1 vs. W3: -0.258	W1 vs. W3: 0.021*	W1 vs. W3: -0.682
					W2 vs. W3: 0.0%	W2 vs. W3: 0.611	W2 vs. W3: >0.999	W2 vs. W3: 0.017

W: week; d: Cohen-d value; CI: confidence interval; ICC: intraclass correlation test; \*two-way random; absolute agreement; average measures; drill: analytical-based soccer drill; \*: significant different (p<0.05).

Table 3. Comparisons between the best PRS attained during the three weeks for each test and scenario.

	5-0-5 <sup>a</sup> (km/h)	40-m sprint <sup>b</sup> (km/h)	Drill <sup>c</sup> (km/h)	Match <sup>d</sup> (km/h)	Pairwise Difference (%)	Pairwise comparison (p-value)	Pairwise comparison (d)
Best	21.2±1.1	30.6±1.5	30.1±1.1	26.3±2.4	a vs. b: 44.3%	a vs. b: <0.001	a vs. b: -6.863
					a vs. c: 42.0%	a vs. c: <0.001	a vs. c: -7.868
					a vs. d: 24.1%	a vs. d: <0.001	a vs. d: -2.685
					b vs. c: -1.6%	b vs. c: 0.029	b vs. c: 0.339
					b vs. d: -14.1%	b vs. d: <0.001	b vs. d: 2.094
					c vs. d: -12.6%	c vs. d: <0.001	c vs. d: 1.910

Drill: analytical-based soccer drill