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Mapping of Vertical and Horizontal Jump Tests Used to Evaluate Muscular Power in Basketball

Adriano Vretaros[1]

[1]Strength and Conditioning Coach
[1]Postgraduate in Physiological and Methodological Basis of Sports Training Federal University of São Paulo – UNIFESP. São Paulo – Brazil.

ABSTRACT

Field tests involving vertical and horizontal jumps are routine practice in the physical training of basketball players. Therefore, the aim of this research is to map the vertical and horizontal jump tests used to assess muscular power in basketball. In this literature review, four electronic databases (Google Scholar, Scielo, PubMed, MEDLINE) in English, Spanish and/or Portuguese were consulted, where 34 primary scientific studies were chosen to analyze the vertical and horizontal jump tests used for assessment of muscular power in basketball. Basically, jump tests can be classified into stationary vertical jump tests, vertical jump tests with approach running, stationary horizontal jump tests, and horizontal jump tests with displacement. A total of 24 jump tests were found to be used in the assessment of muscular power in basketball. The five most frequently mentioned tests are the countermovement jump (CMJ, 28.3%), squat jump (SJ, 12.3%), drop jump (DJ, 7.40%), Abalakov jump (ABK, 6.17%), and horizontal jump (HJ, 4.93%). When we examine the five tests, it is clear that four of them belong to the category of stationary vertical jump tests (CMJ, SJ, DJ, ABK) and only one is classified as a stationary horizontal jump test (HJ). Four jump tests allow the assessment of explosive power (CMJ, SJ, ABK and HJ) and one measures reactive power (DJ). It was concluded that these jump tests have other essential purposes that could contribute to a more refined fit in the control and distribution of workloads.

KEYWORDS: *Basketball, Strength Training, Physical Fitness Testing, Exercise*

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1. INTRODUCTION

Basketball is a team situational sport. The variability of motor actions that occur in a match are difficult to predict in advance[1]. Currently, basketball is understood as a complex sport that combines varied technical skills, broad tactical knowledge, psychological stability and high physical fitness.[2] The sum of these factors makes competitive basketball an interesting, exciting and attractive spectacle for the media and spectators.[3]

Intermittent acyclic activities are performed in reduced dimensions on the court and with ball possession disputes through direct contact between opposing teams. Consequently, territorial invasion becomes a typical offensive tactical skill in basketball.[2,4,5,6]

The bioenergetic demand in competitive basketball encompasses alactic anaerobic (via phosphagen resynthesis), anaerobic lactic (via glycolytic) and aerobic (via oxidative) metabolism. With these multiple bioenergetic systems properly trained, players' fatigue on the court is reduced.[7]

The modern game has a high speed of technical-tactical player movement, requiring intense explosive actions in a short period of time.[1,8] Some of these movements that stand out would be accelerative runs, sudden decelerations, vertical jumps, horizontal jumps, quick changes of direction, blocks, passes, reactive agility maneuvers, among others.[5,8,9]

These explosive behaviors during the matches end up requiring the muscular power of the athletes' upper and lower limbs. So, the specific physical conditioning of basketball players will denote a real need for continuous improvement in the manifestations of strength, in order to reach satisfactory levels of muscular power consistent with a high athletic performance.[6,10,11]

The foundation to develop adequate functional work capacity in improving muscular power begins with maximal strength training.[5,8,9,12] By capitalizing on gains in maximum strength, neural and, to a lesser extent, morphological changes are awakened.[13] From this, the central nervous system activates intramuscular and intermuscular coordination better.[6] Then, in a periodized planning, methodologies are introduced that stimulate muscular power (Olympic lifting techniques, ballistic method, contrast method, plyometric method).[5,6,14,15]

Training of muscular power would involve activating the excitability of motor neurons, fast-twitch fibers, and the use of the stretching-shortening cycle.[5,16,17] It can be stated that the optimized combination between maximum strength and speed are key components that govern the ability to produce muscular power effectively. In this way, an important focus of the exercises must be centered on improving the rate of force development (RFD).[18,19] By stimulating the RFD, it is possible to increase contractile competence in generating force at high speeds as quickly as possible.[10]

The ability to jump vertically and horizontally expresses the muscular power of the lower limbs in basketball players. Both are evident in many competitive situations and in training sessions. Thus, jumpability plays a decisive role for success in a wide spectrum of offensive and/or defensive movement patterns.[4,20] According to KELLIS *et al.* (21) the correct jumping technique should be learned from a younger age in formative athletes. A pedagogical strategy for the players' jumpability to evolve in the medium and long term would be to implement sessions aimed at increasing maximum strength, movement speed and motor coordination of the technical gesture.[22]

To indirectly assess the muscular power of the lower limbs, a battery of tests is usually used that covers the jumping ability.[1,2,23] It is routine in professional practice to monitor neuromuscular responses to training interventions through jump tests.[23] Jump tests are simple to apply, low cost, minimally invasive, time-efficient, and have a high kinematic correspondence with specific skills.[24,25] Such tests are carried out both vertically,[1,4,5,7,21,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42] and horizontally.[12,43,44,45,46,47,48]

In the training process, jump tests serve several purposes, such as: verifying acquired acute and chronic neuromuscular adaptations, readiness for work, fatigue levels, recovery status, strength asymmetries between dominant and non-dominant leg, explosive power, reactive power, power endurance, lateral power, detraining, among other factors.[7,21,28,30,31,38,39,43,44,48,49,50]

However, when consulting scientific publications, it is clear that there is a lack of studies analyzing this set of tests aimed specifically at basketball. In addition to this, it is necessary to establish classification criteria for the numerous tests available. Therefore, the aim of this research is to map the vertical and horizontal jump tests used to assess muscular power in basketball.

2. METHODOLOGY

This investigation is characterized as a literature review. In this type of approach, the theme is delimited based on the formulation of a main object of study. In conducting the research, a systematic methodical posture is adopted that explores the acquisition of new knowledge or renewal of existing knowledge, based on the selected bibliography.[51,52] The interpretation of the data is done in a judicious, quantitative and exploratory way, seeking to elucidate and describe the problem under study through the construction of an analytical text without bias. In this way, it is possible to map, develop theories, identify contradictions and try to fill existing gaps.[52]

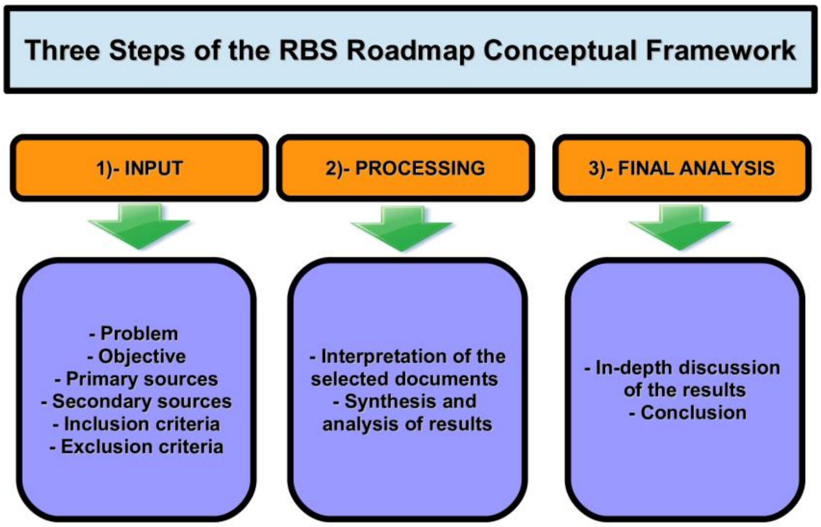
The conceptual framework of this literature review is supported by the codified eligibility of the RBS Roadmap protocol (figure 01). In this strategy, the literature review process takes place in three stages: 1)- input (problem, objective, primary sources, secondary sources, inclusion criteria, exclusion criteria), 2) processing (interpretation of selected documentation, synthesis and analysis of the results), 3)- final analysis (deep discussion on the results and conclusion).[53]

Data from this manuscript were collected from four electronic databases (Google Scholar, Scielo, PubMed, MEDLINE) in English, Spanish and/or Portuguese. The central scope is to select scientific texts with the theme vertical and horizontal jump tests used to assess muscular power in basketball. In the Boolean search for words, the following key terms were used: “basquetebol AND\OR testes de saltos verticais”, “basketball AND\OR vertical jumps tests”, “baloncesto AND\OR pruebas de salto vertical”, “basquetebol AND\OR testes de saltos horizontais”, “basketball AND\OR horizontal jump tests”, “baloncesto AND\OR pruebas de salto horizontal”, “basquetebol AND\OR potência muscular”, “basketball AND\OR muscular power”, “baloncesto AND\OR potencia muscular”, “basquetebol AND\OR potência explosiva”, “basketball AND\OR explosive power”, “baloncesto AND\OR potencia explosiva”, “basquetebol AND\OR potência reativa”, “basketball AND\OR reactive power”, “baloncesto AND\OR potencia reactiva”, “basquetebol AND\OR testes de campo”, “basketball AND\OR field tests”, “baloncesto AND\OR pruebas de campo”, “basquetebol AND\OR ciclo alongamento-encurtamento”, “basketball AND\OR stretch-shortening cycle”, “baloncesto AND\OR ciclo de alargamiento-acortamiento”, “basquetebol AND\OR força máxima”, “basketball AND\OR maximum strength”, “baloncesto AND\OR fuerza máxima”, “basquetebol AND\OR curva força-velocidade”, “basketball AND\OR force-velocity curve”, “baloncesto AND\OR curva fuerza-velocidad”.

Criteria for inclusion and exclusion of articles were adopted to make the investigation more academically rigorous. In the inclusion criteria, the following were chosen: 1)- research discussing vertical and horizontal jump tests in basketball, 2)- vertical and horizontal jump tests that assess muscular power in basketball, 3)- vertical and horizontal jump tests in team sports , 4)- vertical and horizontal jump tests in basketball with different purposes, 5)- muscular power training in basketball and 6)- muscular power training in team sports. Exclusion criteria eliminated incomplete texts, articles in duplicates, tests of vertical and horizontal jumps in individual sports.

The final composition included 34 primary scientific articles published between 1999 and 2022, 27 complementary articles and 06 textbook chapters in the field of sports training theory.

Figure 01. Schematization of the RBS Roadmap methodology used in this investigation



3. MUSCULAR POWER IN BASKETBALL

The mechanical power in the physical law can be expressed in three different equations: 1)- P=FxV (stating that the power is the result of the product of the force by the velocity), 2)- P=Fxd\t (stating that the power is related with the force developed over a movement in a certain period of time) and 3)- P=FxV\t (stating that the power is the product of the force applied by the velocity of the movement in a certain period of time).[10,11,54]

In sport-specific human action, muscular power (explosive strength) is the muscle capacity to produce high levels of force in a short period of time.[9] In other words, the greater the force applied to move a resistance (body weight or external load) the greater the speed produced and, as a result, we have muscular power.[10]

The development of muscular power in basketball is of crucial importance, as there is a high positive correlation between it and vertical jumps, horizontal jumps, accelerations, changes of direction and speed.[55] Athletes with good muscular power levels tend to have a higher proportion of fast-twitch fibers in their muscle architecture.[8]

Muscular power training in basketball players must be properly guided. In this sense, two classifications for muscular power can be observed in the literature: explosive power and reactive power. The explosive power is manifested in tasks with foot-to-ground contact time greater than 250 milliseconds and, with that, the long stretch-shortening cycle is triggered. On the other hand, reactive power is present in explosive actions with foot-to-ground contact time of less than 250 milliseconds, activating the short stretch-shortening cycle.[10,12,35,56,20,57]

The role of the stretch-shortening cycle in muscular power training is associated with the ability of the musculotendinous unit to produce a powerful concentric or ballistic muscle contraction immediately after the eccentric action. This neuromuscular response depends on the pre-stretching that activates the myotatic reflex and creates a reserve of elastic potential energy to trigger an power output of great magnitude.[10,11,50,57]

Furthermore, it is worth mentioning that the difference between the long and short stretch-shortening cycle is in the range of motion during the jump. In the long stretch-shortening cycle, there is a greater range of motion, causing a longer time of foot-to-ground contact. On the other hand, in the short stretch-shortening cycle, there is less joint amplitude and, therefore, less time of weight-to-ground contact. Therefore, it can be stated that explosive power training has a slower execution speed when compared to reactive power. These temporal magnitude discrepancies occur in the eccentric and concentric phase of the movement.[23]

The classic modus operandi for prescribing muscular power training consists of creating a good baseline of maximum strength before starting work on muscular power. Another concrete possibility is to jointly stimulate maximum strength with muscular power work.[6,9,17,58] Maximal strength is an essential prerequisite for raising muscular power to the higher stages. The conceptual definition of maximal strength connects with the greatest force that the athlete's neuromuscular system can produce. Usually, it is reached in 0.4 seconds cubed.[11,16]

Maximal strength training can induce a large number of neural adaptations and, to a moderate degree, morphological adaptations occur. Intramuscular coordination (synchronization in neural firing rate) and intermuscular coordination (conjugated operation between agonist, antagonist, synergist, stabilizer, and neutralizer muscle groups) are considered pronounced physiological effects.[6,13,14,57] In practical-methodological terms, it is suggested that athletes of both sexes be able to perform the squat exercise with a minimum load equivalent to twice their body mass in order to better activate their muscular power. This situation distinguishes strong athletes from weak athletes.[9,19] Consequently, it is speculated that the maximum strength modulates the performance of explosive power and reactive power.[6,13,14,57]

The improvement in explosive power is orchestrated by three aspects that maximize the final results during training. The first aspect concerns the effective use of the RFD that would optimize the generation of explosive power in short periods. The second aspect requires an ability to produce high strength in the final phase of the eccentric muscular regime in the transition to the concentric regime. In the third aspect, the athlete must be able to maintain high strength according to the speed of muscle shortening.[14]

The reactive power in basketball is in great demand, as the movements that players perform during a game tend to be non-linear and highly unpredictable. This type of complex panorama requires neuromuscular reactivity.[10] An athlete with satisfactory reactivity absorbs high speeds of movement in the eccentric regime and converts them into explosive concentric actions in a time-efficient way.[35] Research shows that continuous training of reactive power increases stiffness in the muscle tendon unit, and tasks with jumps acquire less time of foot-ground contact in the vertical and horizontal direction.[42,57]

Power endurance is another manifestation of muscular power that is coupled with the ability to sustain degrees of power for prolonged periods of time. Basketball players with high proficiency in power endurance demonstrate regular physiological, biomechanical and technical parameters in the performance of explosive activities that require fatigue tolerance. For example, being able to maintain the value of height and speed of movement during the vertical jump found at the beginning of the game throughout the subsequent four quarters of the game.[4,6,27,34]

In a planning for a sustainable growth in the performance of the muscular power of the basketball players it is recommended to observe some determining points: maximum isometric strength, maximum dynamic strength, RFD, stretch-shortening cycle, intra and intermuscular coordination and specific motor skills.[6,10,56,59] A didactic recommendation is to vary the focus of the power training load by going through the various parts that constitute the strength-velocity curve.[19]

With the evolution in the field of sport sciences, the most advanced method to train muscular power in team sports is through the calculation of the individual profile of the force-velocity curve. In this approach, it is possible to identify the athlete's real operational need based on a mechanical representation of their functional capacity (force-deficit or velocity-deficit).[17,60]

Based on this premise, an integrated training program aimed at improving muscle power in basketball needs to be properly periodized. It is necessary to select a periodization model to be implemented in order to organize the contents. This periodization model needs to be adjusted to the league's competitive schedule, player-specific needs, biological maturation, and gender. Then, the rational and logical manipulation of external load variables (intensity, volume, frequency, density and complexity of tasks) is carried out over time in compatibility with the development of other biomotor capabilities.[6,15,18,58]

4. JUMPING TESTS FOR EVALUATION IN BASKETBALL

In the prescription and indirect assessment of muscular power, jump tests are adopted to obtain a more accurate understanding of the training program.[1,2,23]

The vertical and horizontal jump tests used to assess muscular power in basketball have in common multi-joint and ballistic movements.[34] From the kinesiological point of view, both tests require the triple extension. That is, the simultaneous extension of the joint segments of the ankle, knee and hip. This particularity is relevant because the tests demonstrate biomechanical similarity with the specific basketball motor actions such as accelerating starts, changes of direction and jumps.[6,61]

These two types of tests (vertical and horizontal) evoke the stretch-shortening cycle in their actions.[16,23,36,50] Apparently, the muscles of the quadriceps and gluteus maximus significantly contribute to the mechanical work during the execution of vertical and horizontal jumps.[5,59]

The vertical jump tests express the vector of force in the vertical (axial) direction, which is often used in specific skills such as jumping to shoot, rebounding and blocking. On the other hand, horizontal jump tests denote the vector of force in the horizontal direction (anteroposterior), used in accelerative sprints, constant changes of direction and lateral shuffles.[23,47,48,56,59,62]

It should be noted that vertical jump tests are more manipulated than horizontal jump tests on a daily basis by physical trainers and in research. The two test versions record metrics of the force-time, speed-time and power-time curves.[18,63] The amount of metrics that can be generated in the vertical and horizontal jump tests vary according to the objectives of the study. A simple vertical jump test performed on the jumping mat or on the force platform produces nine metrics on average.[23,24,28,38,39,64] However, a horizontal jump test can produce at least two to fifty-two metrics, depending on the amount of technological equipment available and the adopted protocol.[43,44,45,49,63,65]

It appears that the jump tests used in basketball have satisfactory objectivity, reproducibility, reliability and ecological validity, as well as being correlated with other biomotor capabilities.[23,36,44,63] For example, maximal dynamic strength in the squat exercise and maximal isometric strength in the isometric mid-thigh pull exercise strongly correlate with height achieved in the vertical jump test. This is probably due to the similarity in the vertical force application vector.[8,56] The peak power metric of the countermovement jump is correlated with the maximum isometric strength developed in the isometric mid-thigh pull (r=0.43-0.75) and, also, in the maximum dynamic strength of the squat (r=0.66-0.84). The biomotor capabilities speed in the 10-meter sprint (r=-0.49 to -0.69) and agility in the t-test (r=-0.77) are correlated with the countermovement jump height metric.[24] The absolute and relative peak torque of the knee extensors\flexors are highly correlated with the angular velocity of 240°\s (r=0.72 and r=0.88, respectively) and 300°\s (r=0.46 and r=0.54, respectively).[66] Countermovement jump tests and squat jump test are correlated with relative strength of lower limbs (r=0.496-0.538), 10-meter sprint (r=0.742) and 40-meter sprint (r=0.598).[25] In addition, there is a significant correlation between the bipodal horizontal jump test and the Abalakov vertical jump test (r=0.68-0.69).[63]

Numerous tests of vertical and horizontal jumps are documented by experts. In general, we can classify them into four elementary categories: stationary vertical jump tests, vertical jump tests with approach running, stationary horizontal jump tests and horizontal jump tests with displacement (table 01).[1,4,5,7,12,20,21,26,27,28,29,30,31,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,55,56]

The stationary vertical jump tests reflect statically performed jumps that have moderate to high specificity with the modality's motor actions and allow verifying gains in muscle power and analysis of neuromuscular fatigue. Some variations found in these tests would be the use (countermovement jump test with arms swing - CMJAS, Abalakov vertical jump test – ABK, and Sargent test) or not of the upper limbs (countermovement jump test - CMJ, squat jump test - SJ, drop jump test - DJ) in jump dynamics, jumps with bipodal takeoff (CMJ, SJ, ABK, bilateral stationary vertical jump test - SVJ) or single leg (vertical single leg jump test with countermovement - SLCMJ), jumps repeated continuous tests (continuous vertical jump test repeated for fifteen seconds – RJ15, continuous vertical jump test repeated for thirty seconds – RJ30, continuous vertical jump test repeated for sixty seconds – RJ60 and continuous vertical jump test until exhaustion - CJE), vertical jump with overload (countermovement jump test with load - CMJL), vertical jump with lateral force vector (lateral countermovement jump test -LCMJ).[4,5,7,21,26,27,28,29,30,31,32,33,34,35,37,38,39,40,41,48,55,56]

In tests of vertical jumps with approach run, its characteristics gather dynamics related to the more specific motor actions of basketball, such as the lay up. For this reason, tests with approach running demonstrate higher numerical results when compared to stationary vertical jumps. Variations on these tests are single-leg take-off (vertical jump test with approach run and single leg take-off - RVJ1) or two legs (vertical jump test with approach run and two-leg take-off - RVJ2, modified Abalakov vertical jump test with approach run - ABKM) and pivot step (vertical jump test with pivot step – PSJ).[1,20,23,36,42]

With regard to stationary horizontal jumps tests, we found tests with moderate specificity, but they are used for indirect analysis of muscular power (bipodal horizontal jump test - HJ) and strength asymmetry (unipodal horizontal jump test - SHD) of the lower limbs.[12,43,44,46,47]

Horizontal jump tests with displacement also allow for the interpretation of the muscular power of the lower limbs (quintuple horizontal jump test – 5JT, triple single leg horizontal jump test - THD) and to detect asymmetries (THD, cross horizontal jump test – CHD, test of 6-meter horizontal jump per time – 6TH). Differently from what happens in stationary horizontal jumps, these jumps with triple or quintuple displacements involve dynamic movements with strides in a linear direction.[43,44,49]

Basically, a systematic control of physical training with jump tests will allow a more rigorous assessment of neuromuscular readiness, levels of fatigue and the state of recovery in the face of organically imposed loads, arising from training sessions and competitions.[7,38] Despite these three listed primary points, publications have recommended the use of vertical and horizontal jump tests for other purposes. In this case, they would include measuring the asymmetry of strength between lower limbs.[8,44,45], dynamics of functional changes in relation to the training load[43], power endurance[26,34], detraining[31], biomechanical parameters[23], correlation with other biomotor capabilities[36], discriminate between strong and weak players[56], understand explosive power by playing position[1], test relationship with internal load[37], etc.

Throughout the season, the results of the jump tests may suffer oscillatory variations that are influenced by the residual fatigue of the loads, mental stress, moment of the season, circadian rhythm, menstrual cycle, among other aspects.[11,25,66]

Table 01. Classification of vertical and horizontal jump tests used to assess muscular power in basketball

Classification	Denomination of Tests
Stationary Vertical Jump Tests	SJ, CMJ, CMJAS, ABK, DJ, LCMJ, Sargent Test, RJ15, RJ30, RJ60, SVJ, SLCMJ, CJE, CMJL
Vertical Jump Tests with Approach Run	RVJ1, RVJ2, PSJ, ABKM
Stationary Horizontal Jump Tests	HJ, SHD
Horizontal Jump Tests with Displacement	THD, CHD, 6TH, 5JT

[**LEGEND:** ***PSJ***=*vertical jump test with pivot step,* ***CMJ***=*countermovement jump test,* ***CMJAS***=*countermovement jump test with swing arms, SJ=squat jump test,* ***ABK***=*Abalakov vertical jump test, DJ=drop jump test,* ***ABKM***=*modified Abalakov vertical jump test with approach run,* ***SHD***=*single leg horizontal jump test,* ***THD***=*triple single leg horizontal jump test,* ***CHD***=*horizontal cross jump test, 6TH=6-meter horizontal jump test time,* ***LCMJ***=*lateral countermovement jump test,* ***SVJ***=*bilateral stationary vertical jump test,* ***RVJ1***=*vertical jump test with approach run and single leg take-off,* ***RVJ2***=*vertical jump test with approach run and bipedal take-off,* ***RJ30***=*continuous vertical jump test repeated for thirty seconds,* ***5JT***=*quintuple horizontal jump test,* ***SLCMJ***=*one-leg vertical jump test with countermovement,* ***CJE***=*continuous vertical jump test until exhaustion,* ***HJ***=*bipodal horizontal jump test,* ***RJ60***=*continuous vertical jump test repeated for sixty seconds,* ***RJ15***=*continuous vertical jump test repeated for fifteen seconds,* ***CMJL***=*countermovement jump test with load, Sargent test=vertical jump test with swing arms*]

5. RESULTS

A scan of scientific publications allowed us to find a total of 34 studies reporting on the vertical and horizontal jump tests used to assess muscular power in basketball (table 02). Therefore, this topic intends to describe in detail the sample size, competitive category, gender, tests used and objectives of the tests in these studies. In the later topic, discussion, a detailed analysis is carried out based on investigations on the subject.

In the thirty-four selected researches on vertical and horizontal jump tests in basketball, the total sample size consisted of 1625 (100%) basketball players. Of this sample amount, 16.6% (n=270) of the players belong to the professional category, 2.46% (n=40) semi-professionals, 31.3 (n=509) college, 0.73% (n=12) amateurs and 48.8% (n= 794) are formative. Regarding the gender of the athletes, 68.9% (n=1121) are male and 31.0% (n=504) are female.[1,4,5,7,12,20,21,26,27,28,29,30,31,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,55,56]

In these investigations, twenty-four tests of vertical and horizontal jumps that are frequently used to assess muscle power were identified, namely: 1)- vertical jump test with pivot step (PSJ), 2)- countermovement jump test (CMJ), 3)- countermovement jump test with arms swing (CMJAS), 4)- squat jump test (SJ), 5)- Abalakov vertical jump test (ABK), 6)- drop jump test (DJ), 7)- modified Abalakov vertical jump test with approach run (ABKM), 8)- single leg horizontal jump test (SHD), 9)- triple single leg horizontal jump test (THD), 10)- horizontal cross jump test (CHD), 11)- 6-meter horizontal jump test time (6TH), 12)- lateral countermovement jump test (LCMJ), 13)- bilateral stationary vertical jump test (SVJ), 14)- vertical jump test with approach run and single leg take-off (RVJ1), 15)- vertical jump test with approach run and bipedal take-off (RVJ2), 16)- continuous vertical jump test repeated for thirty seconds (RJ30), 17)- quintuple horizontal jump test (5JT), 18)- one-leg vertical jump test with countermovement (SLCMJ), 19)- continuous vertical jump test until exhaustion (CJE), 20)- bipodal horizontal jump test (HJ), 21)- continuous vertical jump test repeated for sixty seconds (RJ60), 22)- continuous vertical jump test repeated for fifteen seconds (RJ15), 23)- countermovement jump test with load (CMJL) and 24)- Sargent test. The twenty-four tests mentioned above are classified as stationary vertical jump tests (SJ, CMJ, CMJAS, ABK, DJ, LCMJ, Sargent Test, RJ15, RJ30, RJ60, SVJ, SLCMJ, CJE, CMJL), vertical jump tests with approach run (RVJ1, RVJ2, PSJ, ABKM), stationary horizontal jump tests (HJ, SHD) and horizontal jump tests with displacement (THD, CHD, 6TH, 5JT). Thus, this conglomeration of tests is arranged in the following proportion: 14 (58.3%) stationary vertical jump tests, 04 (16.6%) vertical jump tests with approach run, 02 (8.33%) stationary horizontal jump tests and 04 (16.6%) horizontal jump tests with displacement.

When performing a quantification of the most used tests, it is noted 28.3% (n=23) CMJ, 12.3% (n=10) SJ, 7.40% (n=06) DJ, 6.17% (n=05) ABK, 4.93% (n=04) HJ, 4.93% (n=04) CMJAS, 3.70% (n=03) RJ30, 3.70% (n=03) RVJ1, 2.46% (n=02) LCMJ, 2.46% (n=02) RJ15, 2.46% (n=02) RJ60, 2.46% (n=02) SVJ, 2.46% (n=02) RVJ2, 2.46% (n=02) SHD, 2.46% (n=02) THD, 1.23% (n=01) Sargent test, 1.23% (n=01) ABKM, 1.23% (n=01) SLCMJ, 1.23% (n=01) CJE, 1.23 % (n=01) CMJL, 1.23% (n=01) PSJ, 1.23% (n=01) CHD, 1.23% (n=01) 6TH and 1.23% (n=01) 5JT.

Regarding the objectives of the tests, the studies indicate twelve main functions: 34.8% (n=15) with the purpose of evaluating the explosive power, 16.2% (n=07) power endurance, 11.6% (n=05) neuromuscular fatigue, 6.97% (n=03) reactive power, 6.97% (n=03) strength symmetry, 6.97% (n=03) correlation with other biomotor capabilities, 4.65% (n=02) discriminate explosive power by playing positions, 2.32% (n=01) detraining effects, 2.32% (n=01) correlation with internal load, 2.32% (n=01) distinguish strong and weak athletes, 2.32%(n=01) biomechanical parameters and, 2.32% (n= 01) lateral power.

Table 02. Summary of research on vertical and horizontal jump tests used in the assessment of basketball players

Study	Sample Size (gender)	Jump Test Employed	Purpose of the Test
KELLIS *et al.*, 1999[21]	n=379 formative basketball players (both genders)	SJ, CMJ, DJ, RJ15, RJ30	Comparing explosive power (SJ, CMJ), reactive power (DJ) and power endurance (RJ30) of lower limbs between genders.
VAQUERA *et al.*, 2002[26]	n=10 formative basketball players (male)	SJ, CMJ, ABK, RJ30	Evaluate explosive power (SJ, CMJ, ABK) and power endurance (RJ30).
CHENG *et al.*, 2003[27]	n=20 formative basketball players (male)	SJ, CMJ, CJE	Assess explosive power (SJ, CMJ) and power endurance (CJE).
MOREIRA *et al.*, 2005[43]	n=09 professional basketball players (female)	CMJ, SJ, HJ, THD	Evaluate the neuromuscular changes in the explosive power of the lower limbs in a given periodization model.
BOBER *et al.*, 2006[28]	n=11 professional basketball players (male)	DJ	Evaluate the reactive power of lower limbs at different heights of fall.
ABDELKRIM *et al.*, 2010[49]	n=45 professional (n=15) and formative (n=30) basketball players (male)	CMJ, 5JT	Evaluate the explosive power of the lower limbs.
FERNANDEZ-RIO *et al.*, 2010[29]	n=31 formative basketball players (female)	SJ, CMJ, RJ15, CMJL	Evaluate the explosive power and power endurance of the lower limbs after vibration training.
QUINTANA *et al.*, 2010[30]	n=09 formative basketball players (male)	CMJ	Assess levels of neuromuscular fatigue after games.
BORIN *et al.*, 2011[4]	n=11 professional basketball players	CMJAS	Evaluate levels of neuromuscular fatigue between quarters of the match and by

	(male)		playing positions.
SANTOS & JANEIRA., 2011[31]	n=24 formative basketball players (male)	SJ, CMJ, ABK, DJ	Evaluate the explosive power of lower limbs and the effects of detraining on neuromuscular function.
ANDRADE *et al.*, 2012[23]	n=19 professional basketball players (female)	CMJ, RVJ2	Evaluate biomechanical parameters during vertical jump performance.
SANTOS & JANEIRA., 2012[32]	n=25 formative basketball players (male)	SJ, CMJ, ABK, DJ	Evaluate the effects of a strength training program on the explosive power levels of the lower limbs.
ASADI *et al.*, 2013[12]	n=20 formative basketball players (male)	SVJ, HJ	Evaluate the effects of a plyometric program on the explosive power of lower limbs.
MYERS *et al.*, 2014[44]	n=372 college basketball players (both genders)	SHD, THD, CHD, 6TH	Evaluate strength symmetry between dominant and non-dominant leg between genders and competitive category.
SINGH *et al.*, 2014[33]	n=30 formative basketball players (male)	SJ, CMJ, RJ60	Evaluate the explosive power (SJ, CMJ) and power endurance (RJ60) of the lower limbs.
FORT-VANMEERHAEGHE *et al.*, 2015[45]	n=29 formative basketball players (female)	SLCMJ, SHD, LCMJ	Assess strength symmetry between dominant and non-dominant leg.
LONGORIA *et al.*, 2015[34]	n=12 amateur basketball players (male)	RJ60	Evaluate the power endurance of the lower limbs.
MARKWICK *et al.*, 2015[35]	n=13 professional basketball players (male)	DJ	Evaluate the reactive power of lower limbs at different heights of fall.
NIKOLAIDIS *et al.*, 2015[46]	n=72 formative basketball players (male)	CMJ, HJ, RJ30	Evaluate the explosive power (CMJ and HJ) and power endurance (RJ30) in correlation with the body mass of the athletes.
RODRÍGUEZ-ROSELL *et al.*, 2017[36]	n=59 formative (n=41) and professional (n=18) basketball players (male)	CMJ, ABK, RVJ2, RVJ1	Evaluate the correlation between running approach jumps (RVJ-2 and RVJ-1) and traditional jumps (CMJ and ABK), 20-m sprint, and maximal lower limb strength.
THOMAS *et al.*, 2017[56]	n=16 formative basketball players (male)	CMJ, DJ	Evaluate explosive power and reactive power levels by discriminating strong players from weak players.
ALTAVILLA *et al.*, 2018[1]	n=40 professional basketball players (male)	SJ, CMJ, CMJAS, ABKM	Evaluate the explosive power of the lower limbs among the different tactical roles of the players.
CRUZ *et al.*, 2018[37]	n=10 formative basketball players (female)	CMJ	Evaluate the relationship between internal load and performance in countermovement jump.
FREITAS	n=23 semi-	CMJ, HJ	Evaluate the explosive power of the lower

et al., 2018[47]	professional basketball players (male)		limbs after a complex training program.
HEISHMAN *et al.*, 2019[38]	n=22 college basketball players (both genders)	CMJ, CMJAS	Evaluate strength symmetry between dominant and non-dominant lower limbs.
SANDERS *et al.*, 2019[7]	n=13 college basketball players (female)	CMJ	Assess neuromuscular fatigue during a competitive season.
HEISHMAN *et al.*, 2020[39]	n=22 college basketball players (both genders)	CMJ, CMJAS	Assess long-term changes in performance (CMJAS) and look for acute changes in neuromuscular readiness and fatigue (CMJ).
CHERNI *et al.*, 2021[5]	n=27 professional basketball players (female)	SJ, CMJ	Evaluate the explosive power of the lower limbs after a plyometric program.
SANTOS *et al.*, 2021[40]	n=07 college basketball players (male)	Sargent Test	Assess changes in neuromuscular performance.
TALPEY *et al.*, 2021[20]	n=17 semi-professional basketball players (male)	SVJ, RVJ1, RVJ2	Evaluate the explosive power of jumps with approach running and correlate with speed-strength tests of lower limbs.
VILLARREAL *et al.*, 2021[41]	n=40 college basketball players (male)	CMJ, ABK	Evaluate the effects of three training interventions (plyometrics, strength and changes of direction) on the explosive power of the lower limbs.
LEIDERSDORF *et al.*, 2022[48]	n=140 college (n=33) and professional (n=107) basketball players (male)	LCMJ	Evaluate the application of one-legged lateral force on the lateral power vector.
THEODOROU *et al.*, 2022[42]	n=15 formative basketball players (male)	PSJ	Evaluate the explosive power of the lower limbs with a pivot step.
YÁÑEZ-GARCÍA *et al.*, 2022[55]	n=33 formative basketball players (male)	CMJ	Evaluate the explosive power of lower limbs after a strength training program.

[***LEGEND:*** ***PSJ***=*vertical jump test with pivot step,* ***CMJ***=*countermovement jump test,* ***CMJAS***=*countermovement jump test with swing arms,* ***SJ***=*squat jump test,* ***ABK***=*Abalakov vertical jump test, DJ=drop jump test,* ***ABKM***=*modified Abalakov vertical jump test with approach run,* ***SHD***=*single leg horizontal jump test,* ***THD***=*triple single leg horizontal jump test,* ***CHD***=*horizontal cross jump test,* ***6TH***=*6-meter horizontal jump test time,* ***LCMJ***=*lateral countermovement jump test,* ***SVJ***=*bilateral stationary vertical jump test*, ***RVJ1***=*vertical jump test with approach run and single leg take-off,* ***RVJ2***=*vertical jump test with approach run and bipedal take-off,* ***RJ30***=*continuous vertical jump test repeated for thirty seconds,* ***5JT***=*quintuple horizontal jump test*, ***SLCMJ***=*one-leg vertical jump test with countermovement,* ***CJE***=*continuous vertical jump test until exhaustion, HJ=bipodal horizontal jump test,* ***RJ60***=*continuous vertical jump test repeated for sixty seconds*, ***RJ15***=*continuous vertical jump test repeated for fifteen seconds,* ***CMJL***=*countermovement jump test with load,* ***Sargent test***=*vertical jump test with swing arms]*

6. DISCUSSION

In the samples, the most investigated target population were basketball players in the formative category, representing 48.8% (n=794) of the total. The explanation for this lies in the fact that this category in particular encompasses a wide age range (under-12 to under-20).[46,49] This group of formative players are in the process of growth and body development and tend to show marked physiological differences according to their biological maturation.[32,44,49] In a strength training program well conducted in the medium and long term, respecting the particularities of the age group, these formative basketball players manage to improve their levels of maximum strength and muscular power. These longitudinal changes can be noted in jump tests that assess muscular power.[16,31,32]

Regarding the gender of the players, 68.9% of the samples are male athletes. There is a lack of more studies directed at female basketball athletes. In counting the chosen researches, only eleven investigations used female athletes in their samples.[5,7,21,23,29,37,38,39,43,44,45] Female athletes usually present peculiar morphological characteristics in their composition of muscle fibers, such as a predominance of oxidative fibers and differences in muscle architecture (pennation angle and length of fascicles) when compared to male athletes. This observation directly impacts the ability to use the stretch-shortening cycle.[5] Female athletes are more likely to develop strength asymmetries in the lower limbs, which will be reflected in the performance of jumping tests.[44,45] Additional research on the population of female basketball players is imperative to understand how they respond to muscular power interventions and which jump tests are more sensitive for a better interpretation of the results.

In the thirty-four studies analyzed, twenty-four tests of vertical and horizontal jumps were identified. Of this amount, the five most used tests in studies about basketball were CMJ (28.3%), SJ (12.3%), DJ (7.40%), ABK (6.17%) and HJ (4.93%). An examination of these five tests shows that four of them belong to the classification of stationary vertical jump tests (CMJ, SJ, DJ, ABK) and only one is categorized as a stationary horizontal jump test (HJ). The CMJ, SJ, ABK and HJ tests evaluate the explosive power and the DJ test measures the reactive power. From there, let's inspect each of these five tests individually to understand their main features, as well as strengths and weaknesses.

The CMJ is the test most regularly used in investigations of basketball jump testing. The CMJ protocol establishes that the athlete must start the test standing on the bipedal base and with the hands fixed on the hips. Then, the athlete does a quick countermovement emphasizing the eccentric component and jumps vertically through a powerful concentric contraction, fully extending the legs.[22,37,56] CMJ is characterized as a dynamic muscle action movement that requires the stretch-shortening cycle.[39] The angular velocity during the CMJ impulse phase reaches values of 500°/s.[66] This test is used in basketball players to measure explosive power, neuromuscular fatigue, strength asymmetries, among other aspects.[4,30,37,38,49,50,55] The CMJ is considered the gold standard test for muscular power analysis.[2] The sum of these factors perhaps explains why this stationary vertical jump test is most often used in basketball.

The SJ is a jump test in which the athlete starts with the hands fixed on the pelvis, in a semi-squat position at a 90° angle, remaining in this isometric posture for three to five seconds and then jumping vertically. This stationary vertical test version exclusively evaluates the concentric contraction regime of the knee extensor musculature.[5,11,24,26,29,67] The efficiency of the stretch-shortening cycle is obtained through the height value of the SJ test associated with the height value of the CMJ.[67]

The DJ test is performed with the athlete standing on top of a box, with feet close to the edge. The height of the box in the DJ test tends to vary depending on the population of athletes being evaluated. Then, the athlete lands on the ground trying to minimize foot-to-ground contact time and jumping vertically as high as possible. During the landing and subsequent jump, the hands remain fixed on the hips.[28,35,56] This test measures the reactive power through the use of the short stretch-shortening cycle.[56] A popularly known metric of the DJ jump test is the reactive force index.[35]

The execution of the ABK vertical jump test is similar to the CMJ, but its protocol allows the swing of the upper limbs at the time of vertical jumping.[11,41] The swing of the arms in the ABK jump and CMJAS confer greater specificity with the technical gesture of basketball.[39] The ABK vertical jump test is little explored in basketball studies.[11]

The HJ test begins with the athlete positioned on a bipedal stance with feet shoulder-width apart behind a boundary line. Then, through a swinging movement of the arms in conjunction with a countermovement driven by the hips, knees and ankles, the jump is performed in the horizontal direction, seeking the maximum reach.[16,43,44,46,61] Normally, horizontal jump tests are a less complex technical gesture when compared to vertical jumps.[16] However, horizontal jump tests are less likely to be used in scientific investigations of basketball players. In this research, out of a total of thirty-four studies analyzed, only four investigations used the HJ test.[12,43,46,47] The accentuated detail that differentiates the HJ test from the other stationary vertical jump tests is its force application vector, which is directed in the anteroposterior axis.[59] There should be a greater use of these five jump tests, as they have other tasks, in addition to those already mentioned: verifying the state of detraining (SJ, CMJ, ABK, DJ), analyzing biomechanical parameters (CMJ), correlations between biomotor capabilities (CMJ, ABK), discriminate tactical functions (CMJ, SJ) and internal load correlation (CMJ). Finally, it should be noted that the vertical and horizontal jump tests that assess muscular power in basketball serve as a support to adjust training loads with reference to the results presented.

7. CONCLUSION

Muscular power is a manifestation of strength that plays a considerable role in basketball performance. However, in a well-oriented program, it is necessary to build good levels of maximum strength so that athletes express muscular power in all its magnitude. At this point, the pedagogical solution is to create a periodization model that continuously alternates cycles of maximum strength with muscular power.

The vertical and horizontal jump tests are field didactic instruments that help physical trainers when assessing the muscular power of basketball players. Therefore, there is a large amount of tests available in the literature.

In this literary review research, twenty-four vertical and horizontal jump tests were found used in the evaluation of muscular power in basketball. Among the five most reported tests are the CMJ, SJ, ABK, DJ and HJ. Four of these tests are stationary vertical jumps (CMJ, SJ, ABK, DJ) and a stationary horizontal jump test (HJ). Four jump tests allow assessing muscle power (CMJ, SJ, ABK and HJ) and one measures reactive power (DJ).

Finally, vertical and horizontal jump tests that assess muscular power in basketball have other essential purposes that could contribute to a more refined adjustment in the control and distribution of workloads. Therefore, additional research on this topic is needed so that we can elucidate with greater clarity the different functions about the vertical and horizontal jump tests aimed at the population of basketball players.

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