

Review

Collection and Advice on Basketball Field Tests— A Literature Review

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Featured Application: This work provides a collection of validated basketball-related field tests and test packages intended to aid coaches and other experts in the selection of tests and the building of testing protocols. In addition to collecting study results using these tests, practical advice on test planning and execution is also given to help with the correct application of field tests.

Abstract: We conducted a review to collect the validated basketball-specific physical field tests and to provide practical advice for their appropriate selection and application. A comprehensive electronic literature search was performed via three electronic databases (PubMed, GoogleScholar, and SportDiscuss). Results of 93 studies provided recommendations for seven test packages and eighteen individual tests that have already been validated for basketball players. Although there is a lack of standardized, widely, and systematically used test protocols for testing the fitness levels of basketball players, standardized, normative data from NBA Combine Testing and other basketball-specific tests have the potential to help coaches compare their players with elite basketball players. Our review indicated that agility and reactive agility are fundamental skills in basketball; however, linear sprinting ability should not be considered a determining factor of success for basketball players. Finally, the countermovement jump test can help experts monitor fatigue, loss of explosive force, and interlimb asymmetries. In general, we found that identifying and developing a talented player is a complex task and requires experts from different fields, including trainers, coaches, performance- and movement analyzers, and physiotherapists. We found that during the testing of basketball players, experts always have to normalize their data with anthropometric measures for valid results. Most importantly, although experts always need to define an aim of testing and should follow the protocol of the chosen test, they also have to be open to making adjustments if the actual circumstances require it.

Keywords: basketball; match performance; physical testing; field test

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1. Introduction

Basketball requires a high level and wide variety of athletic skills [1–3]. A basketball player makes a thousand changes of motion during a typical game; consequently, the players work in a high-intensity heart rate zone (above 165 beats/min) during 15% of a basketball match [3]. Lateral movement can account for up to one-fifth of the total traveled distance during a game [4,5], suggesting the importance of agility skills among basketball players. Testing and monitoring of player skills and performance may have multiple aims. In some

cases, we need to identify talents, determine strengths and weaknesses, or predict future performance; in other cases, we want to evaluate the effectiveness of training programs or monitor current health and fitness levels. Despite these reasonable goals, the results of such field tests can also simply be a motivating factor for players and trainers as well [3,6].

The appropriate selection, systematic planning, and correct utilization of physical tests are fundamental [7]. Overall, sport-specific field tests have higher specificity and ecological validity [6]; however, maturity status [3,6,8–11] and anthropometric values [2,3,11–22] need to be considered as they can both influence the results and evaluations of physical tests. To the best of our knowledge, only Drinkwater et al. [3] examined the statistical methods for evaluating changes in fitness. Although null-hypothesis significance testing is the most common method, evaluating the likelihood of meaningful changes or differences is a more exact method of analysis. Moreover, scientists and sports experts must be prudent when comparing data from different sources as they may differ fundamentally [23]. For example, a USA high school court is 22.56 m long, whereas the NBA court is 28.65 m.

Overall, the literature identifies several sport-specific physical field tests of athletic abilities that can help trainers and scouts to make the best decisions during talent identification and development. Our previous review [24] focused on the physical abilities that may potentially differentiate basketball players the most efficiently at different positions and playing levels. We found that successful players can be identified by their unplanned agility and reactive power, considering that these factors affect match outcomes the most at the same competitive level [24]. In contrast, to the best of our knowledge, no prior review aimed to collect field tests to help athletes and experts select the most appropriate one from this wide variety of available tests. Therefore, in the present review, we aimed to summarize the basketball-specific physical field tests logically and to provide practical advice for their appropriate selection and application. We present the identified test packages that are already used to assess the physical condition of basketball players, and we also collect the tests that had been validated in basketball players in the last 11 years. The collected tests reflect on the most recent tests in the literature, thus they do not represent every possibly useful test. Moreover, we collected and present practical advice for test implementation grouped by test types (jump tests, strength tests, sprint tests, and agility tests).

2. Materials and Methods

2.1. Data Sources and Search Strategy

Three electronic databases (PubMed, GoogleScholar, and SportDiscuss) were first searched for publications dated 2000–2020, with the search performed on 12–13 July 2020. However, we finally decided to narrow the publication date limits to 2008–present. Keywords were basketball, agility, power testing, physical assessment, speed performance, jump test, and additional synonyms of these terms. Search terms were modified according to the required search format of each database. As an example, a complete electronic search strategy for the GoogleScholar database is provided here. In the Advanced search option, the following terms were added with Boolean conjunction to search for in 'All in Title': basketball, agility OR speed OR jump OR assessment OR testing OR monitoring OR power. We used some extra articles which we have found for our other literature research on similar topics. The search was refined to journal, book, and thesis publications. Key search terms were identified and agreed upon by AGP and RMK; the electronic search and downloading of results were carried out by AGP. Screening, eligibility check of materials, and data extraction were carried out by AGP, BP, JN, and AC. Following the removal of duplicates, the identified materials were screened based on title and abstract.

2.2. Inclusion and Exclusion Criteria

To meet the inclusion criteria for the review, full-text peer-reviewed English manuscripts investigating healthy basketball players and analyzing the physical field tests of athletic abilities were considered. The exclusion criteria were (1) language of the article was not English, (2) participants were disabled basketball players, or the study focus was injury or injury prevention, (3) the article was an impact study, (4) the main topic was tactical or technical basketball testing or mental and habitual testing, (5) the primary evaluation was based on a subjective measure (e.g., a subjective, visual video analysis), and (6) the main topic was the comparison of basketball with other sports.

2.3. Data Extraction and Analysis

After screening, information extracted from the selected publications include: (1) author and date, (2) applied physical tests, (3) results of the testing, (4) group size of participants, (5) age and sex of groups, and (6) practical advice on testing. We did not undertake a risk of bias assessment because the included studies were not randomized controlled studies and our evidence synthesis method is outside of systematic reviews. However, the quality of the papers was assessed during data synthesis considering the study level, based on study design and participant group characteristics. Results are reported narratively.

3. Results

The search in the PubMed database yielded 1183 records; in the GoogleScholar database, 644 records; in the SportDiscuss database, 241 records (Figure 1). Four additional records from an initial investigation were also included. After removing duplicates, 1211 records remained. After narrowing the date limit to 2008–2020, we had 928 records. We screened out 720 records based on their title and abstract. From the remaining 208 records, only 182 full texts were available. During the eligibility check, we excluded 115 records based on the exclusion criteria. The remaining 93 records met the inclusion criteria and got included in the present review article.

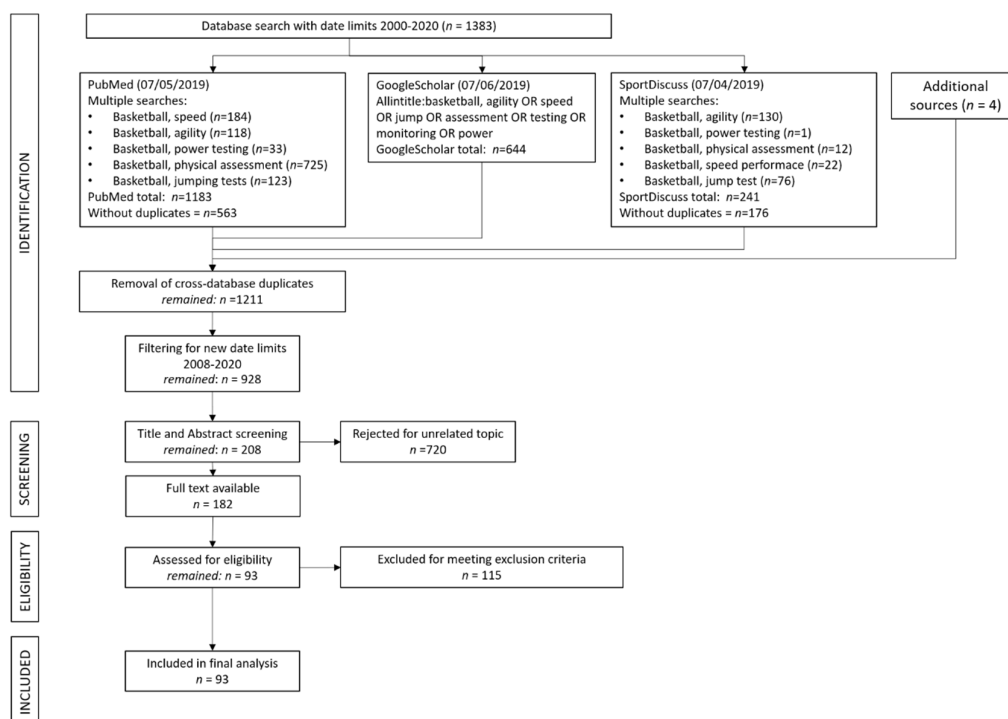


Figure 1. Flow diagram of search results and study identification.

Physical test packages identified through the search are presented in Section 3.1, including four well-known packages which have already been widely used and two other packages recommended by experts based on literature and experience. This section is followed by a collection of 14 previously validated field tests in Section 3.2. In Sections 3.1. and 3.2., a brief description of the tests is given, along with explanatory figures and the most important results of the relevant article records. A more detailed textual description of all included tests and packages is available as Supplementary Material.

3.1. Physical Test Packages

3.1.1. Basketball-Specific Movement Screen

The Australian Institute of Sport (AIS), in coalition with Basketball Australia, developed a comprehensive basketball-specific movement screen that includes five primary movement screens (1. back squat with dowel; 2. overhead squat with dowel; 3. in-line lunge with a dowel, both sides; 4. 30 cm box drop to landing; and 5. single-leg hop plus stick landing, both sides) and four supplementary tests (1. single-leg glute bridge, 12 repetitions on both sides; 2. push-up, 6 repetitions; 3. prone plank test, 1 min; and 4. single leg calf raise on both sides) [25]. The movement screen aims to identify the functional limitations of the athletes throughout their kinetic chain- and sport-specific performance characteristics, i.e., core stability, muscular strength, balance, and coordination. One to three points are given for each primary test depending on the execution. Successful execution of the supplementary tests is a necessary criterion for a valid test. The overall cut-off score was established at 12, under which the risk of injury is considered higher. However, it seems that the predictive ability of the cut-off score has not yet been investigated.

3.1.2. National Basketball Association (NBA) Combine Testing

The NBA Combine Testing [23,26,27] consists of four physical tests (1. bench press; 2. vertical jump tests; 3. lane agility drill; and 4. three-quarter court sprint), and anthropometric measures, i.e., height with and without shoes, weight, wingspan, and standing reach. Currently, body fat percentage is also being measured. The tests and measures of accurate execution are defined by the NBA [26].

3.1.3. Recommendation of the National Sport Science Quality Assurance (NSSQA) Program from Australia

NSSQA recommended a testing protocol [23] for a wide variety of sports, including basketball. It consists of three physical tests: one-step maximal countermovement jump (CMJ), a 20 m straight-line sprint from a standing start, and a 20 m multistage shuttle run test. Besides fitness testing, they recommend anthropometric measurements, including standing height without shoes, nude body mass, and a summation of seven skinfold sites taken from the triceps, subscapular, biceps, supraspinal, abdominal, thigh, and medial calf as an indirect measure of body fat.

3.1.4. Speed, Power, Agility, Reaction, and Quickness (SPARQ)

Sports manufacturer Nike started a new commercial venture named SPARQ [23]. It focuses on the rating system and selling advanced functional fitness training equipment. They created a standardized test for measuring athletic fitness levels between ages 13 and 18. This test package includes CMJ, approach jump (similar to maximal jump in NBA Combine Testing), two agility drills to assess change-of-direction speed separately in offensive and defensive movement patterns, a medicine-ball chest pass, and a multistage cross-court shuttle with short recovery intervals. The ranked result of each test is scored, and these scores are combined into a single summary statistic, the SPARQ Rating [23].

3.1.5. Other Recommendations

Wen et al. [27] analyzed several fitness tests toward identifying essential power-related attributes important in basketball and discussed the suitability of conventional and novel power-related tests. Their results advised the following test protocol: 10 m linear sprint with 5 m and 10 m split times recorded; modified agility T-test; 505 change-of-direction (COD) test; lateral bound; Sargent jump; one-step jump test; and isometric mid-thigh pull.

Additionally, Schwesig et al. [28] explored the validity of a new basketball-specific complex test called the Basketball Specific Complex Test (BBCT, Figure 2), which is based on the match performance of the players and the treadmill test. They concluded that the current match performance score seems to reflect the complexity of basketball match performance in an acceptable, appropriate manner.

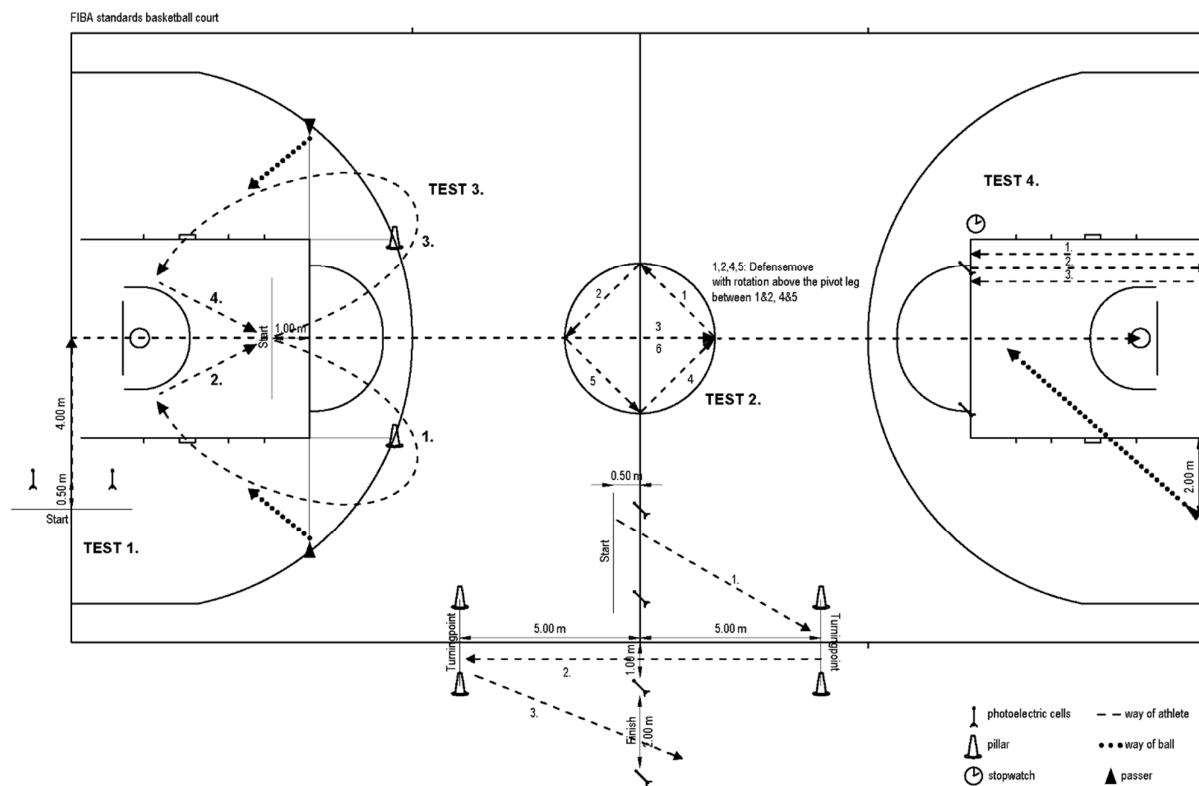


Figure 2. Basketball Specific Complex Test (BBCT) Test 1: 20 m sprint with two changes of direction after 5 m and 15 m with and without the ball. (green runway); Test 2: Fast break with a bounce pass and lay-up (red runway); Test 3: Lay-up parcour, consisting of a throw pass while running (orange runway); Test 4: Brick test—a sprint endurance test consisting of side steps and sprints without the ball (blue runway); adapted and edited from [28].

3.2. Already Validated Tests for Basketball Players

3.2.1. Lane Agility Test (LAT)

The LAT test consists of two times four 90° cutting. Between the cuttings, the players are sprinting, shuffling, and backpedaling, as previously described by Brown et al. [29] (Figure 3). Although their findings indicated that the LAT is a reliable ($r = 0.9$, $p = 0.05$) test of agility, its correlation with some (Agility-T test, Pro Agility test) but not all (Coach Rank) previously validated tests and measures questioned its function as a predictor of agility performance in a basketball match.

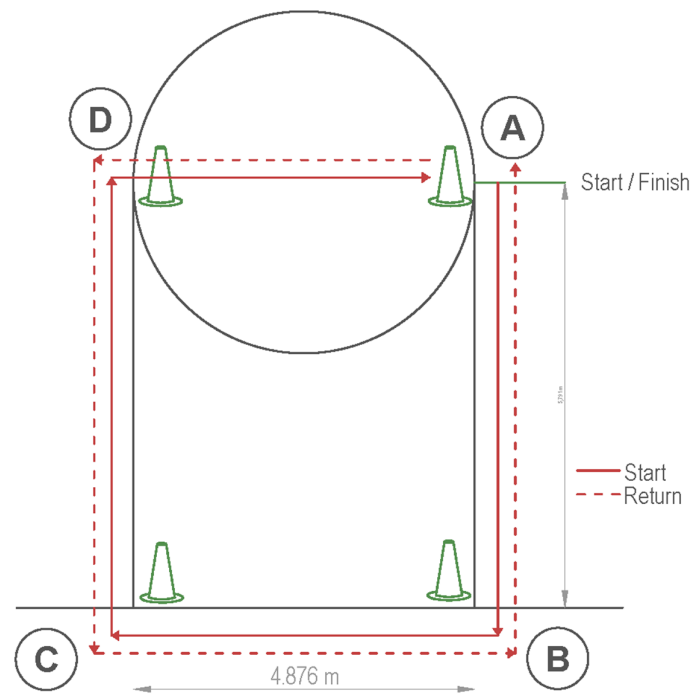


Figure 3. Lane Agility test; adapted and edited from [29].

3.2.2. Running Anaerobic Sprint Test (RAST)

This test consists of six maximal 35 m running round trips, divided into two 17.5 m shuttle runs with 10 s rest intervals. Gobatto et al. [30] found a significant correlation ($p < 0.05$) between most of the metrics of RAST and the 30 s non-motorized treadmill running test (maximal, mean, minimum values, and fatigue index for force, velocity, and power) using complex network analysis. According to their results, the RAST is a reliable test for measuring the anaerobic capacity of basketball players. Therefore, the RAST adapted for the basketball court should be considered an important assessment tool for this sport, especially for young athletes.

3.2.3. STARtest

This running test also considers the dribbling skills as the participant has to do the test with and without the ball as well [31]. The running course forms a star on one-half of a FIBA standard basketball court. The trajectory uses the lines of a 3-point area with a radius of 6.25 m (Figure 4), as previously described by Wierike et al. [31], who tested 52 basketball players from the Netherlands. They showed that the STARtest is a scientifically reproducible and highly reliable ($ICC > 0.9$) test to measure and monitor the COD speed and ball control of youth basketball players, which is supported by its significant, strong correlation with the results of the slalom test.

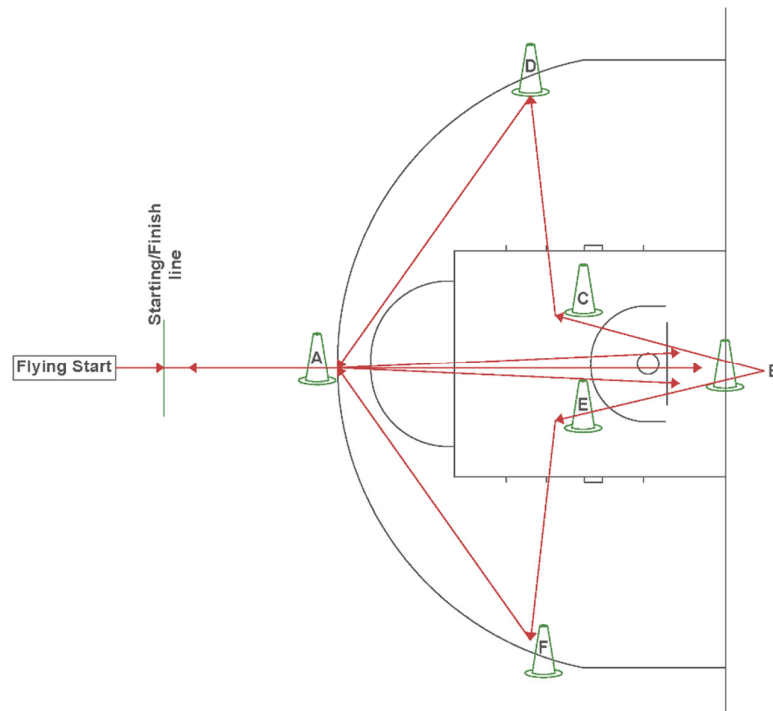


Figure 4. STARtest; adapted and edited from [31].

3.2.4. Edgren Side-Step Test 4 Lateral Shuffle Tests (LST)

In this test, the participant has to side shuffle as fast as he/she can for 6 or 10 s. The participant's score takes the number of lines crossed during the duration of the test (Figure 5). Although all conditions (distance: 3.66 m or 2.44 m, and duration: 6 s or 10 s) have an excellent internal consistency across three trials during the same testing period and also showed an excellent test-retest reliability ($ICC > 0.93$), the LST-2.44 m \times 10 s appeared to be the most reliable ($ICC = 0.938$) and valid (Cronbach's $\alpha = 0.928$) test to measure COD speed [32]. Although the LST negatively correlated with body height, it may still be better than other alternatives that include straight-ahead sprinting.

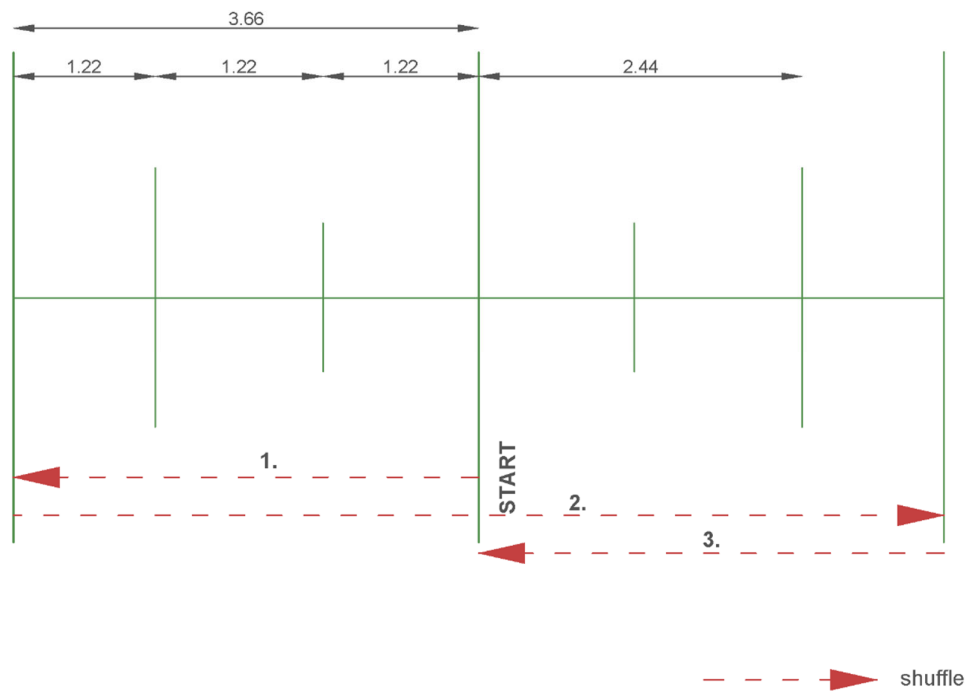


Figure 5. Edgren Side-Step Test 4 lateral shuffle tests (LST); adapted and edited from [32].

3.2.5. Line-Drill (LD) Test

The LD protocol is convenient to describe performance changes in adolescent basketball players. During the LD test, the participants have to run as fast as they can with several 180° direction changes [33]. This test is commonly known among players as “suicide run” because it is very exhausting. The single-trial LD test appears to be a valid (ICC = 0.91) test for determining the anaerobic power of basketball players [33,34]; moreover, its results moderately correlated with the results of the Wingate test and significantly correlated with the 30-sec vertical jump test [33]. Nevertheless, a previous study from Carvalho et al. [35] suggests shortening the protocol distance by 58 m and all-out effort by 10–15 s, remaining sensitive to training exposure, and independent of maturity status and body size.

3.2.6. COD Tests

The factorial validity and the usefulness of the 1. Lane Arrow Closeout (Figure 6); 2. Lane Agility Drill (Figure 3); 3. Reactive Shuttle Test (Figure 7); 4. Run-Shuffle-Run (Figure 8); 5. Compass Drill (Figure 9); and 6. Modified 505 (Figure 10) COD tests were examined by Stojanović et al. [18]. All six COD speed tests were found to have good to excellent reliability (ICC = 0.50–0.88) and measured the same preplanned agility skill [18]; however, Lane Agility Drill and Run-Shuffle-Run seemed to be the most adequate basketball-specific COD speed tests to quantify changes in performance [36].

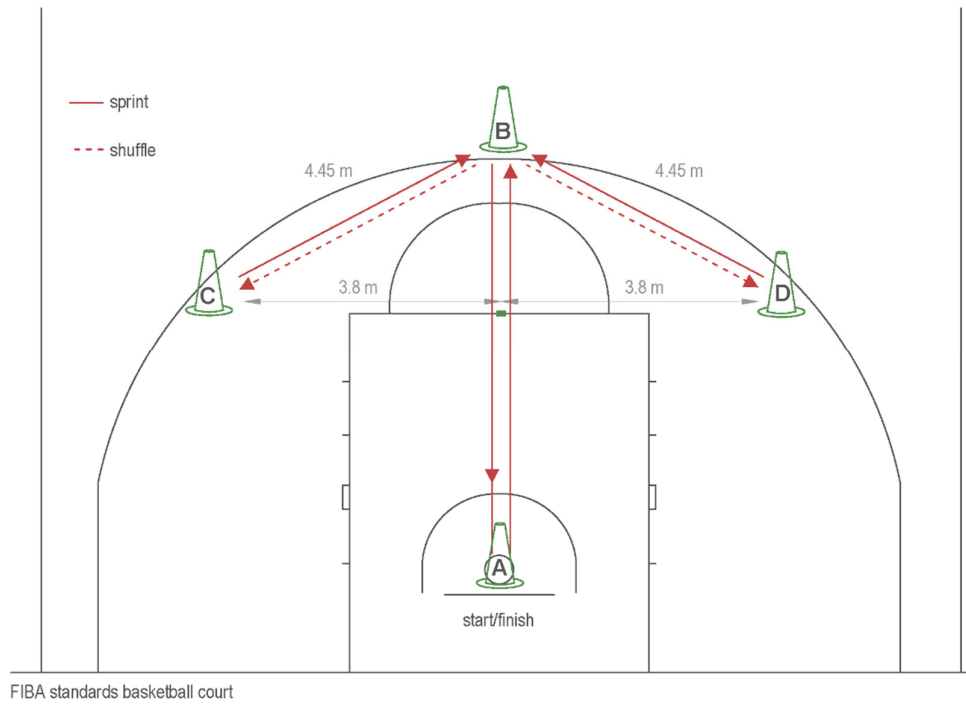


Figure 6. The trajectory of the Lane Arrow Closeout Test. Adapted and edited from the article by Stojanović et al. [18] from which the full description of the test can be found.

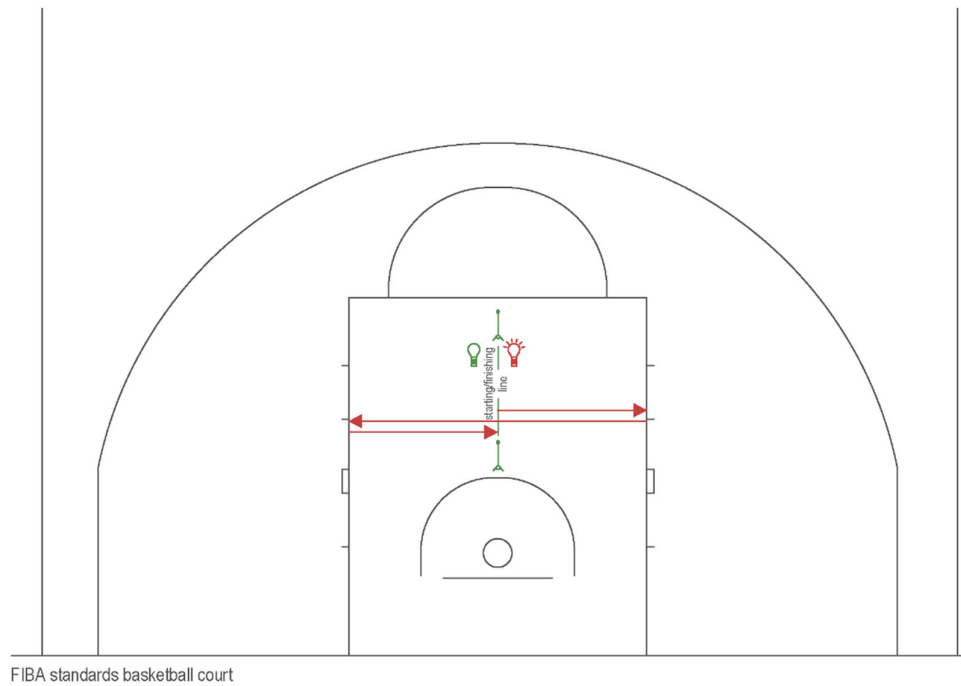


Figure 7. Reactive Shuffle Test. An average shuffle test with reactive starts (light signals); adapted and edited from [18].

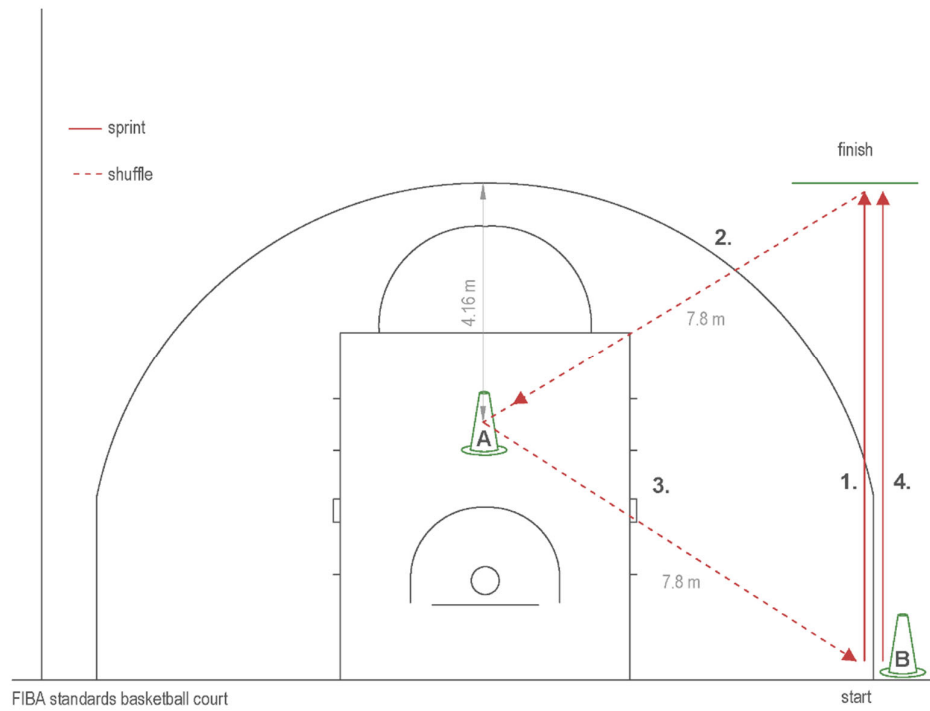


Figure 8. The trajectory of the Run-Shuffle-Run Test, consisting of sprinting and running; adapted and edited from [18].

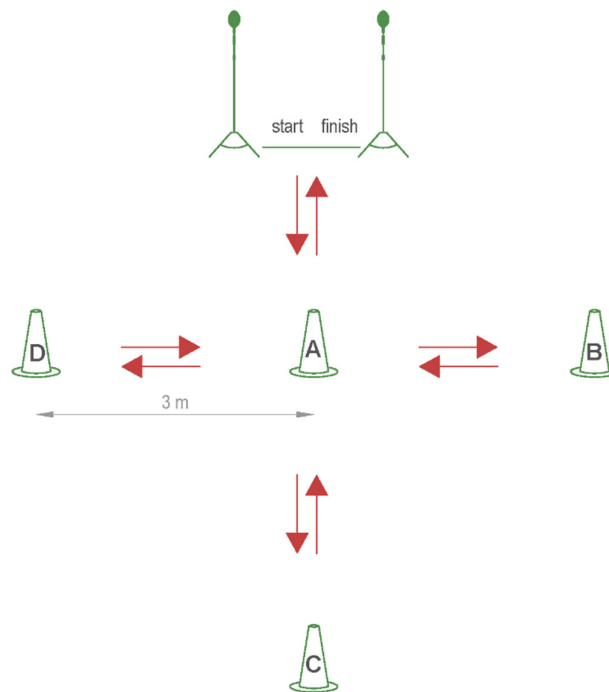


Figure 9. Compass Drill. The running path of the test forms a star. The participant has to run along the trajectory and touch the cones. Adapted and edited from [18].

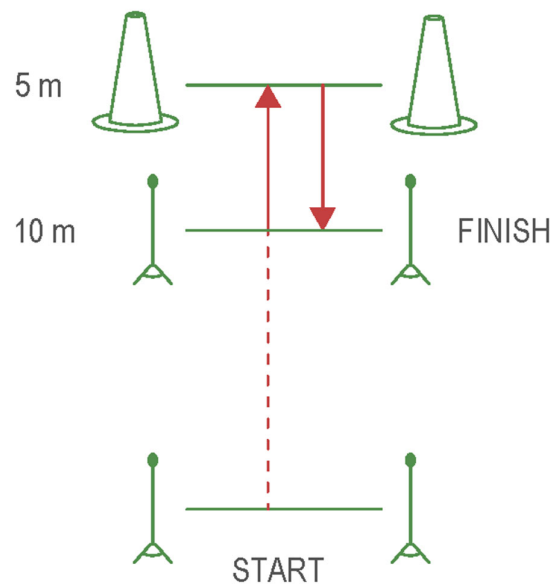


Figure 10. Modified 505 Test. A single COD sprinting test, as previously described by Stojanović et al. [18] from which the picture was adapted and edited.

3.2.7. Basketball-Specific Multicomponent Agility Test (BMAT)

The BMAT test consists of the basic movements from basketball, such as sprinting, jumping, and throwing (Figure 11). It has good interrater reliability (ICC = 0.946) and intraclass reliability (ICC = 0.997) [36]; therefore, the regular application of the test by basketball experts is highly recommended for monitoring the training program's efficiency on basketball players [36]. The disadvantage of this challenging test is that no data were found regarding correlation with match performance or other COD tests.

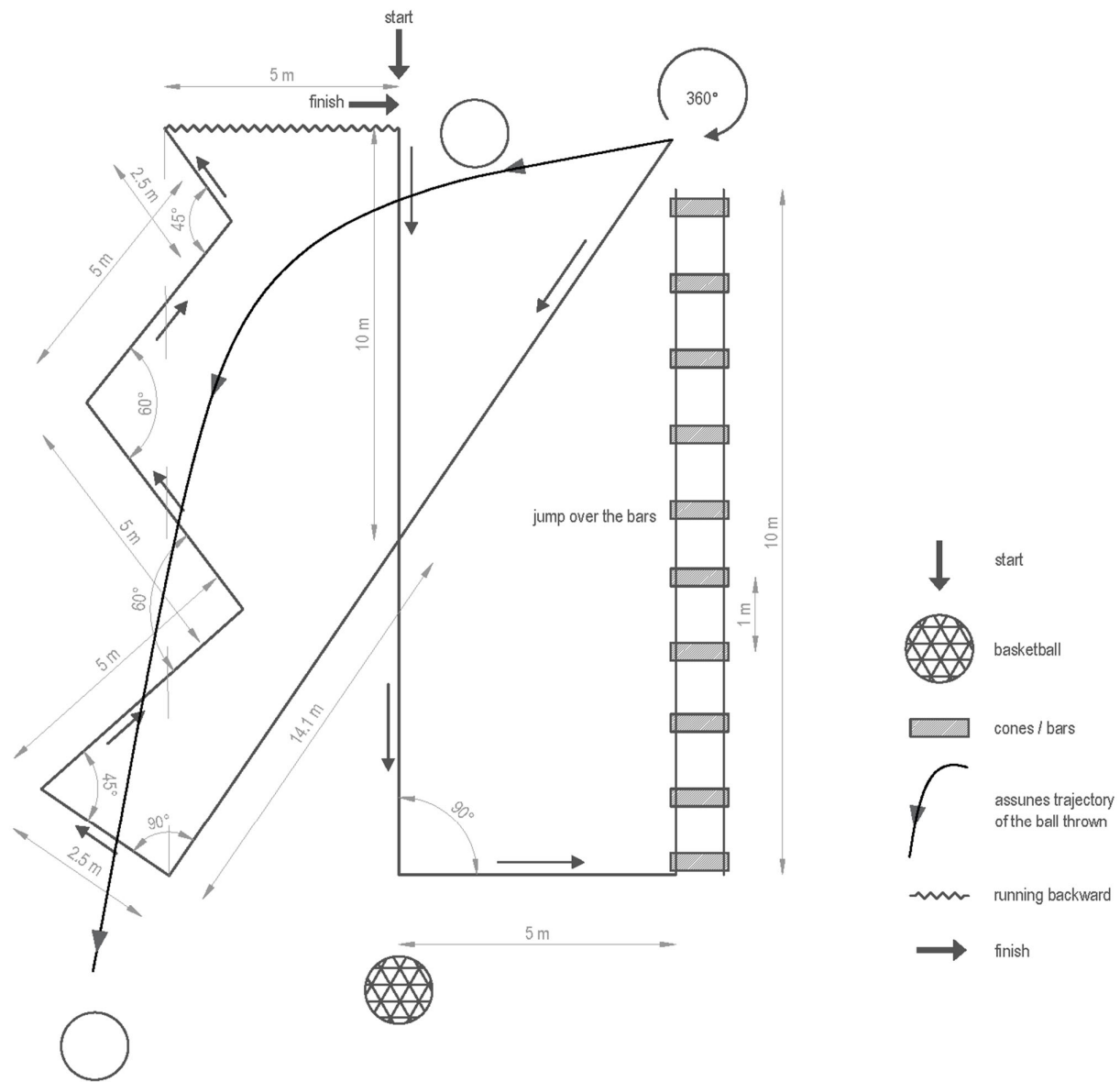


Figure 11. Basketball-specific Multicomponent Agility Test; adapted and edited from [36].

3.2.8. Experimental Repeated-Sprint Ability Test (RSA5COD Agility Test)

During the test, the athlete has to complete a T-shaped runway running test (Figure 12) as fast as possible. The RSA5COD agility test has not only a good test-retest reliability ($ICC \geq 0.64$) but is also similar to actual gameplay, considering the sprint distances and action change frequency/direction [37]. Overall, it could be a valuable option for players and coaches for training basketball-specific agility and assessing physiological demand.

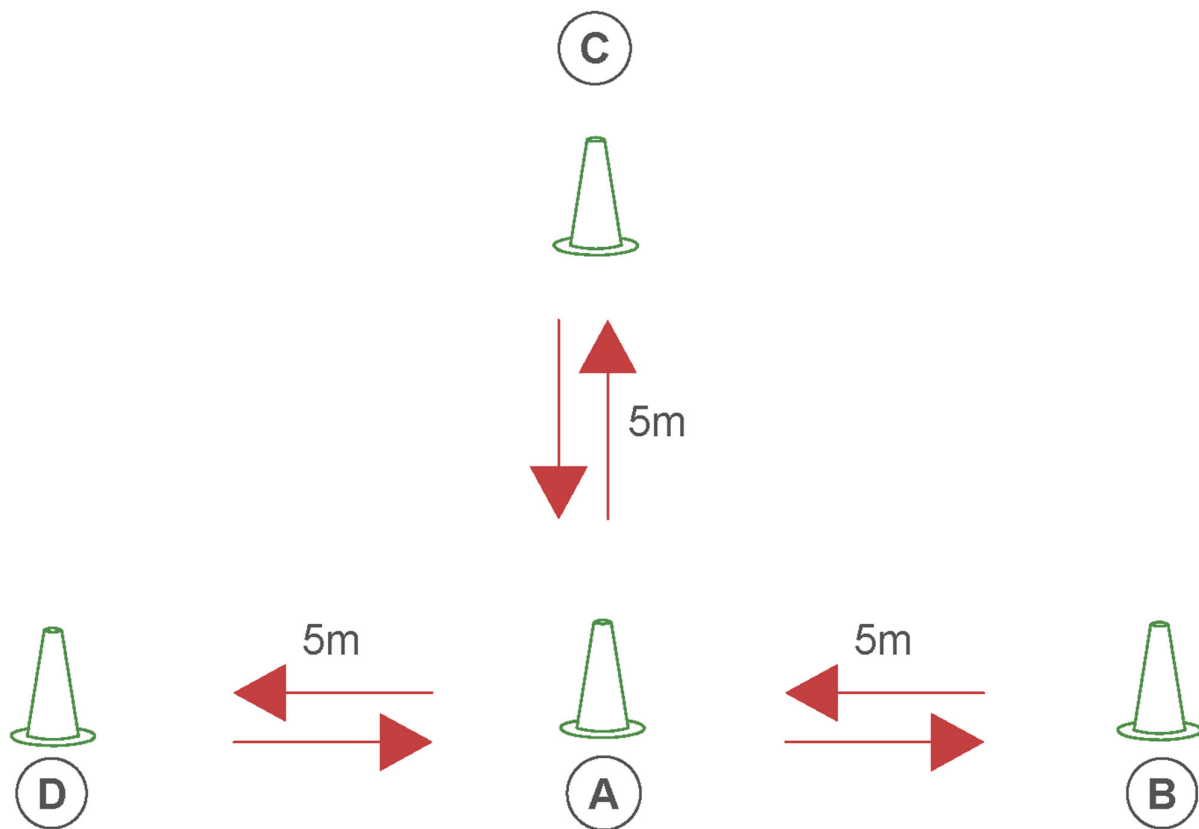


Figure 12. Experimental repeated-sprint ability (RSA5COD Agility Test) and Multi-direction repeated sprint ability (RSM); adapted and edited from [37].

3.2.9. Multi-Direction Repeated Sprint Ability (RSM)

RSM consists of six 5 m sprints divided into sections with five changes of direction (Figure 13); the order is self-selected [38]. The test's reliability is comparable with values of repeated sprint ability, and its results show a significant correlation ($p < 0.05$) with performance indices (positive correlation with SJ or CMJ; negative correlation with Yo-Yo Intermittent recovery test) [38].

3.2.10. New Preplanned Agility Test (NPP Agility)

The NPP agility test is a forward and backward slalom test (Figure 13) that appeared to have acceptable reliability ($ICC = 0.88$) and validity for junior basketball player testing [39]. Nevertheless, significant differences can be found between the measured values of girls and boys. While linear speed was a predictor of planned agility only in girls (positive correlation between linear speed time and NPP agility time), unilateral jump performance and body mass were the most important predictors of the NPP agility test score in boys.

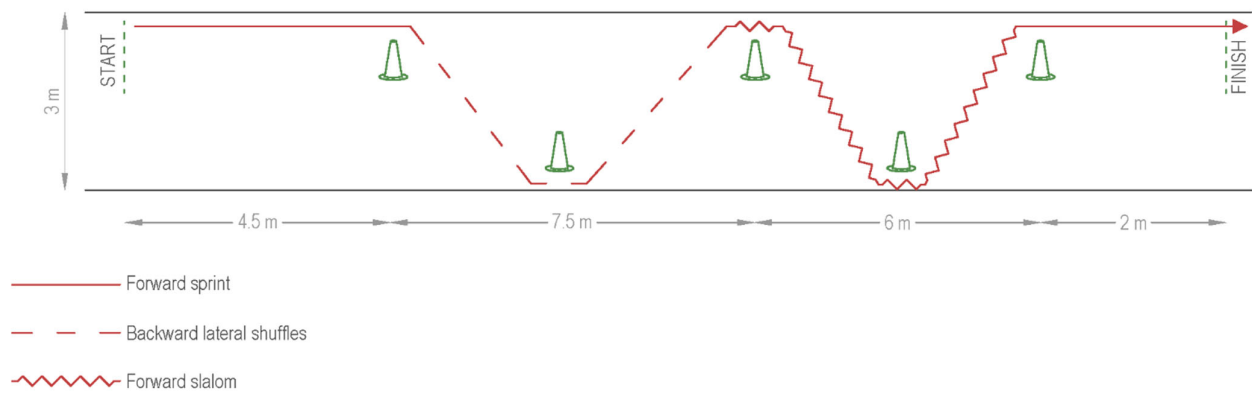


Figure 13. The trajectory of the New Preplanned agility test (NPP agility); adapted and edited from [39].

3.2.11. New Basketball Specific Preplanned (BBCOD) and Nonplanned (BBAGIL) Agility Tests

During BBCOD and BBAGIL agility tests, players have to react to an external stimulus, i.e., a light signal with or without prior knowledge of which cone is going to light up (Figure 14). Although the reliability of both tests is good to excellent (ICC = 0.81–0.95) and both are suitable for defining position-specific agility performance, the BBAGIL test of nonplanned ability might be more valid for determining differences between basketball athletes from two different competition levels [40].

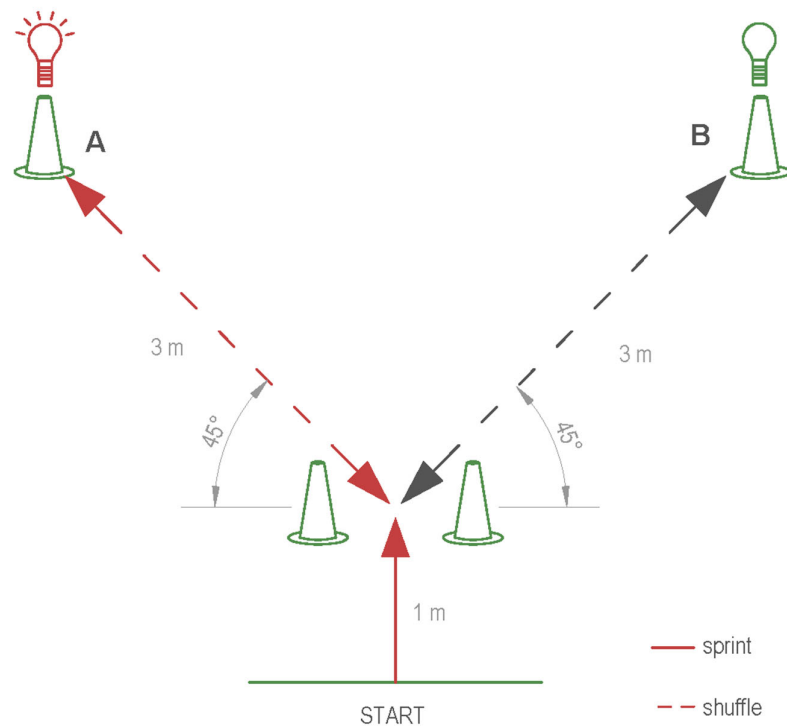


Figure 14. New Basketball-specific-non-planned agility test (BBAGIL); adapted and edited from [40].

3.2.12. Intermittent Shuttle-Running Test (ISRT)

ISRT is a submaximal field test that consists of a 20 m shuttle running for 4 min at 9, 10, and 11 km/h. According to a review article [23], the 20 m shuttle running test and the Yo-Yo Intermittent Recovery test are the most common modes of testing aerobic fitness. Although the speed at the lactate threshold (LT) during the ISRT was shown to be significantly lower than the speed at LT during Treadmill running (10.1 ± 1.7 km/h vs. 12 ± 2.3 km/h), they correlated significantly ($r = 0.82, p < 0.001$) with each other [41]. Therefore, the test is considered to be a useful and valid field test to assess submaximal aerobic fitness in young basketball players [41].

3.2.13. Vertical Jump as a Field Test of Anaerobic Power

The test is similar to a Sargent test [42]. The significant positive correlations between average power and peak power of the vertical jump test ($r = 0.970, p < 0.05$) and the Wingate test ($r = 0.263, p < 0.05$) [43] support the validity of the vertical jump as a field test of anaerobic power.

3.2.14. Handgrip Strength Test

The excellent reliability (ICC = 0.94–0.98) of handgrip strength assessed by a dynamometer is well known [44]. While maximal and absolute handgrip strength shows a linear increase with age, no differences can be found between the values of the preferred and the non-preferred hand [44]. However, it shows correlation with BMI for the basketball players only ($r = 0.406, p = 0.026$) in contrast with healthy non-athletic controls [45].

4. Discussion

In the present review, we aimed to summarize the basketball-specific physical field tests logically and provide practical advice for their appropriate selection and application. Our most important conclusion is that in addition to planning the training programs, experts and sports specialists must also design the testing protocols. It is necessary to draw up an aim or a final goal and prepare the testing protocol accordingly. Systematically following a proper and deliberate testing protocol has the potential to achieve success. The following sections present recommendations regarding test selection (Section 4.1) and practical advice for test implementation grouped by test types (Section 4.2).

4.1. Recommendations on Test Selection

A large number of tests can be found both online and in the literature; however, choosing and applying the most relevant one needs to be based on age, gender, playing level, and the aim of the testing. Our conclusion is similar to Drinkwater et al. [23], i.e., there is a lack of standardized, widely, and systematically used testing protocols for testing the fitness of basketball players. Nevertheless, there are noticeable tendencies on a few specific tests that are used to assess athletic abilities in basketball players [46].

With our review article, we aimed to collect physical tests to help athletes and experts to select the most appropriate one from the wide variety of available tests. First, we collected test packages that are currently widely in use. We found seven recommendations. Two of them (the NBA Combine and Basketball-specific movement screen) had standard, normative results for basketball players. Using these test packages, we can easily compare our players with elite basketball players. Two other recommendations (the NSSQA and SPARQ protocols) are commonly used in other sports as well to monitor athletes' physical skills. We then collected eighteen tests that have already been validated for basketball players. However, the characteristics of modern basketball are constantly changing, suggesting the need for developing new basketball-specific tests. Although including one or a maximum of two newly developed tests might be reasonable, we should keep in mind one major advantage of older tests: they have standard, typical values, making it possible to compare the results with other athletes.

Consequently, we suggest handling the newly developed tests with care, at least until they have been validated for basketball players.

Results of the current and our previous review [24] indicate that general anamnesis, orthopedic-, anthropometric-, and spiroergometric measurements are needed before the off-season period. Although COD (e.g., Lane Agility Drill) and RCOD (e.g., BBAGIL) testing, strength testing (e.g., handgrip strength test, 1RM bench press), and jump testing (e.g., CMJ, DJ) appear to be the most relevant tests during the pre-season, values of the dribbling deficit and COD decrement might also be worthwhile to measure. During the season, regular (weekly) testing of CMJ and short RCOD is fundamental to avoid overtraining and to monitor the actual status of the players.

To successfully reach a previously established final goal, preparing and systematically following a proper and deliberate testing protocol is fundamental. Although including one or a maximum of two newly developed tests might be reasonable, we recommend tests that have already been validated and have standard, normative results for basketball players. Finally, experts and researchers must always normalize their data with anthropometric measures for valid results.

4.2. Practical Advice on Test Implementation and Interpretation

Before choosing and applying the most appropriate tests, the effects of many factors on field test results must be considered. After collating the tests identified in the search results, we identified the factors that should be considered during testing. The foremost factor is anthropometry. In our previous review [24], we found that body size affects playing position and playing level as well; therefore, experts and researchers always have to normalize their data with anthropometric measures for valid results. For example, allometric scaling models could successfully explain the influence of body size descriptors on performance, so the prediction for the future performance of the player could be more realistic [47]. Thus, body size should be taken into account when evaluating and comparing any kind of test results.

4.2.1. Jump Tests

Jumping ability is a common physiological and biomechanical factor among basketball players; therefore, jump tests are common methods of testing reactive power of the lower limbs [48–50]. They are some of the most popular tests among basketball experts because they do not require expensive tools and are easy to perform on a court. According to Bazanov et al. [49], improvement of the jump ability can be achieved by strengthening the overall musculoskeletal state. In the case of jump tests, our most important observation is that CMJ is a practical test to monitor players' current conditions. Using CMJ, experts can monitor fatigue, loss of explosive force, ANSr, and interlimb asymmetries. Based on quantitative biomechanical analyses, we think that trainers have to pay more attention to teaching the correct technique of jumping to save energy. During testing, experts must clarify the aim of the jumping (e.g., height or explosiveness) and should precisely determine the jumping protocol (e.g., CMJ AS or CMJ NAS, recovery time) because different protocols will lead to inconsistent results.

Counter Movement Jump (CMJ) and Vertical Jump (VJ)

Results from previous studies are inconsistent as to whether anthropometric parameters might influence vertical jump (VJ) performance. Counter Movement Jump (CMJ) is a very well-researched, although simple test. Although normalizing the numerical results of CMJ might not be necessary [51], anthropometry [52] and maturity status [53,54] appear to have a significant impact on jump performance. Furthermore, whereas body-mass normalized CMJ force is not a determining factor to detect sex differences between strength-matched subjects, eccentric phase impulse and concentric

phase peak power appear to be influenced by sex differences independent of matching strength levels [54].

VJ performance is more related to motor skills and abilities than to training history [55]. For instance, VJ performance markers not only positively correlate ($r = 0.812$, $p < 0.001$) with explosive leg power [14,45], but the increase in fatigue is directly proportional to the decrease in eccentric CMJ variables [14], indicating that eccentric jump variables have the potential not only to measure the loss of explosive force but also to detect overtraining or overreaching [56]. It is well known that reactive muscle strength is dependent on the eccentric phase. Although a deeper squat helps reach the maximum height, different strategies are needed to increase the jumping speed [57]. Increases in eccentric and concentric joint work and total joint work correlated with an increase in CMJ height [58–60]. However, concentric vs. eccentric joint work is a better indicator of CMJ performance, and it might not be surprising that the knee is the most important joint-level determinant of CMJ height [58].

Jump tests are also used to evaluate Automatic Nervous System responses (ANSr) that serve as a reliable picture of the player's current condition [61,62]. For example, Pontes Morales et al. [63] found that the 5 Vertical jump test is sensitive for ANSr, i.e., a 5-min recovery was not enough for the onset of vagal tone (parasympathetic modulation), suggesting that the resting time between jumps is crucial. Overall, if experts want to measure reactive strength or even just the height and force values of jumps, they should give enough recovery time to avoid the high response of sympathetic modulation.

Although quantitative measures of the CMJ test with and without arm swing (CMJ AS, CMJ NAS, respectively) correlated to a large or very large degree [64], CMJ AS might be a better indicator of longer-term changes in performance, e.g., alterations in performance across training phases [65]. RSIMod, adopted from the Reactive Strength Index (RSI), is one of the most common, easily calculated variables of CMJ that reliably assesses an athlete's explosiveness by providing independent information from the CMJ NAS and CMJ AS [64]. Either RSIMod or Flight Time to Contraction Time Ratio may be utilized to monitor changes in performance, but both may not be necessary.

Since most players have some degree of interlimb asymmetry, a cut-off value of 85% for the limb asymmetry index had been established [66]. Besides the so-called Four Functional Hop Test [1], both CMJ NAS and CMJ AS provide reliable information of interlimb asymmetries; however, experts should use a single protocol consistently during testing [66]. To show the differences between legs, sports experts categorize legs as dominant and non-dominant. Nevertheless, identification of the dominant and non-dominant leg is not equal to identifying the more and less skillful leg because dominance is task-specific, and a subjective assignment of the dominant and non-dominant leg may not be sensitive for detecting differences between limbs for most tasks [67].

Drop Jump (DJ)

For the highest efficiency, the height of the box used in the DJ test should be personalized based on the already mentioned reactive strength index (RSI, maximum flight height/contact time) or the maximum vertical rebound jump (MRV) with the purpose of making the training more profitable, considering that the box heights corresponding to the highest RSI values and MRV might be different [68]. Although only a single trial is necessary when assessing either RSI or jump height from 20–50 cm drop heights, measuring jump height seemed to be the most useful variable (DJ at 20 cm ICC = 0.96; DJ at 40 cm ICC = 0.95; DJ at 50 cm ICC = 0.99) for creating a reactive strength profile [69]. Moreover, it was shown that RSI values depend on the drop jump technique [70] and may also differ between males and females [14]; therefore, markers should not be compared between sexes because of the differences in jumping ability.

Running Single-Leg Jump (RSJ)

During RSJ the peak ground reaction force, eccentric loading rate, and higher muscle activation of gastrocnemius of pre-activation phase and tibialis anterior of the push-off phase were found significantly larger ($p < 0.05$) when the speed of the running was faster than which the athlete preferred [71]. According to the authors, RSJ improves not only the muscle activation level but also the stretch reflex, which could reduce the risk of injury.

Horizontal Jumps

Notably, we found a lack of research interest regarding the evaluation of horizontal jumps. However, Delextrat et al. [39] advised that selection programs for basketball players should include horizontal CMJ performed unilaterally.

4.2.2. Strength Tests

For our search strategy and keywords, we did not find many articles regarding strength testing. The reason for this may be not including the “strength” keyword, instead, we chose the “power testing” keyword. Furthermore, we excluded studies that used a dynamometer and laboratory equipment since we focused on field testing.

Most of the identified studies investigating strength testing found no significant differences between strength tests, jump tests, and shuttle-run tests [72–74]. In contrast, an existing connection between sprint test and strength test results seems to be in evidence [72,73,75]. Additionally, despite a strong correlation between abilities of strength and COD, no correlation between reactive agility tasks and strength tests has been found. Furthermore, muscular strength also failed to correlate not only with the results of the anaerobic sprint ability test [72] but also with CMJ measures [45]. Consequently, comparing one or two strength tests with COD or agility tasks does not seem to be a valid method, and results from a strength test might not be adequate to represent the athlete’s overall strength capacity [74]. Nevertheless, strength development might have a higher chance to translate strength improvements to performance improvements via an effect on the COD ability [74].

In contrast, several researchers found a significant connection between isometric midhigh pull variables and sprint kinetics [75–77]. In line with this, a significant positive correlation was found between squat 1RM and sprint times over 5, 10, and 30 m [78]. Although squatting exercises might be applicable for emphasizing the maximal force mobilization during the concentric phase of the exercise, bench press exercises should not be overemphasized in elite basketball players’ training [78].

4.2.3. Sprint Tests and Dribbling

Among young basketball players, skeletal maturity, body mass, and leg length are the most important predictors for all maximal short-term power output measures [11,53]. This result is consistent with the finding that amongst U14 basketball players, the principal selection factor is maturity status [79]. It might be not surprising that body fat affects most indicators of physical performance negatively [11], including the results of the 20 m sprint test [2], which highlights the fundamental role of dietitians. Thus, nutritional advice is recommended to control the percentage of body fat to improve sprint performance.

Improving sprint performance is a part of physical training for basketball players. Trainers apply different training strategies to improve running speed over 10, 20, and 40 m [80]. For example, improving relative power seems to support achieving faster linear and COD speed [50]. One may need to consider creating a training program according to a sprinting profile based on sprint performance and mechanical outputs [81] using the spreadsheet from Morin et al. [82] for sprint acceleration force-velocity-power profiling. Regarding specific muscles, adductor longus and vastus medialis were found to be the most relevant muscles for sprinting [83]. Although maximal short-term running abilities

correlated with the years of training [34], the results might be questionable since the study pooled the results from U14–U16 aged basketball athletes.

Scanlan et al. [84] investigated sprinting and dribbling from a novel aspect. They defined the dribbling deficit calculated from the differences between the best total time for the dribbling trial and the best total time for the corresponding non-dribbling trial for the linear sprint and COD sprint. They showed that dribbling deficit is a viable method to measure dribble speed independent of sprint speed. Furthermore, dribbling deficit distinctively separates right or left hand to evaluate the hand dominance. Use of the dribbling deficit value in pre-adolescent ages (U10 and U9) helps identify possible deficiencies in dribbling skills [85]. However, the sensitive periods of improving dribbling skills are 7–10 and 12–13 years of age [86].

4.2.4. Change of Direction (COD) and Agility Tests

Before analyzing agility and the influencing factors of agility performance, we present some beneficial results from Horicka et al. [87]. They compared, among others, the tests of preplanned agility (COD) and reactive agility (RA). They found that COD and RA are two different and independent skills. As the complexity of agility tasks increase, the influence of motor abilities (speed of acceleration, strength) on performance decrease. During RA tasks, the most influencing factor is cognitive mental abilities. Scanlan et al. [88] also reported that cognitive measures (response time and decision-making time) have the foremost influence on nonplanned (i.e., reactive) agility performance in male basketball players. Gokhan et al. [89] had a consistent result when they found a significant negative linear relationship ($r = 0.842$ and $r = 0.827$, $p < 0.01$) between the total time of the RA test and the result of the Speed and Distance Estimation Test. These findings suggest that for improving real agility performance, it is not enough to practice COD tasks. However, it is also necessary to improve reaction time, decision-making abilities, and other mental and cognitive skills.

Mancha-Triguero et al. [90] tested U14 and U16 basketball players with two agility tests (T-test with and without the ball) and the so-called SIG/ANA Anaerobic Test. Based on the high intra- and inter-test correlations, they concluded that doing too many tests is unnecessary. Instead, the coach should choose the most specific test to obtain highly reliable and valid data.

There is a consensus about the importance of agility among basketball players. In the following, we tried to summarize which factors affect agility. An obvious question is the influence of anthropometric values on agility performance. In a regression analysis by Begu et al. [91] among players aged 14–15, body height, leg length, and thigh circumference had a low impact on agility test scores, whereas other anthropomorphic variables showed no effect. Regarding maturity, Jakovljevic et al. [92] found that 14-year-old players who performed better in the agility T-test also performed better in the other tests, but that was not true for 12-year-old players.

Stojanovic et al. [18] investigated the usefulness and the factorial validity of 6 COD tests. Their results indicate that a minimum of one familiarization trial before application to stabilize during the Reactive Shuttle Test, Run-Shuffle-Run, and Compass Drill, and more familiarization trials are necessary for the Lane Arrow Closeout and the Lane Agility Drill. Although each test measured the same preplanned skill, “Line Agility Drill” and “Run-Shuffle-Run” seemed to be the most appropriate basketball-specific COD speed tests to quantify changes in performance.

Mandic et al. [57] reported a significant influence of reactive strength on both basketball-specific COD speed and reactive agility. They concluded that even though improvements in broad-jump capacity could improve COD speed, the increase in reactive strength could be beneficial in developing both COD speed and reactive agility in basketball players. This is in line with the results from Sukhiyaji et al. [93], who found significant, negative correlations between the Modified Illinois Change of direction test

and vertical jump height ($r = -0.319$ with $p = 0.045$) and positive correlations between the Modified Illinois Change of direction test and the 20 m sprint test ($r = 0.573$, $p < 0.001$).

Direction changes play a crucial role in agility testing. Zamparo et al. [94] found that the turning angle does not affect the physiological responses of shuttle runs ($n = 9$). Their results indicate that only the distance of the shuttle should be manipulated to increase the metabolic demands of a shuttle run (of a training protocol), while the turning angle is not a defining factor. Furthermore, this result does not mean that running without a change of direction has the same metabolic response. Paulauskas et al. [95] used two different sprinting modes and found that even though longer sprints with longer recovery periods place a higher demand on the anaerobic glycolytic system, shorter and more frequent sprints elicit greater fatigue in players. Heart rate responses and local oxygenation showed a similar activity of aerobic reactions through the two agility exercises. In addition, another study found that the changes of direction and acceleration/deceleration ratio correlate positively with player load [96]. Notably, most experts agree that speed and agility are two distinct physical qualities. Therefore, in training practice, speed and agility should be trained separately [39].

Scanlan et al. [97] compared performance decrement across a basketball-specific repeated COD ability protocol (Figure 15) and found that rapid braking and accelerative force generation demand higher muscular effort than continuous linear running, suggesting that COD decrement may have the potential to better isolate decrements in COD speed across repeated sprints compared with total performance time. Thus, basketball trainers and conditioning professionals might assess this decrement during repeated COD sprints when planning the development of repeated-sprint ability, which could also be a helpful index during draft team selection processes.

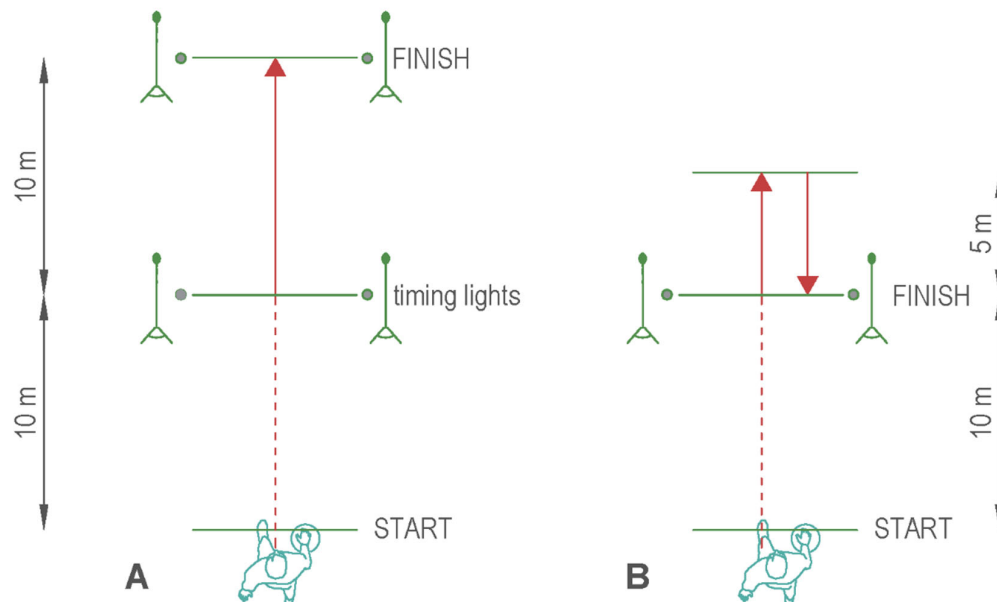


Figure 15. Layout of the (A) 20 m linear sprint and (B) Agility-505 test; adapted and edited from [97].

Agility and reactive agility are fundamental skills in basketball that could be measured by several COD and reactive COD (RCOD) tests. Experts should systematically use these tests after determining the aim of testing. For example, to increase the metabolic demands of the test, the distance of the shuttle should be manipulated. Depending on the complexity, one or more familiarization trials are necessary to reach consistent results. In addition to the COD test, when familiarization is an important factor, experts should also test player

performance in unexpected situations. The RCOD test measures a different ability of the players than COD that might be one of the most influencing factors in total performance. We support the idea that COD deficit is superior to total performance time, as it has the potential to better isolate decrements in COD speed during repeated sprints [97].

5. Conclusions

The identification and development of a talented player is a complex task and requires the contribution of experts from different fields, including trainers, coaches, performance- and movement analysts, and physiotherapists. Most importantly, although experts always need to define an aim of testing and should follow the protocol of the chosen test, they also have to be open to making adjustments if the actual circumstances require so. We collected and evaluated several physical tests of basketball players and provided advice on them, which may support experts in obtaining reliable and useful information about the players. According to our research, we can generally say that assessing the influencing factors on the test is as important as the correct implementation of the measurement.

Supplementary Materials: The following are available online at www.mdpi.com/article/10.3390/app11198855/s1, Supplementary document S1: Description of the included tests and packages.

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