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Review

A Narrative Review of the Dominant Physiological Energy Systems in Basketball and the Importance of Specificity and Uniqueness in Measuring Basketball Players

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Abstract: Basketball playing entails the repetitive performance of short intense actions using lower limb explosive power. As such, it is important to measure this capability in basketball players, especially among young players, and to optimize training programs and game plans. After presenting an in-depth understanding of the specific physiological requirements when playing basketball, as well as the type of movements required, the aim of this review is to better understand the importance of the physiological energy systems in basketball, to examine the contribution of each energy system and, accordingly, to heighten awareness of the importance and dominance of the alactic anaerobic physiological system in basketball for actions requiring high-level explosive power. This review of the literature depicts the horizontal and vertical physical movements and physiological requirements entailed in playing basketball and presents eight standardized anaerobic alactic measurement tools relevant to the game. As some of these tests suit a number of ball games, the findings of this review article are important for making the order of the elements unique to basketball as well as additional parameters to consider when testing basketball players. By reliably and validly testing the anaerobic alactic capabilities of basketball players, test results can be used for training purposes and for improving game outcomes. Despite the fact that much of the information in this review is familiar to coaches, highlighting the specific needs of basketball will help them choose the most suitable tools and also shed light on new directions for developing basketball-specific assessment tests.

Keywords: physiology; basketball; testing; explosive; unique; specific movements

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1. Introduction

In sports in general, and in competitive team sports in particular, it is important to frequently assess players' physiological capabilities in order to design, implement, and evaluate training programs and track players' progress throughout the season, especially in young players [1,2]. Among team sports, basketball is characterized by short, intense, anaerobic actions that are performed throughout the game [1,3,4] using anaerobic power, i.e., explosive power for up to 10 s [5]. In other words, the main energy sources that contribute to these alactic anaerobic activities are adenosine triphosphate (ATP)/creatine phosphate (CP), referred to as ATP-CP, which are stored in the muscles and are easily accessible [6]. In addition, the glycolysis system also contributes to anaerobic activities. For actions that last more than 10 s and up to three minutes, the body's anaerobic glycolysis is required [7].

Although in basketball, the more dominant source is anaerobic alactic energy [3,5], it is also characterized by specific anaerobic actions, such as jumps, sudden stops, short sprints,

and changes in direction [2,8]. The body's aerobic system also plays a key role in players' recovery to ensure successful frequent repetition of high-intensity anaerobic actions [9,10]. Moreover, the introduction of new rules to the game of basketball in May 2000 (e.g., reduced attack time from 30 to 24 s and reduced time on the backcourt from 10 to 8 s) is believed to have altered the demands of basketball—both tactical and physical—increasing the speed and intensity of the game [11,12]. In turn, these changes also impact the players' physiological characteristics, resulting in higher physical demands on the players and expected improved athletic abilities. Such new demands mainly relate to the players' need to recruit their explosive power for performing and maintaining the rapid anaerobic pace of the game [13,14].

These physical activities place a heavy load on players' muscles and joints, which must be developed to withstand such physical pressures [4,5]. This is not an easy feat, especially as the skeletal muscular and nervous systems must be improved simultaneously. For example, scientific research indicates that the greater the load on muscles, the slower their rate of contraction [3,15]. To determine the necessary ratio between the strength and agility required to enhance explosive power, specific aspects of the sport must be examined [2,16]. For example, while ball game players and sprinters must perform fast movements with their relatively low body mass, bodybuilders and weightlifters must overcome high resistance from external objects [17]. Specifically, in basketball, the relationship between body mass and the performance of jumping and running varies according to age [5,11,13,18].

The main aim of this review is to better understand the importance of the physiological energy systems in basketball, to examine the contribution of each energy system, and, accordingly, to heighten awareness of the importance and dominance of the alactic anaerobic physiological system in basketball, for actions requiring high-level explosive power. In addition, this review clarifies the specific movements of basketball players in the various movement planes, including more complex movements that combine both horizontal and vertical movement such as penetrating for a layup. This review also offers the most relevant specific tests found in the literature. At the same time, it sheds light on the need for more designated field tests to assess players' explosive power abilities because today, many such tests serve a variety of ball games. It is important to take additional parameters into consideration when tests are conducted for basketball players. Although many of these issues are known to coaches and researchers, it is important to make the order of all the elements unique to basketball.

This review will begin with the physiological energy systems activated in basketball. In most basketball-related activities, both the aerobic and the anaerobic energy systems are involved, yet the ratio between the two energy sources varies according to the demands of the specific activity [2,3,5], including its intensity and duration (Table 1).

Moreover, the game of basketball demands a unique combination of technical skills that require players to perform horizontal, vertical, and combined movements on the court [1,2,19]. These movements rely heavily on the anaerobic alactic physiological system and explosive power, which are crucial attributes for basketball players. Understanding the technical requirements associated with these movements and their physiological underpinnings is essential for optimizing performance and success in the game [5,12].

Technical proficiency in basketball encompasses a wide range of skills, including shooting, passing, dribbling, and executing specific movements that involve horizontal, vertical, or a combination of both directions. These movements are fundamental to the game, enabling players to navigate the court, create scoring opportunities, and outmaneuver opponents [2,12]. Horizontal movements, such as lateral shuffling or moving laterally while dribbling, allow players to change directions quickly and maintain their balance while evading defenders or guarding opponents [20–22]. Vertical movements, such as jumping for rebounds or executing powerful slam dunks, showcase an athlete's explosive power and ability to generate force vertically. Additionally, combining horizontal and vertical movements is crucial in performing skills like layups, where players need to accelerate horizontally toward the basket and finish with an explosive vertical jump [1,2].

Table 1. Physiological energy systems.

Energy System/Meaning	**Anaerobic**		**Aerobic**
Physiological requirement and importance for basketball	Alactic/ATP-CP (explosive power)	Glycolysis	VO_2Max
Relates to the physical ability components commonly addressed in the literature pertaining to the energy system	Anaerobic power	Anaerobic capacity	Aerobic capacity
Duration of activity for each energy system, in general, from a physiological aspect	0–10 s	10 s–3 min	>3 min
Specific contribution to the game of basketball	Sprints, change in direction, jumping, fast break, layup, etc.	Mainly RSA, continued transition	For the duration of the game. Mainly supports recovery times during the game and helps athletes to perform short (alactic) actions and explosive power optimally.
Legend: Repeated sprint ability (RSA)	Dominant system in basketball		

The anaerobic alactic physiological system plays a vital role in supporting the technical requirements of basketball movements. This energy system provides athletes with the ability to generate explosive power in short bursts without relying on oxygen consumption [2,6,7]. During intense game situations that require horizontal or vertical movements, such as fast breaks, aggressive drives to the basket, or executing quick changes in direction, the anaerobic alactic system enables players to tap into their energy reserves and produce maximum force output [2,11,23]. The rapid and forceful execution of these movements relies on the efficient utilization of the anaerobic alactic system, allowing players to perform with speed, agility, and power [2].

Explosive power is a key attribute closely tied to the anaerobic alactic system and is specifically emphasized in basketball. The ability to generate rapid and forceful movements is essential for executing the technical requirements of the game [5]. Vertical explosive power is particularly important for skills like jumping for rebounds, blocking shots, or executing powerful dunks, which can significantly impact the outcome of a game [24]. Horizontal explosive power enables players to quickly change directions, maintain balance while dribbling, and execute lateral movements with speed and agility. Moreover, the combination of horizontal and vertical explosive power is critical in skills like layups, where players need to accelerate horizontally toward the basket and finish with an explosive vertical jump to avoid defenders and score efficiently [2,24].

The technical requirements in basketball, encompassing horizontal, vertical, and combined movements, are intricately linked to the anaerobic alactic physiological system and explosive power [12]. Developing and refining these skills requires targeted training programs that enhance muscle strength, power output, speed, and coordination [1,25,26]. Training interventions often incorporate exercises such as plyometrics, resistance training, sprint intervals, and skill-specific drills to optimize explosive power and technical proficiency [2,12].

The introduction of this article highlights significant and interesting subjects related to basketball. These subjects have provided a basis for the development of original research ideas. The topics discussed include the dominant physiological energy system in basketball, the concept of explosive power in basketball, specific movements in basketball, variations in explosive power based on age and gender among basketball players, disparities in explosive power across different playing positions, and the measurement of specific capa-

bilities related to explosive power according to the physiological demands of the anaerobic alactic system.

1.1. The Physiological Anaerobic Alactic System That Is Dominant in Basketball

The body's energetic potential is utilized by breaking down ATP, which is adenosine triphosphate [27]. Energy is released from the molecule when one of the three phosphate groups is degraded through a rapid chemical process by the ATPase enzyme [6,27]. As a result, two new molecules are created: adenosine diphosphate (ADP), with only two phosphate bonds, and free phosphate (P), as seen in Figure 1.



Figure 1. Flowchart showing the energy potential from ATP molecules.

ATP, often referred to as the body's "energy currency", enables the body to perform a range of biological activities [7]. These include complex and rapid actions needed for performing, completing, and recovering from actions performed in basketball [2]. Despite their vast importance, ATP resources in muscles are relatively small. With only 5–7 millimoles per kg of muscle during rest, this energy source is only sufficient for very short periods of time [7]. The fastest and simplest way to renew ATP is by also utilizing the body's CP resources, which offer about 3–5 times more energy (about 20–25 millimoles per kg of muscle) than ATP [5,7]. As such, CP resources are an important and immediate energy resource for the body's cells, transferring their phosphate to ADP to create new ATP molecules [7,28], as seen in Figure 2.

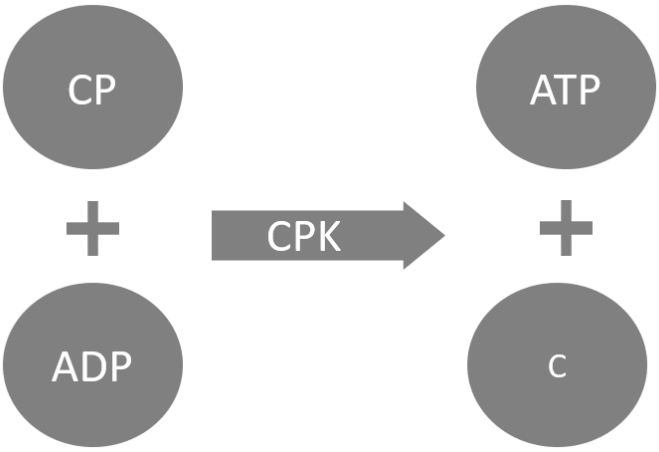


Figure 2. Flowchart showing the ATP-CP energy system.

This rapid process takes place within the cell through a reaction that is enhanced by the creatine phosphokinase (CPK) enzyme. As CP is readily available in the body's cells and this chemical process is extremely fast, this anaerobic means for renewing muscle energy is referred to as the "immediate anaerobic system" [28,29]. However, as the quantity of CP in a muscle is also relatively small, it too is limited to only providing energy for a number of seconds. The combined ATP-CP resources in the muscles provide immediate energy for quickly contracting a muscle. Without the intervention of CP, the ATP resources would suffice for a maximum of 1–2 s of activity [3,5,7]. In addition, the optimal anaerobic supply reflects the ability of the immediate anaerobic system (ATP-CP) to release energy and activate muscles at a maximum pace for short periods of up to 10 s [3,5]. Greater

efficacy of the ATP-CP enzyme activity is seen among athletes and people with a high percentage of fast twitch (FT) muscle fibers [27,28].

As such, athletes with greater anaerobic capabilities will have a clear advantage when participating in a sport such as basketball that requires explosive power [2,5]. Yet, being able to measure players' anaerobic abilities consistently and accurately requires uniform and relevant measurement tests. The aim of this article, therefore, was to review the existing anaerobic alactic measurement tests that can be specifically used in relation to basketball, as a means for providing basketball trainers, researchers, and physiologists with important information about optimal testing.

The next section addresses the demands made on the anaerobic alactic system in basketball.

1.2. Explosive Power and Anaerobic Alactic Demands in Basketball

The analysis of the physiological requirements of basketball players over the past few decades indicates great reliance on the body's anaerobic metabolism to perform sprints and jumps throughout a game [30]. Moreover, the relatively high blood lactate concentration values recorded during games indicate the central involvement of the player's anaerobic capacity [2,5]. As evaluating these factors during basketball practices and games is important, researchers and coaches have developed a range of tests for assessing the anaerobic alactic system and the effectiveness of the players' physical conditioning. For example, Abdelkrim et al. [3] found that in elite male basketball players under 19, the new rules of basketball meant longer time periods for performing high-intensity activities and an increased number of actions per game. Despite this, blood lactate concentration values were found to be slightly lower than those reported in earlier studies [3–5]. Such changes in the players' metabolic load during basketball games must be addressed when developing and applying suitable physical conditioning programs and tests.

In a review that assessed the most important and relevant measurement tests for basketball players, researchers found that following the introduction of the new rules of the game, basketball playing is mainly dependent on anaerobic power rather than on anaerobic capacity [5,15]. To assess the effectiveness of basketball training programs, tests should therefore specifically address players' lower limbs using tests such as vertical jump (VJ), agility T-tests, and short distance sprints (5 m), rather than tests like the suicide run that lasts about 30 s [5]. These tests all assess anaerobic alactic capabilities and explosive power of the players' lower limbs—as seen in basketball training and games.

The next section describes the specific movements that stress the alactic system.

1.3. Specific Movements in Basketball

As explained, basketball players' successful performance depends greatly on their anaerobic alactic systems, with shorter, more intense actions that require greater explosive power [1,2]. As such, training and tests should be developed in line with this important factor. However, it is also important to understand the more frequent movements required of basketball players in each situation. During practices and games, key actions include vertical movements (rebounds and jump shots), horizontal actions (change in direction and sprints), and a combination of the two (usually during shot blocking or when penetrating the basket) [30]. As these high-intensity actions are continuously performed throughout the game [2,10], professionals in the field seek optimal training methods for developing these physical capabilities among basketball players, especially their explosive power [2].

In order to maximize performance and minimize the risk of injuries, a comprehensive understanding of biomechanics is crucial when designing training programs for basketball players [1,31]. Biomechanics, the study of the mechanical principles that govern human movement, plays a vital role in optimizing athletic performance and reducing the likelihood of musculoskeletal imbalances or flaws in technique [3,12]. By analyzing the specific movement patterns in basketball, such as the mechanics of jumping, pivoting, and rapid changes in direction, trainers and coaches can identify areas for improvement and tailor

training exercises accordingly [1,2]. For instance, jump training programs can be designed to enhance vertical jump height and power, while agility drills can focus on improving lateral quickness and quick acceleration–deceleration capabilities [16,23,32].

Moreover, incorporating sport-specific drills that mimic game-like situations can further enhance basketball players' performance. These drills not only train the physical attributes required but also help develop decision-making skills, spatial awareness, and anticipation abilities [2,5,16,33,34]. By simulating realistic scenarios, players can improve their reaction time, adaptability, and overall basketball IQ [12,16]. Additionally, integrating strength and conditioning exercises into a training program can enhance muscular power, endurance, and resilience, which are vital for sustaining optimal performance throughout a game [1,2,23].

Overall, by taking a holistic approach to training, considering both the anaerobic alactic systems and the specific movement patterns inherent to basketball, coaches and trainers can effectively prepare players for the physical demands of the sport. By focusing on explosive power development, optimizing biomechanics, and incorporating sport-specific drills, basketball players can enhance their overall performance, elevate their game, and excel on the court [1,5,35–37].

2. Differences in Explosive Power by Age and Gender

Research has shown that there are differences in explosive power among basketball players based on age, gender, and playing position [38–43]. Regarding age, explosive power typically increases with age during childhood and adolescence, with the greatest gains occurring during the growth spurt that occurs in early adolescence [44–49]. Boys tend to have greater explosive power than girls due to their greater muscle mass, and this difference is most pronounced during adolescence. However, both boys and girls can improve their explosive power with appropriate training programs [25,26,38,50–60].

Explosive power is highly valued by coaches in basketball, and they focus on improving this skill in players of all ages, experiences, and levels of performance. To effectively develop players' explosive power and tailor training programs and game plans, coaches require consistent and accurate tools for assessing players' explosive power development. These tools must be tailored to the specific needs of basketball [1,2,19,20,61–64].

Previous studies have found that men generally have a higher number of type II muscle fibers and greater muscle mass, strength, and quality compared with women [65]. These individual characteristics affect their ability to perform explosive movements that require higher contractile force and speed. Furthermore, age also plays a role in these differences as athletes develop and mature over time.

A research study carried out on young basketball players revealed that age and sex were important factors in determining the strength produced by the lower body. The study found that there were no significant differences in 11–13-year-olds, but in the 15–17 years age group, differences were observed in the force generated by the lower body, with female players exhibiting lower values in relative strength when compared with their body weight [24,38,45,65].

Regarding the differences related to age [38,50,51,66], it was confirmed that the period of puberty can limit the development of skills in young basketball players, particularly in women basketball players, due to changes in physical abilities that occur during this physiological process. This can result in significant differences between the performance of male and female players. In the field of sports, it is common to present information through profiles [9,30,39,67–70].

A literature review reveals the existence of a relationship between horizontal and vertical force production and their combination in explosive strength for basketball players. However, it is important to verify that these abilities in the field of explosive strength and the combination of specific movement demands in these planes also apply to basketball players in different age categories and to consider differences between male and female players in these age groups [38,50,51,65].

3. Differences in Explosive Power by Playing Positions

Explosive power can vary significantly among basketball players based on their playing positions [39,65,71,72]. Forwards and centers tend to have greater explosive power than guards due to their greater size and strength, which is advantageous in activities such as jumping and pushing off the ground [35,65,73–76]. On the other hand, guards tend to be faster and more agile, which may be advantageous in activities such as dribbling and driving to the basket. Coaches and trainers should tailor their training programs to match the demands of each playing position and the specific needs of each player [39,71,74,77–79].

Basketball requires the execution of specific skills, movements, and physiological demands that vary depending on the player's position. Previous studies have shown that different positions in basketball have different physiological requirements, which may also vary by age and gender [38,50,61]. One aspect that has been frequently investigated is the anaerobic power and explosive power, especially in vertical jump performance [13,65,80].

Coaches should take into account the unique physical characteristics of players based on their playing position when designing training programs [1,39,71]. Research has shown that forwards tend to have smaller and lighter body frames compared with centers, but larger and heavier body frames compared with guards [65].

Compared with centers, guards possess greater vertical jumping ability, while centers are marked by their heightened levels of muscular strength and power. Most studies exploring player characteristics based on position have been constrained by a limited number of participants ($n < 60$) or restricted to the preseason training period. Only a few studies have assessed these attributes using a sizable group of players or during the regular season [39,65,71].

Recent studies have revealed that there are variations in explosive power among different positions in professional basketball, namely, guards, forwards, and centers. The results showed that guards have significantly greater explosive power compared with forwards and centers.

In addition, Ziv and Lidor's (2009) study yielded mixed findings with regard to the differences in vertical jump and jumping power among basketball players playing different positions [65]. On one hand, they reported no significant variances in these attributes across positions. On the other hand, they found that guards and forwards displayed significantly greater vertical jump heights compared with centers.

The demands of playing positions in basketball vary in terms of anaerobic power and explosive power, especially in vertical jump performance [39,65]. Moreover, age and gender differences also play a role in these physiological demands, as older and male players tend to have higher anaerobic power and explosive power [50,51,65]. However, further research is needed to fully understand the differences in physiological demands among young basketball players of different positions, ages, and genders [65,71].

4. Explosive Capability Assessments

The ability to produce great power in short periods of time is of the utmost importance in basketball. As such, an emphasis is placed on enhancing explosive power among players of all levels and ages [5,30]. Doing so is not solely a theoretical exercise in fitness training and physiological principles; it requires the development of reliable and valid measuring techniques that offer accurate and consistent outcomes [81,82]. Moreover, to provide coaches with applicable rather than theoretical outcomes, measurement protocols must accurately replicate movements that athletes perform in practices and games, while also offering consistent tools to enable comparisons and generalizations [83,84]. Doing so will ensure that differences in results over time are attributed to changes in the athlete's performance rather than to differences in measuring systems. In addition, when applying measurement protocols, external factors should be controlled (such as time of day, the surface on which the test is conducted, and pre-test requirements), to prevent these environmental conditions and timeframes from impacting the test results. For example, in basketball, tests for explosive power should be conducted at three different points in

time (immediately prior to the training program, about halfway through the program, and immediately after the training program), to gather maximum relevant data about the efficacy of the training program and its outcomes [1,6].

Basketball is unique in that it requires players to perform both horizontal and VJs. As such, the literature offers a range of tests for measuring horizontal, vertical, and combined explosive power in basketball players [1,30,71]. This article addresses those tests that specifically examine players' lower limb explosive power, which plays a central role in most basketball actions (Table 2). The tests presented here are measured in the field or on the basketball court, for the most part, and the coaches and physical therapists analyze important data about the players for the professional staff.

Table 2. Specific anaerobic alactic tests for basketball players.

Horizontal	Vertical	Combined
5/10 m sprint (speed test)	Countermovement jump	Bounding power
Standing broad jump	Squat jump	Spike jump
Horizontal drop jump	Vertical drop jump	
2 × 5 m change in direction ability		

Following are details of these eight basketball-specific tests.

4.1. The 5/10 m Sprint Speed Test

The 5/10 m sprint speed test is used to evaluate players' horizontal explosive power through cyclical movement (i.e., sprinting from a standing starting point). The athlete is asked to perform two sprints from a standing starting point, with 3–5 min of rest between the two sprints. The best time out of the two is recorded. The advantage of using photo-electric cells is threefold, as they provide athletes with an external "start" signal, automatically stop the measurement upon sprint completion, and if required, can record intermediate times during the sprint with modular systems [2,85,86].

The test serves as a valuable tool for evaluating the explosive power of basketball players, a crucial attribute in their performance. By periodically conducting this assessment, coaches and trainers can monitor the progress and development of players over time. It allows for the identification of individual strengths and weaknesses, enabling targeted training interventions to enhance explosive power [2,32,87,88]. The test results also facilitate player comparisons within a team, aiding in the selection of suitable roles and positions [39,78].

Moreover, the 5/10 m sprint speed test contributes to injury prevention. By closely examining athletes' sprinting mechanics during the test, coaches and medical staff can identify any deviations or compensatory movements that may increase the risk of injuries. This information guides the implementation of corrective exercises and injury prevention strategies, ensuring the athletes' safety and well-being during intense gameplay [2,11,66].

Furthermore, the test provides valuable information for the professional staff involved in basketball training. Sports scientists, strength and conditioning specialists, and medical professionals can utilize the data collected from the test to gain insights into the athletes' capabilities [18,23]. This data-driven approach enables evidence-based decision-making in designing training programs, individualized interventions, and monitoring progress over time. Additionally, the simplicity and accessibility of the 5/10 m sprint speed test make it a useful tool for clubs that may not have access to advanced equipment, allowing them to evaluate and monitor explosive power effectively [1,2,5].

Overall, the 5/10 m sprint speed test plays a crucial role in assessing horizontal explosive power in ball games, particularly in basketball. Its periodic implementation aids in monitoring player development, enhancing performance, preventing injuries, and providing valuable information for professional staff to optimize training strategies and maximize players' potential [1,11,25].

4.2. Standing Broad Jump Test

The standing broad jump assessment is also used to assess basketball players' anaerobic alactic capabilities. For this test, athletes are instructed to stand with both feet together by the starting line. They then create momentum for the jump by bending their knees and moving their arms forward. The recorded measurement is the best jump out of three, measured with a standard measuring tape. If the athlete falls backward during any of the jumps, the jump is disqualified, and the athlete is asked to repeat the jump. From 1900 to 1912, the standing broad jump was part of Olympic competitions. However, it has not been part of regular global competitions for over a century. In most cases, this test is used for assessing explosive power among basketball players in clubs that do not have access to advanced equipment [2,89,90].

The standing broad jump test allows for the evaluation of anaerobic alactic capabilities, which are crucial for quick bursts of explosive movements on the basketball court. It provides valuable information about the athletes' explosive power, leg strength, and coordination. These data are essential for coaches and trainers to design targeted training programs that focus on enhancing these attributes to improve overall performance [89–91].

Furthermore, the standing broad jump test can be utilized as a cost-effective and accessible assessment tool in various basketball settings. It does not require advanced equipment, making it suitable for clubs with limited resources. By incorporating this test into training programs, coaches can monitor the progress and development of players' explosive power over time. Additionally, the test can aid in injury prevention by identifying any movement imbalances or technique flaws that may increase the risk of injuries during explosive actions [2,89].

In summary, the standing broad jump test is a valuable assessment tool for evaluating athletes' explosive power and anaerobic alactic capabilities in ball games, including basketball. It provides valuable data for coaches and trainers to tailor training programs, monitor progress, and improve performance. Its accessibility makes it particularly useful for basketball clubs with limited resources, while its emphasis on explosive power aligns with the demands of the sport [2,18,22,75].

4.3. Drop Jump Test

The drop jump test, which can be conducted as a horizontal drop jump (HDJ) or as a vertical drop jump (VDJ) test, is used for measuring and developing athletes' stretch–shortening cycle ability [92]. The athletes are instructed to stand on a pre-set box (at a height of 0.30–0.40 m). The athletes then drop down to the ground, quickly bend their knees, and immediately perform a rebound jump as quickly as possible (<0.25 s), minimizing their contact time with the ground. For the HDJ, they must jump as far forward as possible, while for the VDJ, they must jump up as high as possible. The test ends with their controlled landing on the ground [93,94].

The drop jump test focuses on evaluating the athletes' stretch–shortening cycle ability, which is crucial for the rapid and powerful movements required in ball games, including basketball. The stretch–shortening cycle involves the rapid stretching (eccentric phase) and subsequent shortening (concentric phase) of muscles, resulting in increased power production during explosive movements. By measuring and assessing the athletes' performance in the drop jump test, coaches and trainers gain insights into their ability to efficiently utilize the stretch–shortening cycle [92,94,95].

Moreover, the drop jump test serves as a valuable tool for developing athletes' stretch–shortening cycle ability. By incorporating specific training protocols, such as plyometric exercises, coaches can enhance the athletes' neuromuscular coordination and muscular power, improving their ability to generate explosive movements. This can directly translate into improved performance in ball games where quick and powerful actions are essential [57,93–95].

Additionally, the drop jump test provides valuable information for individualized training programs. By evaluating athletes' performance in both the HDJ and VDJ variations,

coaches can identify specific areas of strength and weakness. For example, athletes who excel in the HDJ may possess exceptional horizontal power and could be suitable for roles requiring quick bursts of speed and agility. On the other hand, athletes who demonstrate superior performance in the VDJ may possess remarkable vertical power and could be well-suited for roles that involve jumping, rebounding, and shot blocking [92–95].

In summary, the drop jump test is a valuable assessment tool for evaluating and developing athletes' stretch–shortening cycle ability in ball games, including basketball. It provides valuable data for coaches and trainers to assess performance, design targeted training programs, and improve overall athletic performance. By focusing on the stretch–shortening cycle, coaches can enhance athletes' power production and explosiveness, leading to improved performance on the basketball court [57,92,95].

4.4. The 2 × 5 m Change in Direction Ability Test

The 2 × 5 m change in direction ability (CODA) test is especially suitable for measuring basketball players' anaerobic alactic capabilities. The test measures sprinting time, turning, and changing direction. The athletes are instructed to perform a 5 m run in one direction, turning around as quickly as possible, and then perform the same 5 m run back to the starting point (a 10 m run in total). Basketball players must possess strong agility capabilities to cope with the multiple stimuli and instantaneous decision-making involved in the dynamic environment in which the game is played. In most cases, the T-test and pro-agility test are the gold standard for assessing agility among athletes [1,16,72]. However, in light of this review of the anaerobic alactic tests that are most suitable and specific for basketball players, the 2 × 5 m CODA test should be conducted when examining players' anaerobic alactic and change in direction capabilities [32,33,96,97].

By conducting the 2 × 5 m CODA test, coaches and trainers can gather data on players' anaerobic alactic capacity and change in direction abilities. This information guides the design of targeted training programs to enhance these skills, ultimately improving overall performance on the basketball court. The test can also aid in identifying areas for improvement and developing strategies to optimize players' agility and quickness [1,2].

In summary, the 2 × 5 m CODA test is a valuable assessment tool for measuring anaerobic alactic capabilities and change in direction ability in ball games, with specific relevance to basketball. It provides valuable information on players' agility and quickness, enabling coaches and trainers to tailor training programs and strategies to enhance performance. The test's focus on sprinting, turning, and changing direction aligns with the demands of basketball gameplay, making it a suitable and specific evaluation method for basketball players' anaerobic alactic and change in direction capabilities [1,2,5,16,74].

4.5. Countermovement Jump Test

The countermovement jump (CMJ) test assesses explosive power in a VJ, with athletes standing up straight, then bending their knees and quickly extending them to leave the ground and rise up as high as possible. The athletes are usually instructed to place their hands on their hips during the jump to minimize upper limb momentum. Players perform up to three jumps in total, with about two minutes of rest between jumps. Jumps can be performed using one or both legs and a transmitting and receiving bar is used that enables the accurate measurement of flight and contact times during jumps [2,82].

The CMJ test plays a vital role in assessing explosive power, a critical attribute in ball games, including basketball. By measuring the height achieved during a vertical jump, coaches and trainers gain valuable insights into the athletes' ability to generate force and power with their lower body. This information allows for the evaluation of performance, identification of areas for improvement, and the design of targeted training programs to enhance explosive power [31,36,98].

Performing the CMJ test with one or both legs enables the assessment and comparison of bilateral and unilateral explosive power, providing valuable data on athletes' leg strength and coordination. This assessment can assist coaches in identifying potential asymmetries

or imbalances that may impact performance or increase the risk of injuries. By addressing these imbalances with targeted training, athletes can improve their overall explosiveness and reduce the likelihood of injury [1,2,82,98].

Moreover, the use of transmitting and receiving bars in the CMJ test ensures accurate measurement of flight and contact times, offering detailed information on athletes' jumping technique and efficiency [2,99]. These data can be analyzed by coaches and trainers to refine jumping mechanics, optimize power production, and minimize energy loss during explosive movements. The insights gained from the CMJ test can guide the development of individualized training programs, targeting specific areas for improvement and enhancing overall athletic performance on the basketball court [1,5,98].

In summary, the countermovement jump (CMJ) test is a crucial assessment tool for evaluating athletes' explosive power in ball games, with specific relevance to basketball. By measuring the height achieved during a vertical jump, coaches and trainers can assess performance, identify areas for improvement, and design training programs to enhance explosive power [2]. The test allows for the assessment of bilateral and unilateral explosive power, aiding in the detection of imbalances [1,2]. The use of transmitting and receiving bars ensures accurate measurement, enabling the analysis and refinement of the jumping technique. Ultimately, the CMJ test plays a significant role in optimizing athletic performance and enhancing explosiveness in the game of basketball [2,18,22].

4.6. Squat Jump Test

The sixth test reviewed in this article is the squat jump test, which also offers a tool for specifically measuring basketball players' vertical explosive power. For this measurement assessment, the athletes assume a low squat position, refrain from any movement, and then jump up as high as possible. During the test, the players are usually asked to place their hands on their hips or behind their backs to prevent momentum from their upper limbs that could impact this assessment [2,18].

The squat jump test serves as a valuable tool for evaluating basketball players' vertical explosive power, a critical attribute in the sport. By assessing the height achieved during the jump, coaches and trainers gain insights into the athletes' ability to generate force and power with their lower body. This information facilitates the evaluation of performance and enables targeted training interventions to enhance vertical explosive power [2,82,100].

Placing the hands on the hips or behind the back during the squat jump test eliminates the involvement of upper limb momentum, ensuring that the measurement accurately reflects the lower body's power generation. This focused assessment allows coaches and trainers to isolate and assess athletes' lower body strength and power, specifically in relation to vertical jumping ability [23,82].

Furthermore, the squat jump test provides valuable information for designing individualized training programs. By evaluating performance in this test, coaches can identify areas for improvement and tailor training strategies to enhance athletes' vertical explosive power. The test allows for ongoing monitoring of progress and the effectiveness of training interventions, facilitating evidence-based decision-making in optimizing performance [2,82,100].

In summary, the squat jump test plays a crucial role in assessing basketball players' vertical explosive power in ball games, particularly in basketball. By measuring the height achieved during the jump and ensuring minimal upper limb involvement, coaches and trainers can evaluate performance, identify areas for improvement, and design targeted training programs to enhance vertical explosive power. The test's focus on isolating lower body strength and power aids in the development of specific training interventions [18,35,61,101]. Ultimately, the squat jump test contributes to optimizing athletic performance and enhancing vertical jumping ability in the game of basketball [2,82].

4.7. Bounding Power Test

The bounding power test also examines basketball players' anaerobic alactic abilities. The athletes are asked to stand on one leg and jump horizontally as far forward as they can six consecutive times. Alternating the jumping legs after each jump means that a total of three jumps are performed with each leg. This test combines both horizontal and vertical capability assessments. In most tests, the athlete performs the final jump using both legs into a sandbox. This test is performed twice, with the longer distance being recorded. Results are measured manually using a tape measure [1,102,103].

In most bounding power tests, the final jump is performed using both legs, and the athletes land in a sandbox or within their specific sports field. By incorporating both single-leg and double-leg jumps, the test captures different aspects of power production and coordination, which are essential in basketball. The specific sports field landing further enhances the specificity of the test, simulating game-like conditions and requiring athletes to execute controlled landings [2,103].

The bounding power test serves as a valuable tool for evaluating basketball players' power and explosiveness, which are crucial attributes for success on the court. By measuring the distance covered in horizontal jumps, coaches and trainers gain insights into the athletes' ability to generate force and power in both the horizontal and vertical directions [1]. This information aids in assessing performance, identifying areas for improvement, and designing targeted training programs to enhance bounding power [102,103].

Moreover, the bounding power test assesses athletes' anaerobic alactic capacity, which is particularly relevant in basketball. Anaerobic alactic abilities enable athletes to produce quick and explosive movements without relying on oxygen consumption [2,3,6]. These abilities are vital for actions such as rapid accelerations, decelerations, and changes in direction on the basketball court. By evaluating anaerobic alactic capacity using the bounding power test, coaches can gain specific information about athletes' power production during high-intensity actions [5,102,103].

In summary, the bounding power test holds substantial importance for ball games, athletes, and basketball. By evaluating both horizontal and vertical capabilities, as well as assessing anaerobic alactic capacity, the test provides a comprehensive evaluation of basketball players' power and explosiveness [1,102]. It aids in evaluating performance, identifying areas for improvement, and designing targeted training programs [1,104]. The specificity of the test, including the landing and alternating leg jumps, ensures its relevance to basketball-specific movements. Ultimately, the bounding power test contributes to optimizing athletic performance and enhancing power production in the game of basketball [1,102,103].

4.8. Spike Jump Test

Finally, the eighth test presented in this review is the spike jump test, which examines the horizontal and vertical explosive power of basketball players, using what is considered a specific volleyball jump. First, the upstretched arm length is measured. Next, they are asked to jump up as high as possible (after taking three or four steps forward, or not). Their upstretched arm length is then measured at the height of their jump. Their static upstretched arm length is then subtracted from their jump arm length, to achieve the relative height of the jump. A standing jump test can also be conducted for this assessment test [105]. These tests are specific for assessing explosive power in ball games and especially for professional basketball players who are required to manifest high levels of explosive power. Elite players will exhibit significantly higher levels in these tests than amateurs or players from lower leagues [5,73].

Notably, the spike jump test is particularly relevant for professional basketball players who are expected to manifest high levels of explosive power. Elite players are expected to exhibit significantly higher levels of performance in these tests compared with amateurs or players from lower leagues. The test serves as a discriminative measure that distinguishes between different skill levels, enabling the identification of athletes with exceptional explosive power [31,73,105].

In summary, the spike jump test is of considerable importance for ball games, athletes, and the game of basketball. By assessing both horizontal and vertical explosive power, the test provides a comprehensive evaluation of basketball players' power generation capabilities. It aids in evaluating performance, distinguishing skill levels, and identifying areas for improvement [2,103]. The specificity of the test to the game of basketball ensures its relevance to the sport's demands. Ultimately, the spike jump test contributes to optimizing athletic performance and enhancing explosive power in basketball players [2,73,103,105].

5. Discussion

This article reviews the existing lower-limb anaerobic alactic tests that are suitable for measuring professional basketball players' abilities, at all levels and ages, including a total of eight assessment tests. The modern game of basketball has become more intensive following the introduction of new rules in 2000. As such, basketball players' agility and anaerobic alactic [3,5] abilities, rather than aerobic capabilities, play a more central role in their performance. Basketball players today are highly conditioned athletes, which is necessary for achieving consistent high-level performance throughout the season [12,106,107]. Moreover, the game is unique as it requires players to perform horizontal movements, vertical ones, and a combination of the two [2,108]. These high-intensity movements are intermittently performed throughout the game, at different time intervals, and from different positions on the court [5,71]. As such, sports researchers, trainers, and strength and conditioning coaches continue to strive to identify optimal measurement tests that are specific to basketball [18,30].

These tests need to take into account considerations such as age, gender, and playing positions [38,39,54]. In competitive sports, particularly basketball, there is difficulty in conducting such research for reasons such as the fact that young individuals, for example, do not focus on specific playing positions [39,74]. Additionally, even when the competitive level is high, there is less patience among less prominent clubs to conduct various types of research on their teams. Nevertheless, the importance is clear: research in the basketball field is being carried out, and even small studies can shed light and serve as the starting point for the development of ideas [1,2,19,103]. When a profound understanding of all aspects related to the development of unique field tests is crucial, the selection of appropriate measurement equipment in the field for assessing explosive force holds significance based on the available options for a professional team. Therefore, it is also important to take into account reliable and valid measurement tools such as the optojump system, force plates, photoelectric cells, and the My Jump 2 app. This equipment is used in the field as a common measuring tool for athletes, and basketball players in particular, and although we chose not to present it in this article, we recommend considering it as well [1,2,99,103,109–115].

Trainers and researchers often use 20 or 27 m tests for assessing players' abilities, as this is similar to the length of a basketball court [6]. However, video analysis indicates that basketball players rarely have to sprint across the entire court. Rather, they mainly perform high intensity runs lasting 1.7–2.1 s, which is more similar to the 5/10 m run [3,30]. To the best of our knowledge, both theoretical and practical field tests are lacking that examine both horizontal and vertical capabilities specifically for basketball players. For example, one study developed a new unique test for assessing the explosive power of basketball players with a ball [103]. This test is highly important and sheds light on the significance of unique tests in basketball. We chose not to present this test in this article because it needs to be further examined in additional studies, including differences by gender, age groups, and playing positions [2,39,45,51,103]. However, it is definitely a significant step forward. The need for additional unique tests to measure the variety of movements presented in this article regarding explosive power is required on the basketball court, as well as for the uniqueness of the agility component that incorporates elements of explosive power within it [2,16]. Furthermore, the need for unique tests in basketball is also relevant for assessing the aerobic physiological system, which received less focus in this review. Researchers in this field have started to develop additional unique tests in this area as well [2,19], and

their use is also important, including continued thinking and development of additional unique tests [47,51]. Development of such unique tests should include preliminary research to assess their reliability and validity, including comparisons to existing standard tests, like those presented in this article. At a later stage, new tests should be applied to a broad range of basketball players, to ascertain differences by age, gender, and on-court positions, among professional and amateur players, if applicable [19,39,45,51,71,103]. Moreover, a number of tests assess athletes' upper body explosive strength (such as the 1-RM bench press test). These were not reviewed in this article as these skills are less frequently used in basketball.

Efforts have been made to create tests that specifically assess lower limb explosive power among basketball players [2,5]. Although studies indicate correlations between vertical and horizontal power [103,105,116], the scientific literature lacks specific tests for examining this power in combined vertical and horizontal movements [1,32,117]. In a study on handball players [108], no association was observed between CMJ tests and the players' time in the air—an action that entails both horizontal and vertical movements. As such, CMJ may not be a reliable tool for predicting jumping ability specific to handball players. On the other hand, a different study revealed a strong connection between CMJ outcomes and the volleyball jump serve, which also combines both horizontal and vertical components, similar to the spike jump in basketball [105]. As such, connections among these variables seem to differ from sport to sport, and perhaps even among athletes with different levels of development. Moreover, it is unclear as to whether CMJ test protocols and others can reliably predict specific basketball jumping abilities (e.g., jumping time when leaping up toward the basket on one leg in various specific jumping styles while holding the ball).

Additional examples of inadequate tests can be seen in a number of intervention studies relating to ball games. While the outcomes of these studies indicate improvements in maximal sprint, strength, plyometric, and complex training, as seen in CMJ performance assessments [1,104,118,119], it is unclear whether these improvements can be transferred to additional game situations, such as basket penetrating and layups. Indeed, transferring physical improvements seen in training to actual ball games is not easy to assess—as additional factors must be addressed, such as players' technical abilities and complex interactions.

Since the main factor for assessing basketball players' capabilities is their anaerobic alactic system, tests that examine their anaerobic glycolytic energy system are less relevant. Tests should specifically focus on players' lower limb explosive power, such as the 5/10 m sprint test rather than the 20 m test. Moreover, it seems that while multiple tests exist, there is no standardization of these assessment tools—nationally or internationally. For example, while the horizontal and vertical drop jump tests may offer important tools for assessing basketball players' plyometric and jump height abilities, drop height and jump height are not always identical and, as such, could result in different measurements [92,93]. Additional limitations of the existing tests can be seen in tests such as the spike jump that combines both horizontal and VJ capabilities, as differences in players' shoulder joint flexibility may impact the outcomes of the test and hinder the ability to reliably compare athletes' measurements [105].

Examining the vertical jump height of basketball players is crucial for understanding their physical capabilities. In basketball, athletes commonly use jump tests to assess the reactive power in their legs. These tests are well-liked because they are cost-effective, can be performed on the basketball court, and provide insights into the overall health of muscles and bones. Research indicates that enhancing jump height is associated with strengthening the muscles and bones of the body [2,98,103]. The CMJ serves as a valuable tool for evaluating the current physical condition of players, aiding in the monitoring of fatigue, loss of explosive power, and disparities between limbs [1,31,98,103]. Coaches play a pivotal role in instructing players on proper jumping techniques to conserve energy. During jump tests, it is essential to clearly define the jump goals (such as reaching a

specific height or maximizing explosiveness) and adhere to a consistent protocol to ensure reliable results [2,23]. For researchers developing new tests, considering these factors is imperative [2,19,103].

Finally, the issue of upper-limb momentum should be addressed, as biomechanical and physiological tools used to study VJs often attempt to neutralize the athletes' arm movement (by performing the test with their hands on their hips or behind their backs). This is completed in an attempt to isolate the effect of leg muscle power as a means for seeking causal relationships between improved lower body muscular power and jump height. However, this does not replicate the exact jump movements that athletes in general and basketball players, in particular, perform during practice and games—especially as jumping without arm momentum is not an action that is performed in competitive sports [18].

6. Conclusions and Practical Applications

Based on the literature review presented in this paper, it seems that specific tests for basketball players are lacking, especially tests for examining agility [16,35], which is a skill that requires lower-limb explosive power. The literature also lacks measurement tests for examining lower limb explosive power that requires both horizontal and vertical movements combined, as required in penetration of the basket [5,18]. It is especially difficult to replicate the dynamic, constantly changing environment that is typical of basketball games—an environment filled with simultaneous multiple stimuli in which players must make split-second decisions that could impact the outcome of the game. Future studies could benefit from developing and researching basketball-specific tools for assessing players' anaerobic alactic energy systems in relation to their lower-limb explosive power. Developing such tools could significantly enhance research and performance in basketball.

Assessment tests must provide useful input and insights that trainers and coaches can utilize in the field. As such, it is important to comply with the principle of specificity in training, whereby a given motor skill is improved (and tested) as it is performed during actual games [2,5,9]. Indeed, with specific respect to basketball, developing an applicable, reliable, and valid field-specific test for assessing players' anaerobic capabilities is important. As such, this article helps to order the specific demands made on the players' physiological energy systems—especially the alactic anaerobic system—and the role they play during a basketball game, as well as the specific patterns in movements. Despite the fact that much of the information in this review article is familiar to coaches and trainers, highlighting the specific needs of basketball may help them choose the most suitable tools and may also shed light on new directions for developing basketball-specific and unique assessment tests.

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