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Methodological Considerations in the Use of Complex Training in Basketball Players

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ABSTRACT

This research aims to discuss, through a literature review, the methodological considerations in the use of complex training in basketball players. This investigation was carried out by consulting scientific databases such as PubMed, Google Scholar, Scielo, LILACS and MEDLINE in Portuguese and/or English, dealing with the topic. In total, 34 articles about complex training and complex training in basketball, 02 textbooks and 01 article with scientific research guidelines were included. The complex method is considered an advanced and time efficient strategy, as it employs in a single session two paired exercises with contrasting characteristics of maximal strength and explosive strength. The important neurophysiological theories that underlie the acute and chronic responses in the application of the complex method are post-activation potentiation and post-activation performance enhancement. Contrast loads, blocks of contrast loads, combined loads, and plyometric exercises are four methodological approaches to complex training. However, to achieve performance improvements with the complex method, it is necessary to pay attention to some parameters during exercise prescription, such as: muscle contraction regime, load volume, load intensity, recovery interval, properties of the paired exercise and characteristics of the athlete. The use of periodization to prescribe complex training with other biomotor capabilities can help organize loads. The training of muscular power with the complex method in basketball players is of crucial importance in athletic performance, but lacks research that respects the principle of specificity.

Keywords: *Basketball, Evoked Potentials, Exercise, Neurophysiology, Training.*

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INTRODUCTION

Basketball is an intermittent team sport of anaerobic metabolic predominance (alactic and lactic), in which explosive movements are often used by players, such as: accelerations, decelerations, changes in direction, jumps, rebounds, blocks, among others[1].

In an analysis of movement in matches, the construction of the structure of these motor actions is dependent on distance, frequency, intensity and duration[2]. These basketball-specific actions require muscular power[3]. Thus, the basketball player's neuromuscular capacity to produce power becomes fundamental for the improvement of his performance and, subsequent sports success[2, 5].

Muscular power is a manifestation of strength work oriented to basketball players. It is a fundamental biomotor capability to be developed in team sports, as it causes increases in specific motor skills such as vertical jumps, accelerating starts, changes of directions and agility[1, 5, 6].

The muscular power or also called explosive strength can be explained mathematically in the following equation: Power=Force x Velocity\Time. Based on this equation, it can be stated that the conceptual definition of muscular power would be the result of applying force at high speed (work rate) by dividing the time taken to perform[5,6,7].

Typically, power training can be addressed in two ways. The first option would be through the use of exclusive loads involving light or moderate resistance, with explosive execution. Another alternative is the combination of high loads at moderate speed with low loads at high speed[6,8]. A relevant aspect when training muscular power is that it is possible to change the so-called rate of force development (RFD). The RFD marks the speed at which an athlete is able to express force. There is a degree of interrelationship between maximum force and RFD[9].

The evolution in the muscular power levels of the athletes can be obtained through different methods. Different training methods are constantly being changed, recycled and modified to seek optimal standards of athletic performance[10].

A central point when discussing methodologies to train muscular power is that this process must be carried out in a planned, systematically methodical, rational and well-organized way. In addition, when selecting the method one must take into account the available time, the objective, the age of the player, the period of the season and the total imposed load[4].

On this issue, among the most used methods in basketball to enable improvements in muscular power would be the Olympic lifting techniques, ballistic method, complex method and the plyometric method[2,4,5, 11].

Complex training originated in Russia in the mid-1980s. At the time, the method was presented as an innovation for muscular power training, in which large and small loads were worked together[12].

Complex training is a method in which the combination of exercises with contrasting loads generates acute and chronic improvements in muscular power. The basic premise of this method is the use of pairs of complex strength exercises. Basically, it consists of a maximal strength exercise followed by an explosive strength exercise that presents biomechanical similarity[10,13,14].

It is possible to notice that among the studies that discuss the complex method, it can be found with different interchangeable designations: complex method, contrast method, composite method, combined method, and/or Bulgarian method[1,6;8,15,16].

This method emerged from the real need to optimize the little time available for the preparation of athletes in the development of biomotor capabilities for the competitive season[16]. From a methodological point of view, complex training is apparently advantageous and time-efficient, as it allows the organization of a maximal strength exercise combined with an explosive strength exercise in the same session[17,18].

This method has been shown to be efficient in muscular power gains in both short-term and long-term situations[4]. This training approach causes neuromuscular adaptations in maximum strength and speed, through the combination of exercises that will directly influence the final generation of muscular power[19] .

Despite the complex training being a method widely documented in the literature, there are still doubts among professionals who work in the field, regarding the use of the correct name, the physiological aspects involved and, mainly, the methodological functioning in the implementation in basketball players.

Therefore, the objective of this research is to discuss, through a literature review, the methodological considerations in the use of complex training in basketball players.

METHOD

This research is characterized as a literature review, as it captures ideas from the intellectual bases on the delimited topic, to expand the interpretative analysis. When well conducted, this type of investigation allows the systematic addition and reformulation of the scientific discourse on the object of study[20].

Five electronic databases such as PubMed, Google Scholar, Scielo, LILACS and MEDLINE were consulted to collect articles in Portuguese and/or English that dealt with the theme of muscular power training, complex training in team sports and complex training involving the basketball. In the Boolean search for words, the following terms were used: “basquetebol + treinamento complexo”, “basketball + complex training”, “complex training”, “complex training + team sports”, “postactivation potentiation”, “treinamento de potência”, “treinamento de potência + basquetebol”, “power training + basketball”, “complex training + acute effects”, “complex training + chronic effects”, “treinamento complexo + metodologia”, “potência muscular + considerações metodológicas”, “plyometric training + basketball”, “pliometria + potência”, “basquetebol + pliometria”, “complex training + meta-analysis”, “complex training + systematic review”, “treinamento de força + basquetebol”, “strength training + basketball”, “power training”, “power training + methodologies”, “potencialização pós-ativação”, “post-activation potentiation”, “post-activation performance enhancement”. The eligibility criteria for inclusion or exclusion of articles were: 1)- reading the title of the article, 2)- reading the abstract of the article, 3)- reading the full text, 4)- article commenting on strength training and muscular power, 5)- article that discussed about complex training, 6)- article that presented the complex training in team sports, 7)- article that related to the complex training in basketball players, 8)-article that discussed methodological considerations of muscular power training.

In the final wording of the text, after filtering, 34 articles published between the years 2000 to 2022 were included. In addition, 02 textbooks about theory of sports training and strength training were added, and 01 article on guidelines for the methodology of scientific research.

NEUROPHYSIOLOGY OF COMPLEX TRAINING

In the field of neurophysiology, the increased response of voluntary contractile muscle action in a neuromuscular conditioning activity is known as potentiation. Potentiation depends on a neural stimulus from anterior muscle activation. This amplified potentiation response can be observed after neuromuscular conditioning work, reaching a peak in a few seconds and with a gradual decrease in the subsequent minutes. In this context, three potentiation formats emerge: ladder (low-frequency sequential electrical stimuli), post-tetanic potentiation (high-frequency electrical stimulation), and post-activation potentiation (increase in the contractile response by voluntary muscle activation) [7.21].

That said, two theories support the neurophysiological understanding of complex training. The theory with a mechanistic approach is called post-activation potentiation (PAP) and the theory that encompasses the performance approach is known as post-activation performance enhancement (PAPE)[10,12,16,21,22,23].

The main system of PAP is a deep interaction between neural and muscular factors[7]. PAP generates gains in explosive muscle strength through the use of maximal or submaximal contractions[10,12]. Explosive tasks that require strength and speed can benefit from PAP through the increase in RFD[24].

Three main mechanisms govern PAP: a)- phosphorylation of myosin regulatory light chains, b)- H-reflex, and c) changes in pennation angle[24,25,31,35].

The phosphorylation of myosin regulatory light chains is related to the sensitivity of calcium molecules released by the sarcoplasmic reticulum. This allows the calcium response in a muscle contraction to generate an increase in myosin cross-bridge activity. The result of this process would generate faster muscle contraction rates[24, 25,35].

Regarding the H-reflex, it is linked to pre-and post-synaptic excitatory neural responses. The H-reflex can be verified in the muscular electromyographic activity as a result of an afferent wave that follows a pulse of the nerve bundle. An increase in H-reflex activity indicates a failure of transmission from synaptic junctions, which is superimposed on voluntary muscle activation. This will allow for an increase in electrical impulse strength and greater recruitment of motoneurons during fast fiber contractile activity[24,31].

Changes in pennation angle can be achieved through strength training. The pennation angle affects the transmission of force to the tendons and bone structure during muscle contractions. After strength training, changes occur in the pennation angle, making it smaller. Thus, a mechanical advantage is achieved in the propagation of force to the tendon unit[24].

The sum of these three aforementioned mechanisms contribute to the effectiveness of complex training. During muscle contraction in the first contrasting exercise that is performed with maximum strength load (>80% 1RM), motoneuron recruitment is increased. Thus, in the second paired contrasting exercise, the fast-twitch muscle fibers would improve performance in the explosive task[24].

In practice, the effects of PAP in the application of complex training depend on the sensitive balance with the levels of fatigue. In this relationship, the contractile muscle response may be improved, decreased or not changed[24, 26].

Fatigue can manifest itself by affecting the central components (decreased action of the central nervous system to activate motor units), and peripheral components (neuromuscular and metabolic). In the neuromuscular aspects of fatigue, we have biochemical changes that attenuate the contractile response. In the metabolic fatigue, the increase in local acidosis and accumulation of by-products impair muscle enzyme activity[15].

The presence of fatigue results from a masking of the final acute responses of complex training[14]. If, after the performance of the maximum strength load, the recovery interval is too short, fatigue will be high, with an inhibition in the PAP, and the desired effects in the conjugated exercise are not achieved. In contrast, if the interval between contrasting exercises is too long, the desired physiological effects are lost[10,14].

The PAPE theory emerged in the scientific literature more recently in 2017 with the aim of explaining a physiological phenomenon that would be temporally associated with PAP. This term refers to increases in strength or performance levels in exercises, after being evoked by previous muscle activity that has stimulated PAP[21]. PAPE is a residual effect of PAP, where a window of opportunity for a delayed potentiation effect occurs[27].

This means that while the effects of PAP are initially high and can last for up to a few minutes after complex training, in the PAPE situation we have effects that are not very intense, but that temporally persist for a longer period[21]. The force-velocity profile is a method used to evaluate performance in explosive tasks. In complex training, PAPE can positively change the athlete's force-velocity relationship[27].

This PAPE phenomenon is achieved by the increase in muscle temperature, water content in the muscle fiber, and by neuromuscular activation. When the temperature of the muscle is raised, its functionality can be improvised, as the viscoelastic muscular and joint resistance is reduced, facilitating the transmission of the nerve impulse. The increase in blood flow and myofibrillar water content affect collagen connective tissues, increasing stiffness, which would increase fiber strength and its respective shortening speed. Neuromuscular activation by voluntary muscle contraction has positive effects on spinal excitability, promoting long-term (~20 minutes or more) facilitatory neural adaptations such as elevation in RFD and maximal strength production[21,23].

So, when prescribing complex training programs it is likely to come across two physiological phenomena (PAP and PAPE). PAP with a more acute presence, with its effects on performance that can last up to approximately 10 minutes. On the other hand, PAPE is evidenced as a residual phenomenon of PAP, with medium and long duration temporality effects (~20 minutes or more)[21,23].

Table 01. *Main differences and similarities between post-activation potentiation (PAP) and post-activation performance enhancement (PAPE) (Adapted from Tillin & Bishop, 2009; Blazevich & Babault, 2019; Prieske et al, 2020)*

VARIABLES	PAP (mechanistic approach)	PAPE (performance approach)
Potentiation Factors	Phosphorylation of myosin regulatory light chains, H-reflex, and changes in pennation angle	Muscle temperature, myofibrillar water content, and neuromuscular activation
Inhibition Factors	Fatigue	Fatigue
Neuromuscular Conditioning Activities	Isometric, dynamic, high intensity	Isometric, dynamic, high intensity
Benefits	Increase in muscle contraction force, RFD and torque production	Elevation in maximum strength and explosive tasks
Temporal Profile	Short term	Medium and long term
Duration Time	Immediate increase after maximal voluntary muscle contraction with gradual decline after ~10 minutes	Residual PAP effect with gradual decline after ~20 minutes

METHODOLOGICAL CONSIDERATIONS IN COMPLEX TRAINING

The literature about theory of sports training usually directs the attention of muscular power programs in a global way. The specificity factor in the construction of methodologies for the development of muscular power oriented to a certain sport appears to be scarce[28,29,30]. When searching the scientific texts, what one finds are articles seeking to interpret the physiological or performance responses to interventions with general methodological characteristics.

The most relevant methodological aspect in muscular power training with the complex method is the optimization of time, as it can perform two exercises with contrasting characteristics in a single training session[17,18] .

Regarding the use of terminology to designate complex training, the literature covers five commonly used terms: complex method, contrast method, composite method, combined method, and/or Bulgarian method[1,6;8,15,16]. These terms can be considered as interchangeable, because their characteristics are very similar, despite the different designation.

A distinction between the complex Russian and Bulgarian method deserves to be highlighted. In the Russian complex method, the combination of paired exercises would involve maximal strength and explosive strength. On the other hand, in the Bulgarian complex method, this combination would occur between an explosive strength exercise and a speed exercise[16].

When prescribing complex training, six variables must be correctly managed: muscle contraction regimen, load volume, load intensity, recovery interval, properties of the second paired exercise, and individual characteristics of the athlete[7,23,24].

The two muscle contraction regimens in complex training exercises would be isometric and dynamic (concentric/eccentric). Both muscle regimens induce PAP activation. However, isometric contraction seems to denote superiority when compared to dynamic contraction, as the isometric regime activates a high number of motor units. The muscle contraction regimen has a direct association with fatigue. In the dynamic regime, PAP induces central fatigue and the predominant mechanism is peripheral. On the other hand, in the isometric regime, PAP induces peripheral fatigue and the predominant mechanism is central[24].

The load volume is related to the number of sets, repetitions and time under muscular tension of the contractile activity. Smaller volumes of load make the PAP stand out in relation to fatigue[24].

In terms of load intensity, it is understood that muscle contractions at maximum or submaximal intensities would be more suitable to activate PAP. Load thresholds for the first exercise paired with maximum strength characteristics would be above 80% of one repetition maximum (1RM) [24].

Regarding the adequate recovery interval between the applied stimuli, there is no consensus in the literature. This period usually varies a lot in research, ranging from 15 seconds to 18.5 minutes[7]. On this issue, one study suggests an ideal time between 3 to 10 minutes[31]. Perhaps an efficient strategy in relation to the time interval can be achieved by classifying athletes based on relative strength levels. Players with high relative strength dissipate fatigue more quickly, so breaks can be shorter. However, in players with low levels of relative strength, intervals should be moderate or prolonged so that fatigue does not negatively interfere with final performance[6].

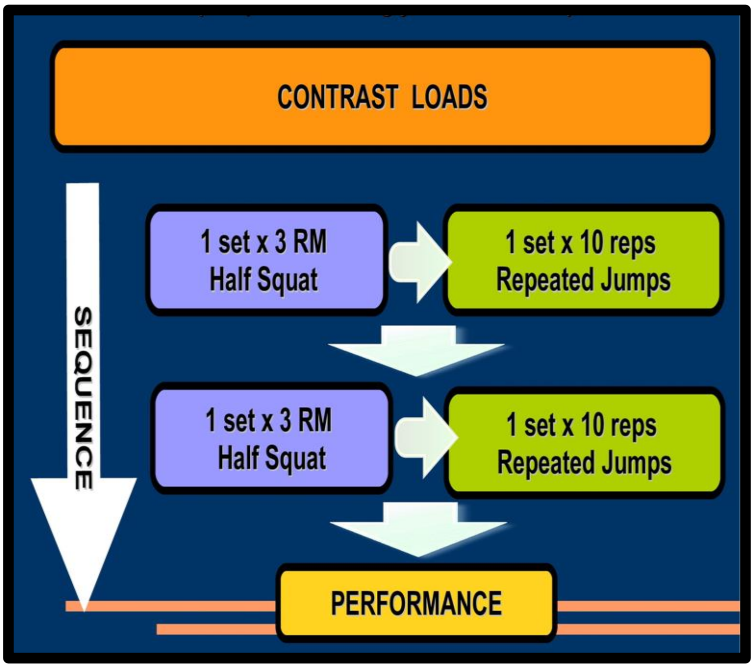
In the properties of the second conjugated exercise, it is possible to employ a variety of muscular regimes: dynamic, isometric, explosive and ballistic. However, PAP tends to be more effective in tasks with explosive and ballistic exercises[24]. An important aspect in the use of these conjugate exercises is that the explosive strength exercise that pairs with the maximal strength exercise in complex training needs to be anatomically congruent, biomechanically similar, and that activate the same muscle groups, so that neuromuscular benefits are obtained[12,14.32].

The individual characteristics of athletes that can interfere with PAP during complex training would be muscle strength (the higher the relative strength levels, the better the ability to evoke PAP), the predominant muscle fiber type (fast twitch fibers generate higher PAP), training status (the higher the neuromuscular conditioning, the better the resistance to fatigue), and strength-to-power ratio (athletes with a lower strength-to-power ratio benefit more from PAP)[14,24,33].

The possibilities for pedagogical variations in complex training are limited to four protocols, arranged as follows: contrast loads, block of contrast loads, combined loads and plyometric exercises[8,16] .

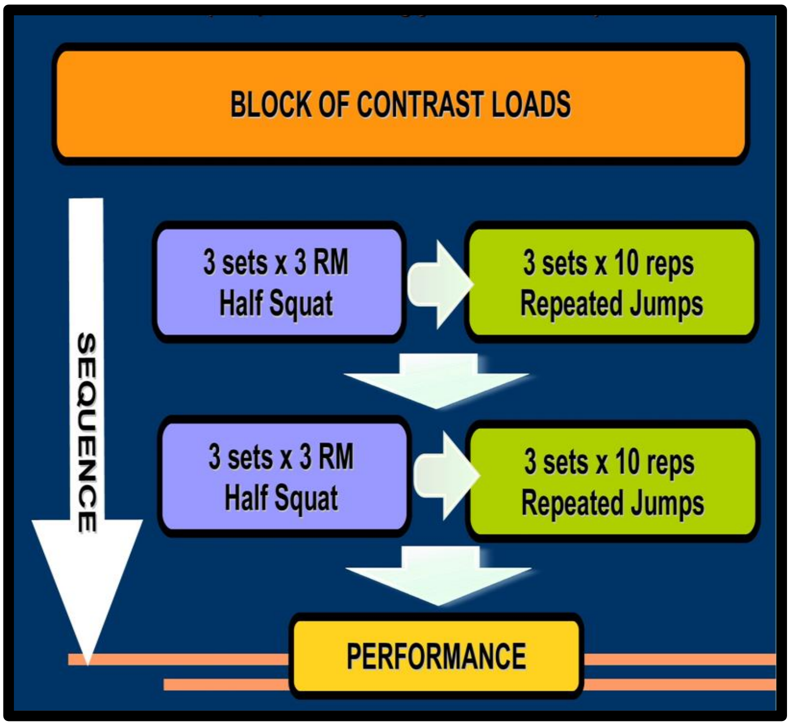
In contrast loads, we have the most commonly applied approach. In each paired exercise, a series is performed and then the same pairs of exercises are repeated with a series of each exercise (figure 01)

Figure 01. *Example of complex training with contrast loads*



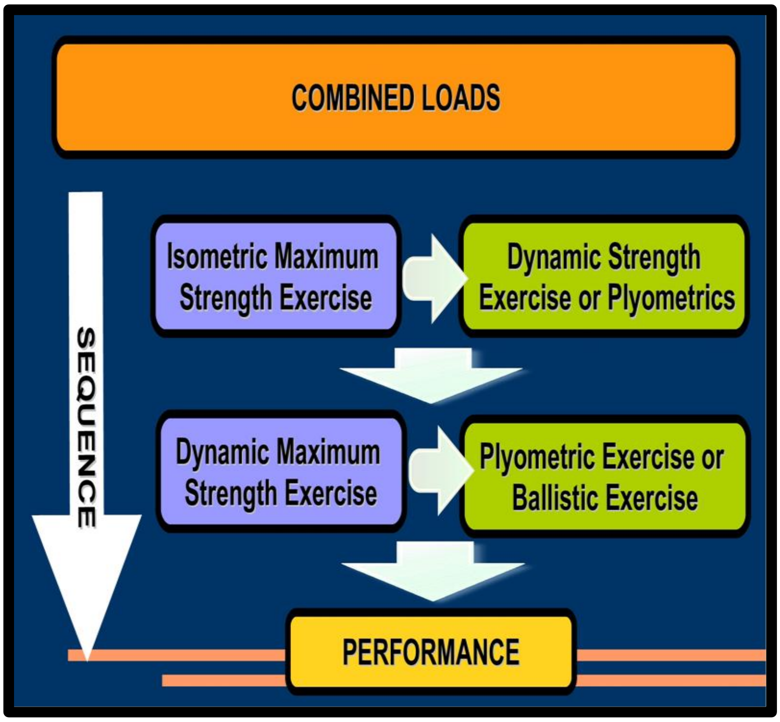
In the block of contrast loads, we work in clusters. All sets of the first paired exercise are performed, followed by all sets of the second paired exercise (figure 02).

Figure 02. Example of complex training with block of contrast load



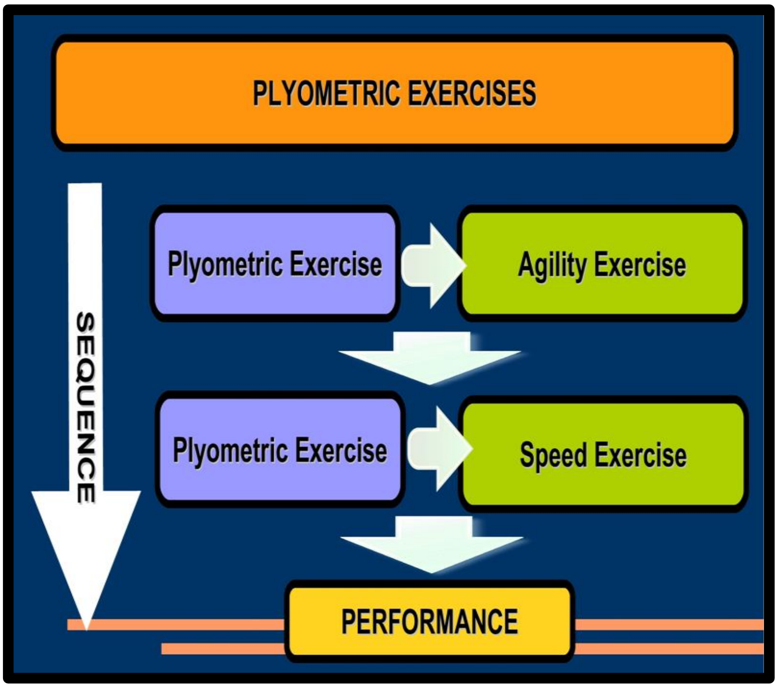
In the protocol of combined loads, there are alternations of muscular regimes between blocks. It is possible to perform an initial block by combining the first paired exercise in a muscle contraction regimen (isometric or dynamic), followed by the second paired exercise using either a maximal strength or plyometric load. In the second block, the first exercise uses a dynamic load of maximum strength, followed by the second paired exercise performing a plyometric or ballistic exercise (figure 03)

Figure 03. *Example of complex training with combined loads*



In the plyometric exercise protocol, the use of explosive exercises predominates. There is the possibility of using the first paired plyometric exercise in the initial block, followed by the second agility exercise. In the second block, the first exercise is plyometric and the second exercise involves speed (figure 04).

Figure 04. Example of complex training with plyometric exercises



An important aspect is that complex training in basketball players needs to be stimulated in the lower and upper limbs. The lower limbs are responsible for locomotion and jumping movements, such as tasks involving sprints, changes in direction, vertical and horizontal jumps. In contrast, the upper limbs need muscular power to execute passes faster, attack and push opponents[1,5, 6,13].

There must be a rational planning in the distribution of training loads throughout the season, when designing power training programs with the complex method, so that not only muscular power is improved, but also other essential biomotor capabilities for basketball. In this sense, selecting one of the various periodization models can contribute to the organization of the training process[5,34] .

In the structuring of muscular power programs aimed at basketball players, complex training gains additional prominence. By using contrasting paired exercises (maximum strength and explosive strength) it manages to optimize time and generate efficiency in the search for athletic performance [17,18].

STUDIES ABOUT THE COMPLEX METHOD IN BASKETBALL

Complex training is an advanced muscular power improvement strategy that can be used in formative and/or professional basketball players[18,19,23,26].

In a survey conducted in the NBA (National Basketball Association), it was evidenced that 60% of the league's physical trainers interviewed have the habit of employing complex training in their players[11] . This fact denotes the importance of understanding the methodological aspects of complex training in basketball players, so that professionals who work in the field can optimize athletic performance.

In this sense, ten relevant studies (table 02) addressing complex training in formative and professional basketball players were gathered for an elucidative discussion[1,3,10,12,13,18,19,26,30,35].

Initially, it is noted that 40.0% of the researches involve formative basketball players and another 60.0% of the studies include competitive athletes from the professional, semi-professional and university categories[1,3,10,12,13,18,19,26,30,35]. These observations reinforce the idea that complex training is a safe method that can be employed in a wide spectrum of age groups, from pre-pubescent players[1] to professional basketball players[26] .

Regarding the gender of basketball players, 50.0% were performed with male athletes, 10.0% with female players, 10.0% with athletes of both sexes, and 30.0% without identification of gender. It appears that there are few researches verifying the effects of complex training only in female basketball players.

Of these studies, 70.0% analyzed complex training in basketball players through chronic interventions, lasting between six to ten weeks[1,3,10,12,18,19,30]. Only 30.0% studies describe the acute effects of complex training [13,26,35].

Regarding the complex training protocol, 60.0% of the studies used paired maximal strength exercises with plyometric exercises[1,10,12,18,19,30] . The other protocols used included maximal strength exercise and ballistic exercise (10.0%), maximal strength exercise and optimal load (10.0%) and only maximal strength exercise (20.0%)[3,13,26,35]. It is clear that investigations have preferred to implement lines of protocols with paired maximal strength exercises with plyometrics, following the complex

Russian method.

In research, the loads of maximum strength exercises ranged from a minimum of 50% to 100% of 1RM. There was an intervention with maximal strength exercise in the isometric contraction regime, whose time protocol under muscle tension ranged from 40 to 70 seconds[1]. This large variation in maximum strength loads (50% to 100% of 1RM) is contrary to what some studies advocate, which suggest loads with intensities greater than 80% of 1RM to activate PAP[6,7,10,24]. In this item, it seems that maximum strength loads greater than 85% of 1RM would not be suitable for team sports, as they cause fatigue and can negatively interfere with PAP[3]. Another aspect is that although most studies have preferred to use the maximum dynamic strength regime, the literature emphasizes that the maximum isometric contraction regime is superior to the dynamic regime, as it manages to activate more motor units[24].

In 60.0% of the studies the loads of the second paired exercise were predominantly with plyometric characteristics [1, 10, 12 18, 19, 30]. Furthermore, there were protocols using exercises manipulating maximum strength (20.0%)[26,35], optimal load (10.0%)[3] and ballistics (10.0%)[13]. It is usually recommended in publications that the second paired exercise in complex training has a profile more oriented towards light loads performed at high speed and that respects biomechanical similarity[10,15,16,17,18,23].

Complex training in basketball players was evaluated in the lower limbs in 60.0% of the studies[1,10,12,19,26,35,], in the upper limbs in 20.0% of the studies[13,30] and, in both situations in 20.0% of the investigations[3,18]. As basketball is a sport that requires specific motor skills from the players of the upper limbs (throwing, passing, dribbling) and lower limbs (vertical jumps, horizontal jumps, accelerations, decelerations, changes of direction) there should be more research encompassing studies on the effects of complex training in both the upper and lower limbs.

The interval between sets of complex exercises in the research showed variations, between the minimum value of 2 minutes and the maximum value of 8 minutes. This range of interval between paired exercises corroborates a study that suggests a recovery period between 3 to 10 minutes[31]. Also, it is important to remember that with the adoption of very long intervals, the physiological effects of PAP may dissipate[10,14].

In the ten publications, to analyze the effects caused by complex training, 33.3% involved muscular power tests, 6.6% ballistic tests, 13.3% speed tests, 13.3% agility tests, 6.6% dynamic maximum strength tests, 6.6% isometric maximum strength tests, 6.6% tests for RFD, 6.6% joint angular velocity tests, and 6.6% evaluated morphofunctional characteristics of the musculotendinous structure[1,3,10,12,13,18,19,26,30,35]. Such tests are related to the specific activities performed by basketball players in matches involving the use of upper and lower limbs.

In the research results, 88.8% of the publications investigated on complex training in basketball players managed to generate significant benefits that ranged from trivial to large, in the performance variables and morphofunctional adaptations that were analyzed. Only 22.2% of the studies did not demonstrate positive effects on athletes' performance. One of the complex training interventions did not show maximum strength gains in the upper limbs, due to stimuli considered weak[3]. The second study that did not demonstrate improvements in muscular power performance was due to low levels of relative strength in the lower limbs of female basketball players[35].

Table 02. Summary of studies involving complex training in basketball players

Study	Sample	Intervention Period	Protocol	Load	Measured Variables	Result
Santos & Janeira (2008)	n=25 male young basketball players	10 weeks – 2 days	DMS + PLYO	DMS (2-3 sets of 10-12 RM) and PLYO (2-3 sets – 10-15 reps)	Squat Jump, CMJ, Abalakov Jump, DJ, and Medicine Ball Throw	↑ Squat Jump, CMJ, Abalakov Jump, DJ, and Medicine Ball Throw
Matthews et al (2009)	n=12 male competitive athletes	01 training session	DMS and MBT	DMS (5 reps – 85% 1RM) and MBT (5 reps – 2.3 Kg)	Chest pass flight time	↓ Flight time in the MS group
Javorac (2012)	n=20 young basketball players	10 weeks - 2 days	DMS + PLYO	DMS (4 sets of 6-8 reps – 50%-80% 1 RM) and PLYO (10 reps)	Sargent Jump, Standing Triple Jump, and Standing Jump	↑ Sargent Jump, Standing Triple Jump, and Standing Jump
Roden et al (2014)	n=20 college basketball players	6 weeks – 2 days	DMS + PLYO	HI (80-85% 1RM Half Squat) versus HR (60-70% 1RM Half Squat)	Vertical Jump	↑ Vertical jump in the HI group
Sygulla & Fountaine (2014)	n=29 female college basketball, softball, and volleyball athletes	01 training session	DMS	DMS (1 sets of 3 reps – 90% 1RM)	SSJ, and mechanical power	↔ SSJ, and mechanical power
Román et al (2017)	n=58 pre-pubescent basketball players (both sexes)	10 weeks – 2 days	IMS + PLYO	IMS (Isometric Half Squat – 40s-70s) + PLIO (50-130 jumps)	SJ, CMJ, SSC, DJ-20cm, DJ-40cm, SLJ, 25-m sprint, and T-Test	↑ SJ, CMJ, SSC, DJ-20cm, DJ-40cm, SLJ, and ↓25-m sprint, T-Test
Freitas et al (2018)	n=18 male semi-professional basketball players	6 weeks – 2 days	MCT + OLT	MCT (80% 1RM) and OLT (optimal load)	1RM Half Squat, 1RM Bench Press, 1RM Hip Thrust, CMJ, HJ, 10-m sprint, and T-Test	↑ 1RM Half Squat, 1RM Hip Thrust, and ↓ 10-m sprint, T-Test in the OLT group
Hasan et al (2018)	n=30 male college basketball players	6 weeks – 2 days	DMS + PLYO versus DMS versus PLYO	DMS (4 sets of 40-100% 1RM) and PLYO (3-4 sets of 6-8 reps)	Angular velocity of shoulder internal rotation	↑ Angular velocity of shoulder internal rotation in DMS + PLYO group
Pożarowszczyk et al (2018)	n=12 male professional basketball players	01 training session	DMS	DMS (60, 70,80, 90 and 100% 1RM)	Stiffness, thickness and elasticity of the Achilles tendon	↑ stiffness and ↓ elasticity and thickness of the Achilles tendon
Kukrić et al (2019)	n=20 young basketball players	10 weeks – 2 days	DMS + PLYO	DMS (4 sets of 4-6 reps – 80% 1RM) and PLIO (4 sets of 10 reps)	SST, MIF, and RFD	↑ SST, MIF, and RFD

[DMS= dynamic maximum strength exercise, PLYO= plyometric exercise, MBT= medicine ball throw, CMJ= countermovement jump, DJ= drop jump, HI= high intensity, HR=high repetition, SSC= stretch-shortening cycle, SLJ= standing long jump, MCT= modified complex training, OLT= optimal load, HJ= horizontal jump, SST= semi-squat test, SSJ= static squat jump, IMS= isometric maximum strength exercise, RFD= rate of force development, MIF= maximum isometric muscle force, ↑= elevation, ↓= reduction, ↔=no change]

DISCUSSION

Complex training is a strength method to improve muscular power that can be used in different categories of basketball players: professionals, semi-professionals, university students and formative ones[1,3,10,12,13,18,19,23,26,35].

However, additional precautions must be taken when using complex training on basketball players who are in the process of body growth and development. A correct way to avoid negative adaptations or increased risk of injuries in this young population would be to respect the sensitive periods for strength development and incorporate gradual progressions in the loads. For example, muscular power training performed with natural body weight movements and/or maximal strength exercise with isometric characteristics[1,4,5] .

In the case of professional basketball players, there must be a rational adjustment in the distribution of the loads of complex training with that of other biomotor capabilities and, also, attention must be paid to the influence of these loads on frequent competitions. In addition, adjustments in complex training loads follow an individualization logic so that the desired effects on performance are achieved[3, 5, 6,34,35].

When referring to the athletes' gender, complex training has been little studied in the female population. In the only research found on the effects of complex training intervention on female players, no positive adaptive responses were obtained due to the low level of relative strength in the athletes lower limbs[35].

Muscular power levels in basketball are distinguished between categories, with players from lower divisions tending to have lower values when compared to players from higher divisions [3,36,37]. The scientific literature shows that college-level basketball players with high levels of maximal strength and muscular power in the lower limbs have greater career prospects to enter the professional category[37] .

Studies have demonstrated the possibility of performing the complex method both acutely and chronically[1,3,10,12,13,18,19,26]. In professional practice, throughout the season, chronic interventions using complex training can be done through cycles alternating loads with complex characteristics and selective loads. Regarding acute interventions, they can be elaborated in the athletes warm-up routines, during matches, to optimize later performance.

Apparently, the most commonly used complex training protocol employs paired maximal strength exercises with plyometric exercises[1,10,12,18,19]. This approach follows the line of the most traditional Russian complex method. However, there are other possibilities of complex method protocols that should not be neglected, such as those mentioned above in the topic on methodological considerations: blocks of contrast loads, combined loads, and plyometric exercises.

Furthermore, in pairs of complex exercises, the first paired exercise that the literature predominantly uses is maximum dynamic strength. However, the maximal isometric contraction exercise is superior, as it generates greater activation of motor units[24]. In the case of the second paired exercise, plyometrics that include explosive tasks seems to be the most recommended. As plyometric exercise stimulates the recruitment of fast fibers, this type of task favors neurophysiological responses that stimulate large magnitude thresholds in PAP[31,33]. The intention is that the second paired exercise be done in an excited neuromuscular state[10,17].

In basketball, it is necessary to perform complex training in the upper and lower limbs, as the specific motor actions of the players require the strength of both limbs[3,13]. PAP stimulation in the upper limbs differs from that of the lower limbs in terms of neural response[17]. In this sense, to obtain similar PAP results in the upper limbs in well-trained athletes, it would be necessary to equalize the volume of loads imposed on the upper and lower limbs[3]. However, the same authors report that the intensity of the imposed load depends on the selected exercise.

Regarding the training loads of the maximal strength exercise, the studies used values between 50% and 100% of 1RM. However, submaximal or maximal loads (>80% 1RM) are recommended in the first paired exercise[6,7,10,24] Thus, in a meta-analysis about the complex method in team sports, the authors found that loads with intensity <85% of 1RM promoted greater gains when compared to loads with intensity ≥85% of 1RM[6]. This corroborates with other studies that advocate maximum strength loads with values ≤85% 1RM would be more suitable for complex training in team sports such as basketball[3].

The most essential factor when discussing recovery intervals between exercises for the complex method is fatigue. Very short intervals between exercises potentiate fatigue and negatively interfere in the performance of the movement pattern of the second paired exercise, which will therefore affect PAP. On the other hand, intervals longer than five minutes between complex paired exercises are not recommended, as the desired neurophysiological effects may be lost[6] .

Respect for individualization is a determining factor in contemporary physical preparation, especially when prescribing loads for complex training[3,6,35] . In this sense, in complex training programs aimed at basketball players, it is sought to observe the player's age (chronological and biological), anthropometric characteristics, level of physical fitness (relative strength) and the tactical position he exercises in the team[4,6,35]. Linked to this, complex training must consider the movement patterns and specific speeds of the players' tasks[3].

There are five specific recommendations in the literature for prescribing muscular power through complex training: 1)- observe the athlete's training status (they must be players with moderate to high strength levels), 2)- training experience greater than or equal to two years, 3)- minimum level of relative strength in the lower limbs (≥1.8 of 1RM), 4)- minimum level of relative strength in the upper limbs (≥1.4 of 1RM) and, 5)- effective interval between sets of complex exercises (~2 -5 minutes)[31].

Periodizing the distribution of complex training loads has been recommended in the literature[34]. Therefore, implementing a periodization model for complex training together with the development of the different biomotor capabilities required in basketball is essential to optimize performance in the season[5,34].

In team sports such as basketball, complex training when well structured, provides gains in maximum strength (~23.4%), vertical jump (~9.3%), displacement speed (~4.7%) and, in tasks that require changes in direction (~4.9%)[6]. In addition, it is possible to generate gains in muscular power in the upper limbs (~3.9%)[13] and also in the angular velocity of shouder internal rotation (~17.4%)[30].

Regarding the specific needs of mucular power in the various tactical functions of basketball players, guards (positions 1 and 2) need power to carry out the constant changes of direction, accelerations, decelerations, vertical jumps and horizontal jumps. Forwards (positions 3 and 4) need explosive strength due to the same movements, but with an emphasis on jumping actions. In position 5 (centers) your muscular power is verified in straight-line movements and changes of directions over short distances[4].

In the practical application of the complex method in basketball players, coaches can resort to creativity so that the second paired exercise can take specificity into account. The inclusion of tasks that have a biomechanical similarity to sport would allow a more effective transfer to motor actions[28,29,30]. The characteristics of each exercise are unique in biomechanical and neurophysiological terms and directly affect muscular power generation[3].

CONCLUSION

In the elaboration of physical preparation programs for basketball players, the development of muscular power is mandatory. One of the methods most recommended and supported by scientific publications is complex training.

PAP and PAPE are two important neurophysiological phenomena that are associated with the complex method. Understanding how such responses act could help in the moment of acute and/or chronic practical application of complex training.

From a methodological point of view, complex training consists of the use of contrasting paired exercises (maximum strength and explosive strength). Within this context, there are four possible operational pedagogical variations: contrast loads, blocks of contrast loads, combined loads and plyometric exercises. It is necessary to correctly manipulate the muscle contraction regime of the exercises, properties of the second paired exercise, volume and intensity of the load, recovery interval, and individual characteristics of the athlete to achieve positive benefits in muscular power by the complex method.

A solution to systematically organize muscular power training loads with other biomotor capacities would be to adopt a periodization model. Finally, respect for basketball's specificity cannot be neglected. Thus, in the preparation of complex training, the second paired exercise must follow a biomechanical similarity of the motor actions of the sport in question, in order to increase the degree of transference.

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