Is physical fitness related with in-game physical performance? A case study through local positioning system in professional basketball players

Alejandro Rodríguez-Fernández1, Rodrigo Ramírez-Campillo2, Javier Raya-González3, Daniel Castillo3 and Fabio Y Nakamura4

Abstract
The purpose of this study was to investigate the relationship between physical fitness and external load determined by local positioning system (LPS) in a simulated basketball game. Fourteen professional male basketball players performed a lane agility drill, 20-m maximal sprint speed, countermovement jump (CMJ), drop jump, and repeated sprint tests. Player movements during games (two games of 4 × 7 min) were measured using a portable WIMUPRO LPS and six ultra-wideband antennas. Distance covered, and distance covered in different speed zones, accelerations, and decelerations were recorded. The results obtained showed significant relationship between (a) distance at high decelerations (> –2.0 m s⁻²) and 20-m maximal sprint speed (r = 0.669, p = 0.049); (b) 20-m maximal sprint speed and maximal speed in simulated games (r = 0.576, p = 0.031); (c) CMJ height and sprint distance (> 24.1 km h⁻¹) covered in simulated games (r = 0.772, p = 0.001); and (d) high decelerations and 20-m maximal sprint speed (r = 0.669, p = 0.049) and best time in the RSA test (r = –0.731, p = 0.039). Coaches and strength and conditioning coaches must adjust their training to optimize speed and jumping ability, as they are reflected in physical performance in-game. Players who reach higher speeds (i.e. RSA_best and 20-m sprint time) and CMJ height in field tests may be affected by greater deceleration load in specific training and competition (eccentric contraction). Since hamstring muscles suffer great strain during deceleration, they are more prone to injury, thus these players may require a specific training program to decrease performance losses and risk of injury.

Keywords
Competition demands, basketball, exercise test, physical conditioning, team sports

Date received: 4 April 2021; accepted: 21 June 2021

Introduction
Basketball is a complex and dynamic team sport where the decision-making process is carried out together with physical actions, such as jumps, changes of direction, accelerations, or decelerations.¹ During basketball games, both internal and external demands, referring to measurable aspects occurring internally (e.g. heart rate) or externally (e.g. distance-covered) to the athlete, have been analyzed. The male competitive match requires the player to run 5–6 km,² corresponding to 82.6 ± 7.8 m min⁻¹, associated with 8.2 ± 1.8 body impacts above 5G,³ peak speed of 22.3 km h⁻¹,⁴ and 43 to 145 accelerations.⁵ Meanwhile, analyses of the internal demands of basketball players have revealed a heart rate corresponding to 85% of maximum,⁶ for maintenance of an average of 70% ± 16% of maximal oxygen consumption.⁷ Of note, these demands are conditioned by the competitive level,⁸ and there is usually a significant reduction in physical demands between the first and last quarters.⁹

Physical fitness can be evaluated using field tests (stressing physiological traits that determine...
performance during the match) or actual assessments of physical performance during a match (i.e. relative distance, speed, or accelerations).\textsuperscript{10,11} Associations between field tests and match high-intensity running performance have been explored in team sports,\textsuperscript{10,11} allowing the selection of field tests which are valid and more specific to the physical demands of actual match-play. Previous studies have analyzed the relationship between physical fitness and the match technical performance index in female basketball players.\textsuperscript{12,13} In addition, a few studies have analyzed the relationship between different physical abilities in basketball players,\textsuperscript{14} although none have examined the relationship between physical fitness field tests and match-related external load demands in simulated games.

Previous studies have analyzed the activity demands in basketball through video systems\textsuperscript{15} or microsensor technology.\textsuperscript{5} Advances in micro-technologies have led to the development of accelerometers, magnetometers, and gyroscopes, as well as global positioning systems integrated with portable satellite systems for indoor use. These micro-technology advances have enabled the use of local positioning systems (LPS) to track players indoors.\textsuperscript{16} Different studies have used this technology in the analysis of the external work load in basketball, analyzing the impact of contextual factors (e.g. team ranking),\textsuperscript{17} changes in physical demands between game quarters,\textsuperscript{9} and the effects of rule changes.\textsuperscript{18} However, no research has directly investigated the relationship between physical fitness in a field test and match-related external load in professional male basketball players using LPS technology. Analyzing this relationship will allow physical and conditioning staff to determine if the evaluation of the player’s physical performance through a field test is valid to determine the match physical performance and adjust the training load. Therefore, the aim of this study was to investigate the relationship between physical fitness in a field test and external load in a simulated basketball game in professional male players. The hypothesis was that faster basketball players in field tests would achieve higher speed in simulated games and in turn would cover greater distance in deceleration.

**Methods**

**Design**

A cross-sectional study was designed to test the associations between physical fitness in field tests and external workloads during simulated basketball games.\textsuperscript{10} The physical fitness field tests were carried out in two separate sessions at the same time of day (i.e. 19:30–21:00 h), under similar environmental conditions (temperature: 22.0°C ± 0.1°C; humidity: 32.0% ± 1.5%), and separated by 48 h of recovery. In the first session, the basketball players performed the lane agility drill test (LAD), and after a 5 min rest, a 20-m maximal speed test was performed. In the second session, the players performed a countermovement jump (CMJ), a drop jump (DJ) with arms akimbo, and a repeated sprint ability (RSA) test. In both sessions, the players performed the same standardized warm-up, consisting of jogging (5 min), static and dynamic stretching (5 min), brief bouts of high-intensity running (5 min), and technical actions (5 min). In the following 2 weeks, during training session MD-2 (i.e. two sessions before the next match game), the players performed two simulated games (one each week) consisting of four quarters of 7 min each. Both the physical fitness assessment and the simulated game sessions were carried out in their usual indoor training court. In order to compile two teams with similar performance levels, the members of each team were the same (members and number per team) across the games and were selected at the coach’s discretion, considering usual performance and positional role of players. The coefficient of variation (CV) for playing time in each quarter was 7.5%. During the simulated games, players carried an LPS (WIMU PRO; Realtrack Systems SL, Almeria, Spain) and substitutions were allowed according to the coach’s criteria.

**Subjects**

Fourteen professional male basketball players (age: 21 ± 2 years; height: 190 ± 5 cm; body mass: 87 ± 6 kg) took part in this study. Subjects recruited for the study were reserve team members of a professional Spanish team playing in the national league. The players were divided into two teams of seven members chosen by the coach. Each team consisted of two centers, three forwards, one point guard, and one shooting guard. All players met the following inclusion criteria: no injuries during the previous 2 months, minimum basketball experience of 6 years, and participated in at least 80% of the training sessions during the month prior to study enrolment. The study was carried out in the last part of the first competitive period. In the months prior to their enrollment, the players attended four weekly training sessions (one fitness session, two technical-tactical sessions, and one simulated basketball game session) and an official game every weekend. All subjects signed a Consent Form before study participation, with the objectives and purposes of the study fully explained to them by the lead researcher. The study was performed in accordance with the Declaration of Helsinki (2013) and approved by the Ethics Committee of the University Isabel I.

**Procedures**

**Lane agility drill (LAD) test.** The LAD has been used to assess change of direction speed in basketball players.\textsuperscript{19} After a standardized warm-up, the basketball players performed the LAD test. Starting at the top left corner of the key, 20 cm behind the free-throw line, they sprinted 5.8 m to the baseline, then side-shuffled 4.9 m to the right across the baseline of the basketball court, then ran backwards to the top right corner of the key at
the free-throw line, and finally side-shuffled 4.9 m to the left to touch the floor with their foot at a designated point. They then completed the same circuit in the opposite direction. The time was registered with photoelectric cells (Polifermo Light Radio, Microgate®, Bolzano, Italy) with 0.03 s standard error of measurement and ~2% CV.20 The best time of two maximal trials with a 3 min recovery was registered. The test CV in the present sample of players was 6.3%.

20-m maximal speed. Subjects completed two maximum sprints of 20-m with 2 min of passive recovery. The players started from a standing position, 0.5 m behind the first photoelectric cell (Polifermo Light Radio, Microgate®, Bolzano, Italy), before running at maximal speed to the second photoelectric cell. The fastest sprint was recorded and the maximum speed was calculated. The test CV in the present sample of players was 5.2%.

Jump test. Subjects performed three CMJ and three DJ with 45 s of passive recovery between maximal attempts. No restrictions were imposed on knee angle during the eccentric phase of the jumps. Subjects were required to maintain straight legs during the flight phase of the jumps. The DJ was performed from a 40 cm box. The starting position involved the subjects standing upright on the box. The subjects were then instructed to step off (not jump off) the box with their preferred leg, which was kept consistent for all the trials. The subjects were then instructed to explode up off the floor, attempting to minimize contact time. Performance in the CMJ and DJ was determined with the mobile application MyJump 2.0. The application demonstrates strong validity (r = 0.995, p < 0.001) and reliability (intraclass correlation coefficient r = 0.997, p < 0.001) for assessing CMJ height.21 Every jump was recorded at 240 Hz with an iPhone 8 Plus mobile device (Apple Inc., CA, USA). The CVs were 15.1% and 15.4% for the CMJ and DJ, respectively.

Repeated sprint ability test (RSA). To assess the RSA, players performed five 30-m (15 + 15 m with 180° turns) sprints, separated by 25 s of passive recovery. The basketball players started from a line situated 0.5 m behind the first timing gate (Polifermo Light Radio, Microgate®, Bolzano, Italy), sprinted 15 m, touched a line with a foot and ran back to the starting line as quickly as possible. After passive recovery, the basketball players completed five more sprints. Players were free to choose the preferred leg to perform pivoting during the change-of-direction in each sprint. The performance in this test was determined by the fastest (best) sprint (RSA_best), summed (total) time from the five sprints (RSA_total), and percentage of sprint speed decrement (RSA_Sdec).22 The test CVs in the present sample of players were 4.0%, 4.1%, and 32.2% for the RSA_best, RSA_total, and RSA_Sdec, respectively.

Assessment of external workloads during simulated games

The week after the physical fitness field tests were completed, two simulated basketball games (1 week apart) were performed on the team’s usual synthetic training and competition surface court, using 5×5 player formats, on a 28 m × 15 m court surface. In the two simulated basketball games, two teams of seven subjects (i.e. two players from each team were on the bench at any given moment) played against each other for four quarters of 10 min. The simulated games started at 19:30 h. During each simulated game, official basketball rules were followed, together with a regular-stop dynamic. To maintain intensity at near-maximal condition, coaching staff freely utilized substitutions or deliberate foul tactics.

Player movements were measured during the simulated games using a portable LPS with inertial measurement units (IMUs)(WIMU PRO; Realtrack Systems SL, Almeria, Spain). These devices include an accelerometer, gyroscope, magnetometer, and LPS. The sampling frequencies for three-axis accelerometer, gyroscope, and magnetometer were 100 Hz and 120 kPa for the barometer. The WIMUs (height 85 mm × width 48 mm × depth 15 mm, weight 65 g) were fitted to the upper back of each player using adjustable harnesses. The system had six ultra-wideband antennas (UWB) placed 4.5 m from the perimeter line of the field, and the sampling frequency for positioning data was 18 Hz. Each player was fitted with the inertial device 20 min before the start of the match. The system operates using triangulations between the antennas and the units.18 For UWB technology, CV (test-retest reliability) between 0.54% and 1% and a relative typical error of measurement (%TEM) (inter-unit reliability) between 1.12% and 1.19% were reported in a previous study.23 Data were analyzed using the system-specific software (WIMU Software; Realtrack Systems SL).

To analyze the relationship between physical performance and external workloads, the following variables were calculated per minute during each simulated game: distance covered and distance covered in speed zones, including walking (≤6.0 km h⁻¹), jogging (6.0–12.0 km h⁻¹), running (12.1–18.0 km h⁻¹), high-intensity running (HSR) (18.1–24.0 km h⁻¹), and sprinting (>24.1 km h⁻¹).3,18 In addition, steps (n min⁻¹) and jumps (n min⁻¹) were registered. The acceleration and deceleration variables analyzed were distance covered and distance measures derived for different intensity categories: low accelerations (<2.0 m s⁻²), high accelerations (>2.0 m s⁻²), low decelerations (<−2.0 m s⁻²), and high decelerations (>−2.0 m s⁻²). The absolute values registered were maximal speed (km h⁻¹), player load, which represents the accumulative
workload in the three axes of movement during all sessions. This was calculated using the vector magnitude expressed as the square root of the sum of the squared instantaneous rates of change in acceleration in each of the three planes divided by 100. These variables were calculated using S PRO WIMU Software (Realtrack Systems SL, Almeria, Spain).

Statistical analysis

Results are reported as mean and standard deviation (SD), minimum and maximum. Data normality was confirmed with the Kolmogorov-Smirnov test. The relationship between physical fitness in field tests and simulated game external workload was assessed using Pearson’s correlation with a 90% confidence interval (CI). The magnitude of the correlation coefficient was considered trivial (r < 0.1), small (0.1 < r < 0.3), moderate (0.3 < r < 0.5), large (0.5 < r < 0.7), very large (0.7 < r < 0.9), and nearly perfect (r = 1.0). The CV was determined as (SD mean)² / 100 to assess the variability of each fitness test. Analyses were carried out using SPSS (v25 SPSS Inc.; Chicago, IL, USA) and statistical significance was set at p < 0.05.

Results

Descriptive statistics of the field tests and simulated match running performance are reported in Tables 1 and 2, respectively.

Relationships between field test and acceleration or deceleration in simulated game external load are reported in Table 3. The physical fitness performances in the T-Test and DJ test were not significantly associated with acceleration or deceleration in the simulated games (data not indicated).

The association between maximal speed in simulated games and 20-m sprint test was significant (r = 0.576, 0.576, 0.576).
Table 3. Correlations between acceleration and deceleration variables and performance in field tests.

<table>
<thead>
<tr>
<th></th>
<th>LAD (s)</th>
<th>20-m maximal speed (km h(^{-1}))</th>
<th>CMJ (cm)</th>
<th>RSA(_{\text{Sdec}}) (%)</th>
<th>RSA(_{\text{best}}) (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accelerations</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(m min(^{-1}))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LAD</td>
<td>r = 0.383; p = 0.349</td>
<td>r = -0.126; p = 0.747</td>
<td>r = -0.188; p = 0.764</td>
<td>r = 0.347; p = 0.400</td>
<td>r = 0.506; p = 0.201</td>
</tr>
<tr>
<td>Decelerations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(m min(^{-1}))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LAD</td>
<td>CI = -0.09 to 0.72</td>
<td>CI = -0.55 to 0.35</td>
<td>CI = -0.60 to 0.70</td>
<td>CI = -0.13 to 0.70</td>
<td>CI = 0.06 to 0.78</td>
</tr>
<tr>
<td>High accelerations</td>
<td>r = 0.783*; p = 0.022</td>
<td>CI = 0.05 to 0.909</td>
<td>CI = -0.30 to 0.288</td>
<td>CI = 0.409; p = 0.315</td>
<td>CI = 0.674; p = 0.067</td>
</tr>
<tr>
<td>High decelerations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(m min(^{-1}))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LAD</td>
<td>r = -0.253; p = 0.546</td>
<td>r = 0.219; p = 0.752</td>
<td>r = -0.133; p = 0.754</td>
<td>r = 0.573; p = 0.736</td>
<td>r = 0.401; p = 0.325</td>
</tr>
<tr>
<td>Low accelerations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(m min(^{-1}))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LAD</td>
<td>CI = -0.64 to 0.23</td>
<td>CI = 0.51 to 0.91</td>
<td>CI = -0.72 to 0.97</td>
<td>CI = -0.06 to 0.73</td>
<td>CI = 0.31 to 0.87</td>
</tr>
<tr>
<td>Low decelerations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(m min(^{-1}))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LAD</td>
<td>r = -0.482; p = 0.227</td>
<td>r = 0.715*; p = 0.046</td>
<td>CI = -0.30 to 0.247</td>
<td>CI = -0.30 to 0.247</td>
<td>CI = -0.27 to 0.247</td>
</tr>
<tr>
<td></td>
<td>CI = -0.077 to -0.03</td>
<td>CI = 0.30 to 0.86</td>
<td>CI = -0.03 to 0.74</td>
<td>CI = 0.30 to 0.86</td>
<td>CI = 0.135 to 0.86</td>
</tr>
<tr>
<td></td>
<td>r = 0.305; p = 0.425</td>
<td>r = 0.302; p = 0.429</td>
<td>r = 0.315; p = 0.447</td>
<td>r = 0.315; p = 0.447</td>
<td>r = 0.529; p = 0.177</td>
</tr>
<tr>
<td></td>
<td>CI = 0.38 to 0.98</td>
<td>CI = -0.18 to 0.7</td>
<td>CI = -0.67 to 0.18</td>
<td>CI = -0.17 to 0.68</td>
<td>CI = 0.09 to 0.79</td>
</tr>
<tr>
<td></td>
<td>r = 0.701; p = 0.534</td>
<td>r = 0.240; p = 0.534</td>
<td>r = 0.268; p = 0.485</td>
<td>r = 0.185; p = 0.660</td>
<td>r = 0.705; p = 0.051</td>
</tr>
<tr>
<td></td>
<td>CI = 0.36 to 0.88</td>
<td>CI = -0.25 to 0.63</td>
<td>CI = -0.65 to 0.22</td>
<td>CI = -0.30 to 0.59</td>
<td>CI = 0.36 to 0.88</td>
</tr>
</tbody>
</table>

CI: confidence intervals; CMJ: countermovement jump; High accelerations: distance covered in acceleration > 2.0 m s\(^{-2}\); High decelerations: distance covered in deceleration > 2.0 m s\(^{-2}\); LAD: lane agility drill test; Low accelerations: distance covered in acceleration < 2.0 m s\(^{-2}\); Low decelerations: distance covered in deceleration < 2.0 m s\(^{-2}\); RSA\(_{\text{Sdec}}\): best time in RSA test; RSA\(_{\text{best}}\): decrement in RSA test. Statistically significant values highlighted in bold.
The aim of this study was to examine the relationship between physical fitness in field tests and external load in a simulated basketball game in professional players. The current study identified that there is a significant relationship between distance covered at high deceleration ($>2.0 \text{ m s}^{-2}$) and performance in 20-maximal speed ($r = 0.669$, $p = 0.049$), RSA$_{\text{Sdec}}$ (very large: $r = 0.718$, $p = 0.045$), and RSA$_{\text{best}}$ (very large: $r = -0.731$, $p = 0.039$). In agreement with the hypothesis, basketball players with better 20-m maximal speed reached higher maximum speed while playing (large: $r = 0.576$, $p = 0.031$), and players with higher jump height in CMJ covered significantly greater distance at sprint in simulated games (very large: $r = 0.772$, $p = 0.001$). Time in the LAD test was significantly associated with decelerations (very large: $r = 0.783$, $p = 0.022$) and low accelerations (very large: $r = 0.715$, $p = 0.046$). These findings may have important implications for practitioners when selecting appropriate tests to determine the level of physical performance, monitoring training effects, and detecting players that require different training strategies.

The results obtained in certain tests are very similar or identical to the results of previous studies. For instance, the results of CMJ height in this study (38.3 ± 5.6 cm) are similar to those shown by other elite basketball players (39.8 ± 5.1 cm) of the same age. One of the most widely used tests to assess speed in basketball players is the 20-m maximal speed. The players in this study had a speed of 23.56 ± 1.08 km h$^{-1}$ or 3.1 ± 0.1 s in the referred test. This speed is similar ($-3.2 s$) to that shown by players of similar age and the same competitive level. On the other hand, RSA$_{\text{best}}$ in the present study was better ($-5\%$) than that obtained by previous studies with younger subjects.

LAD test time in the present study was similar (11.64 vs 11.67 s) to that shown previously for basketball players. In reference to workload demands experienced by players in the simulated basketball games, the distance covered was the strongest predictor of game performance. In this study, players covered a greater distance ($84.96 \pm 8.82 \text{ m min}^{-1}$) than that shown by studies which used LPS in 5vs5 games ($63.4 \pm 3.6 \text{ m min}^{-1}$) or in young elite basketball players ($72.9 \pm 2.74$). The distance covered in the present study was also greater than the distance reported in both the first ($77.5 \text{ m min}^{-1}$) and fourth ($69.0 \text{ m min}^{-1}$) quarters in young players from eight professional men’s basketball teams from six countries. This difference may be due to the age of the subjects, since in the present study, the participants were older than the participants in the referred studies (21 ± 2 vs ~18 years). However, this value is lower (~50%) than that shown by studies that use video analysis. Peak match speed reached during competition was similar to that obtained in previous studies (~20 km h$^{-1}$) using LPS. $^{9,17,16}$ Although maximum speed is an important factor in team sports, the ability to accelerate and decelerate can be more determinant in field performance. Acceleration and deceleration require higher neural activity and are key activities to obtain advantages in team sports. The distances covered in acceleration and deceleration at high-intensity ($>2.0 \text{ m s}^{-2}$) were similar (1.7 vs ~1.8 and 1.9 vs ~1.5 m min$^{-1}$, respectively) to those reported by previous studies. These values are very important for staff, since a higher number of maximal decelerations can largely increase the mechanical stress imposed on players. Therefore, coaches should place a large emphasis on improving this quality.

The main findings of this study were the significant relationship between deceleration at high intensity ($>2.0 \text{ m s}^{-2}$) determined by LPS and 20-m sprint time (large: $r = 0.669$, $p = 0.049$) and RSA$_{\text{best}}$ (very large: $r = -0.731$, $p = 0.039$). Players who reached higher speeds in field tests covered greater distance in...
deceleration at high intensity in simulated games. The deceleration phase is characterized by an important decrease in speed, an increase in eccentric muscle contractions that absorb and disperse forces throughout the body,36 and low locomotor-related metabolic demands.37 Basketball requires period of high-intensity, repeated sprint activity interspersed with short distances of deceleration in order to stop or change direction.2,3,15 In this sense, faster players experience high eccentric forces, generated during sprinting strides, and especially during deceleration,36,39 when they achieve greater peak speeds and have to decelerate more frequently. Quadriceps muscles are actually considered to be the primary muscles to contribute to the absorption of strong eccentric forces that occur during deceleration ground contacts.40 In addition, hamstring muscles play a key role in deceleration, bearing the major strain during the phase of motion when they transition from decelerating the extension of the knee to extending the hip joint, making them more prone to injury.41 This is important when inducing damage, as faster sprint speeds require greater breaking forces to be applied in the deceleration zone and may consequently assist in maximizing the damage response.42 This aspect should be considered in the design of individualized training strategies and injury prevention programs for these players. Prior bouts of eccentric exercise seem to exhibit a protective effect, resulting in little or no damage in subsequent bouts of exercise43 and this could be a strategy to apply with these players, especially during preseason training.

Previous studies have shown the relationship between speed and the performance index in female basketball players.12,13 In basketball, the 20-m sprint is one of the most commonly used field tests to determine maximal speed.28 Agreeing with the present study’s hypothesis, a significant relationship (large) was observed between 20-m maximal speed and maximal speed in simulated games. In addition to achieving greater speed in competition, faster players perform actions at a lower relative intensity when striding, for example, and may delay the onset of fatigue. Also, as sprint demand is not reduced between quarters,9 these players can demonstrate better physical performance throughout the game. Another commonly used field test in the determination of basketball physical performance is the CMJ.28 The results from the present study showed a significant correlation (very large) between CMJ and the distance covered sprinting (>24.1 km h\(^{-1}\)). Vertical jump (i.e. CMJ) performances were associated with maximum speed in the sprint tests in previous studies,44–46 demonstrating relationships between vertical jumping ability and sprint performance. This may be because both actions contain the stretch–shortening cycle in their movement pattern.47 However, studies that reported this association in team sports used field tests to assess sprint performance,48,49 while in the present study, the association was made with speed in simulated games, showing greater practical application, as it is possible that improvements in vertical jump height can result in improved sprint performances in competition. On the other hand, players with better CMJ and 20-m sprint performances may display increased muscle damage and risk of injury in competition, related to a higher eccentric load in the deceleration phases,42 so specific training and injury prevention strategies have to be applied.

Performance in LAD was significantly correlated with some game-related performance measures (e.g. minutes, assists, rebounds) in male basketball players.50 However, there is a lack of research investigating the relationship between LAD and external demands in simulated games. Contrary to the present study’s hypothesis, LAD time was significantly associated with deceleration \((r = 0.783, \ p = 0.022)\) and low acceleration \((r = 0.715, \ p = 0.046)\) distance in simulated games. However, previous studies showed that the LAD test can reproduce competition actions (e.g. lateral race, change of direction).10 Considering the research addressing the associations between LAD testing and match load responses was inconclusive, further studies should analyze these relationships. Moreover, future investigations should take into account the characteristics and nature of the change of direction test in order to expand their construct validity for basketball context.

The principal limitation associated with this study is the low generalization of the findings. Indeed, the study included a small sample size and number of simulated games. However, the subjects were professional basketball players and very few professional teams allow assessment of physical fitness and registration of external load in a simulated basketball game. Future studies may consider multicenter studies to facilitate an increased number of participants and statistical power.51

The main findings of the present study showed a significant relationship between distance covered at high deceleration (>2.0 m s\(^{-2}\)) and performance in 20-m maximal speed \((\text{large}: \ r = 0.669, \ p = 0.049)\) and RSA\(_{\text{best}}\) \((\text{very large}: \ r = -0.731, \ p = 0.039)\). The faster basketball players experienced a longer distance at high deceleration. As this is a phase with a high eccentric load, the risk of injury to these players is higher. Thus, the design of individualized training strategies and injury prevention programs should take these conditions into consideration, especially during preseason workouts. The relationship between CMJ height and distance covered to sprint in competition has great practical application. Since the tests to evaluate CMJ require less time and risk for the basketball player, CMJ is an efficient tool for coaching staff to assess the state of the player. In addition, the relationship obtained between field tests and in-game physical
performance can help in sports detection and the creation of a reference value of the field test physical performance at the beginning of the competitive season.

Conclusion

The significant relationship obtained in this study could help staff to identify and select field tests to determine physical performance in relation to external load in professional basketball players. Basketball staff should focus training on optimizing speed and jump performance due to its reflection on physical performance in-game. In addition, faster players (determined by RSA_{best} and 20-m sprint time) cover a longer deceleration distance in simulated games and since hamstring muscles suffer great strain during deceleration, these players are more prone to getting injured. Therefore, these players may require a specific training program to decrease performance losses and risk of injury.

Acknowledgements

The authors would like to thank the basketball players and the technical staff of the team studied.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iDs

Rodriguez-Fernández, A. https://orcid.org/0000-002-0893-7573
Raya-González, J. https://orcid.org/0000-002-3570-7159
Castillo, D. https://orcid.org/0000-002-4159-6475

References