An Integrative Approach to Strength and Neuromuscular Power Training for Basketball

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ABSTRACT

BASKETBALL PLAYERS ACHIEVE EXCELLENCE BY FITNESS LEVELS, SPORT-SPECIFIC SKILLS, AND DECISION MAKING. IN THIS ARTICLE, THE AUTHORS PRESENT A STRENGTH AND NEUROMUSCULAR POWER TRAINING METHODOLOGY, WHICH INTEGRATES THE LATEST SCIENTIFIC KNOWLEDGE ON STRENGTH TRAINING, SUGGESTS A PRACTICAL, INTEGRATIVE, SPECIFICITY-BASED METHODOLOGY COVERING PLAYER DEVELOPMENT FROM THE WEIGHT ROOM TO THE COURT, AND INVOLVES ALL THE STAFF MEMBERS AROUND THE BASKETBALL PLAYER TO OPTIMIZE HIS/HER PREPARATION.

OVERVIEW

Basketball requires high levels of physical conditioning to allow players to exploit their technical and tactical skills throughout a game. The desired physical characteristics in a basketball player are running faster and jumping higher than the opponents, having strength and balance to endure contacts and hits involved in the game, and performing these demands with less fatigue than their opponents. Furthermore, these tasks must be carried out optimally, in relation to a specific context (i.e., with teammates, against opponents, and according to the ball and the court). In such a specific environment, optimal actions do not necessarily require the peak potential of the player, but it makes sense to think that the better the potential, the greater the availability of resources (47).

Previous analysis of the physiological determinants for success in basketball showed the importance of both aerobic and anaerobic energy pathways (5). Due to the large number of short-high intensity actions and basketball-specific movements such as accelerations and change of direction, screening, blocking or positioning for rebounds, the importance of high levels of strength and neuromuscular power production should not be underestimated. A proper conditioning program should allow players to obtain, maintain, and/or enhance their physical capabilities, which ultimately may optimize sport performance while avoiding the risk of injury.

The purpose of this manuscript is to present a training methodology focused on strength and neuromuscular power development for both performance enhancement and injury prevention for basketball. The program is based on: (a) exercise specificity (i.e., task orientation and approaching level), and (b) player's needs, such as playing position requirements or injury history. Training volumes (i.e., number of sets and number of repetitions), intensities, and rest patterns are not addressed in depth in this work, since this can be found elsewhere (8,56). Nevertheless, some considerations of these training modulators for the different approaching levels are discussed, and examples of exercises that fit into each level are presented. Furthermore, different devices, equipment, and tools identified as suitable for each level are suggested. We consider this work a pedagogical proposal, which can help the coaching staff in designing a training program.

STRENGTH AND NEUROMUSCULAR POWER IN BASKETBALL

Strength and power revolve around 2 fundamental concepts: (a) the maximum force able to be produced and

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(b) the time to reach it (23). Activities performed throughout a game, such as sprinting or jumping, require optimal combination of these 2 variables: force and velocity, implying the ability to produce maximal power output and ultimately to maximize athletic performance. Traditionally, this idea has been represented by the force–velocity, power–velocity, or load–velocity curves (7,23). The greater his/her ability to apply more force in less time, the faster the athlete is. Thus, the ability to apply force efficiently and repeatedly in team sports is important.

Research demonstrates the positive impact of strength and neuromuscular power, or more specifically, rate of force development (RFD), on performance of typical sport physical actions such as sprints, accelerations, jumps, changes of direction, and sport-specific skills. So in terms of sports success, strength and neuromuscular power training have an important role (8,12).

High-intensity actions executed repeatedly and unpredictably over the course of a game involve an inherent risk of injury. In this regard, strength training has significant benefits in terms of reducing likelihood of injury (31). Strength training programs should also include prophylactic goals: adjusting muscular imbalances or weaknesses (6,13,26), preparing muscles and tendons to endure strains produced by high-intensity actions (especially in eccentric contractions, such as landing or braking) (13,34,40), and allowing a player to activate the required muscles suddenly and with adequate force-level ahead of unpredictable situations (neuromuscular control) (13,26,35,38).

CONSIDERATIONS FOR STRENGTH AND NEUROMUSCULAR POWER ASSESSMENT AND TRAINING PRESCRIPTION

It has generally been accepted that intensity is the most important stimulus related to changes in strength level; assessment has usually been done through the one maximum repetition (1RM) or the maximum number of repetitions that can be done with a given submaximal weight (e.g., 5RM) (33). From this perspective, strength training is performed using a maximal or submaximal/relative load (%1RM) through repetitions up to failure. However, training with repetitions up to failure may be counterproductive in terms of power production, due to the physiological transition to slower fiber types (29), mechanical and metabolic strain for subsequent sessions, and excessive fatigue, especially undesirable over the long competitive season. Direct assessment of 1RM value has some potential drawbacks: it may be associated with injury when performed incorrectly or by novice subjects due to their lack of expertise with heavy loads, and it is time consuming and impractical for the large groups common in team sports. Furthermore, the actual 1RM can change quite rapidly after only a few training sessions, and often the obtained value is not the subject's true maximum (24). Therefore, the authors encourage use of the "effort character" (EC), the relationship between realized and realizable (23), for training prescription. The main difference between EC- and RM-criteria is that EC is based on movement velocity and its loss, rather than weight-load. The actual velocity performed or the power developed in each repetition may be the best reference to measure the real effort incurred by the athlete (24). Thus, training with the intention to do the prescribed movement as fast as you can, regardless of the contraction type, load or movement velocity of the exercises used determines power development (3). However, velocity-specific improvements in maximal power are more likely elicited by the actual movement velocity used during training velocity-specific adaptations, which would be more desirable for subsequent force application in the sport actions (8,10). This supports the idea that players need to be not only strong but also efficient.

Today, there are many devices that allow coaches to monitor exercise intensity in the weight room, from which the distance, velocity, force, and mechanical power, among other variables, are obtained (20). Since basketball requires maximal power in many movement patterns, it makes sense to assess movement velocity for assessing and monitoring exercise intensity and training load, at least in the foundational exercises. Additionally, we also can then estimate the 1RM through the load–velocity relationship (22,24). In this regard, linear position transducers or accelerometers (e.g., T-Force System; Ergotec, Murcia, Spain; GymAware; Kinetic Performance, Canberra, Australia; SmartCoach Europe, Stockholm, Sweden; Tendo; Tendo Sports Machines, Slovak Republic, or Myotest, Sion, Switzerland) may be useful tools for proper strength training (for detailed procedures, see (24,43,44)).

For injury prevention, a proper musculoskeletal evaluation is recommended. To identify muscular imbalances or movement deficiencies, in addition to a medical examination, 3D motion capture through a multiple-camera system and ground reaction force through force plates together are the gold standard in kinetic and kinematic assessment (36). Additionally, electromyography has been widely used to evaluate muscle electrical activity (19), which may be of interest as biofeedback for a specific player's needs. More recently, tensiomyography seems to be a tool with great potential to assess muscle mechanical properties (42). Unfortunately, the high costs of most of these devices make such assessment not available to everyone, however, there are more affordable and validated screening tools which can be used (e.g., drop jump screening test, single-leg broad jump test, range of motion and movement efficiency assessments, etc.) (13).

From a teamwork perspective, the present proposal assumes that for proper individualized and integrative strength (and conditioning) training we should integrate members of the coaching staff. In every approaching level, each member will have varying

degrees of influence. So, for our players to achieve the final goal ("to be a basketball player who applies the optimal strength at every moment as required"), our training program should involve multiple perspectives and expertise (Figure 1). Therefore, it is now important for us to understand that strength and neuromuscular power development will not end in the weight room, since learning how to apply strength properly throughout a basketball game requires basketball-specific drills, which can be directed by the player development coach consistently with the other coaching staff members. The next stage of this process will imply using the consolidated skill with more complex decision making (under direction of the head coach and assistant coaches) and it will finish in an actual basketball game.

From a theoretical framework perspective, the fundamental principles of this methodology are

- Any specific movement or action in a real sport context will depend on perception, decision-making process, motivation, and execution (57).
- Any basketball-specific action, such as a layup, a change of direction, a jump, or an acceleration is considered as a combination of strength manifestations (isometric, concentric, eccentric; explosive, reactive, etc.) (23);
- Muscular endurance and speed are different expressions of strength, with different physiological and neural characteristics (53); and
- Range of motion and coordination are facilitator capacities of strength manifestations (53).

PROGRAM STRUCTURE

First, to classify the wide variety of technical skills existing in basketball, the authors propose to cluster those skills into 2 different groups: areas and contents (37) (Figure 2):

- Area: all the different movements and skill patterns are clustered into 3 areas: (a) jump, (b) fight, and (c) displacement. Basketball also implies "pass" and "shoot"; however, we omit them here as being not primarily dependent on strength.
- Content: is a specific technical skill, with all its variations, for instance, a layup, a crossover, a body check, a block, a post-up, etc. Each one of them will be related to one or more areas.

Figure 1. Coaching and medical staff involved in player's strength (and conditioning) development process.

A training progression should be developed according to (a) the task orientation or specificity (i.e., the degree of similarity in relation to actual basketball: general, directed, special, and competitive (48)), and (b) the approaching level, subcategories within the task orientation (0^-, 0^+, I, II, III, IV, and V) (37). A summary of the characteristics of every approaching level is presented in Table 1.

GENERAL ORIENTATION (LEVELS 0^-, 0^+, AND I)

This orientation covers the player's general needs: lean mass gain (body composition), maximal strength, endurance strength, neuromuscular power (force production), and specific injury prevention (imbalances and weaknesses). Methodologically, we can use any training modality to achieve the desired goal without taking into account its relation to basketball movement patterns. Injury prevention programs will be prescribed through complementary and compensatory exercises (see description below).

1. Level 0^-: exercises have no direct transfer to sport-specific movement patterns. Basic proprioception, balance, activation, and dynamic flexibility are common capacities to develop in this level. The focus is on the secondary muscles (stabilizers or fasteners) required in the main basketball movements. Repetitive efforts or strength endurance would be appropriate in this level. Decision making does not exist. Exercises are of 2 types, mainly:

- Compensatory: directed to injury prevention, addressing asymmetries and imbalances; involving muscle groups not included in the main exercises of the workout, and serving to reduce the aggressiveness of them (e.g., rotator cuff, buttocks, core-stability, adductors, and stretching).
- Complementary: although we agree that muscles do not act in isolation, and we train movements, not muscles, sometimes a player can benefit from strengthening some muscles in isolation (gluteus medius,

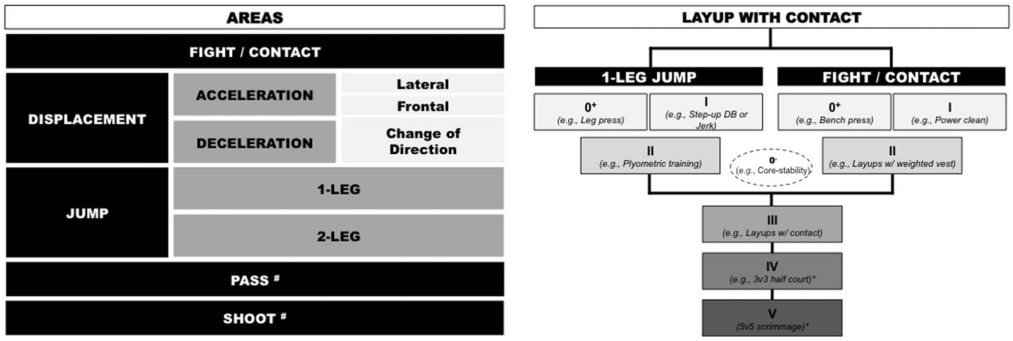

Figure 2. Program structure: Areas and contents. Left: Areas for basketball: fight/contact, displacement, jump, pass, and shoot; and suggested subcategories. #Pass and shoot are not primarily dependent on strength. Right: Example of a content development, interaction of areas, and some exercise suggestions at each level. Level 0^- will be present throughout the whole process. *In small-sided games and scrimmages, incentives or rule modifications can be used to achieve more frequency of the desired actions/contents.

peroneus, biceps, forearm muscles), through mono-articular or analytical exercises, such as biceps curls or calf raises.

1. Level 0^+: exercises are not related to basketball-specific movement patterns; however, strength gains in these exercises can be transferred to more specific exercises or performance skills. Intensity is higher than in level 0^-; we associate this level with traditional resistance training, such as squat or bench press and multi-joint exercises with non–basketball-specific range of motion or velocity (e.g., pushups on vibratory platform, seated leg press machine, single-leg deadlift, etc.). Decision making does not exist, or it is simple and unspecific.
2. Level I: this level is associated with explosive strength training (i.e., the ability to produce great force in least amount of time [RFD]). Traditional ballistic exercises, plyometric (reactive/elastic strength), and weightlifting exercises would be recommended, but it must bear some relation to basketball stances, at least the kinetic-chain characteristics (open/closed) allowing a greater transfer to performance (e.g., jump squat, regular squat with overloaded eccentric phase, unilateral and bilateral medicine ball throws, jumping variations, Olympic-style lifting [e.g., snatch, clean, jerk, hang-power clean, hang-power snatch or high pull]). Decision making does not exist or is simple and unspecific. Check to see how similar the proposed exercise is to the targeted basketball skill or area. The checkpoints shown in Table 2 could help as a guide.

For prevention of muscular and tendon injuries (and for performance enhancement) the use of devices which accentuate the eccentric muscular contraction have been demonstrated as an effective resource [i.e., inertial technology such as fly wheels, cones, and slide boards (2,9,39,41)]. For neuromuscular control, different successful protocols have been reported previously in the literature (28,51).

DIRECTED ORIENTATION (LEVELS II AND III)

This orientation includes exercises which should be closely related to actual basketball contents and require "all-out" efforts. It is divided into 2 levels, both characterized by functional strength and speed. Level II is more physical capacity dependent and level III is more motor skill dependent (coordination, technique). Specific training enhances performance, but potentially increases imbalances; work injury prevention will remain essential at this level.

- Level II: this level demonstrates the importance of exercise specificity and the effect it can have on the adaptations in sport-specific tasks. Exercises should replicate basketball-specific movement patterns and basketball skills, but overloaded or ballasted. Repeated high-intensity efforts, speed-agility, quickness, ballistic, and plyometric training are recommended, preferring a moderate plyometric training frequency to a higher one (14). It would be better to use a variety of methods rather than only one form. The use of elastic bands has become increasingly popular in strength and conditioning training programs (30) and can be very useful as ballast, as well as the overloaded vest or medicine ball. This type of work could be performed on court, adding body contacts (fights), jumps (with attention to 1-leg and 2-leg jumps and landings), straight accelerations, and repeated changes of direction (15,16,54), with or without basketball-specific pathways, considering playing position needs (45). Quality is preferred over quantity, and appropriate mechanics are critical. Finally, to improve

Table 1
Approaching levels characteristics

Orientation	Approaching level	Similarity	Training method	Place	Ball	Decision making	Confrontation format	Intensity	Main Strength manifestation	Example [**]
Competitive	V	Basketball	Actual or simulated game	On court	With	Actual complexity	4v4, 5vX	Optimal [modified rules?]		4–6 × [2–4 min "5v5 game", mainly low post situations]; 2–4 min rest
Special	IV	Basketball	Small-sided games	On court	With	Complex	(1v1), 2vX, 2v2, 3vX, 3v3, (4vX)	Optimal [modified rules?]		4 × [3', 3v3, half-court, mainly low post situations]
Directed	III	Basketball-based	Individual skills development	On court	With/without	None or simple	1v0, 2v0, (3v0)	"All-out" (optimally)		Post-up (improving balance and spins through lower center of mass)
	II	Basketball-based	Ballasting Skills/ plyometrics	On/off court	With/without	None or simple	None	"All-out"	Explosive-reactive (Functional)	3 × [6 "dunks" from low post with 3–5 kg medicine ball]
General	I	Basketball-based	Depends on goal	Off court	Without	None	None	Depends on goal but usually high	Explosive	Adapted Olympic-style lifts
	0^{+}	Nonspecific	Depends on goal	Off court	Without	None	None	Depends on goal	Maximal dynamic strength	Bench press with dumbbells (selective hypertrophy)
	0^{-}	Nonspecific	Depends on goal (complementary/ compensatory)	Off court	Without	None	None	Depends on goal	Dynamic strength (ECC & CON), isometric	Core stability, hamstrings (eccentric), monoarticular exercises

(): optional but normally unused; X: a number smaller than the indicated firstly (e.g., 3vX = 3v1 and 3v2, but non 3v3 or 3v4); [*]: here are shown only a few examples, there are a myriad of options.

MB = medicine ball.

Table 2
Checklist for strength exercises selection (levels 0^+ and I)

Upper body
Arms
Static or dynamic
Lateral, frontal or diagonal
Up to down or down to up
Pushing or pulling
Grip
Neutral
Prone
Supine
Alternate
Trunk
Static
Flexion-extension
Rotation
Lower body
Legs
Disposition: parallel or split stance
Displacement: none, 1 cycle (lunge and get back), continuous (march)
Feet
Neutral
External rotation
Internal rotation

screening, blocking or positioning, sprinting and changes of direction efficacy, good balance from lowered body center of mass is paramount and can be corrected during these types of workouts (49,50).

- Level III: this level is related to basketball-specific technical skill development. The player development coach will direct it consistently with the other coaching staff members. We can perform analytical or integrative workout sessions around a specific skill (from concrete to global drills). Decision making is simple and basketball based or does not exist.

GAME-BASED ORIENTATIONS

Special and competitive orientation tasks (levels IV and V respectively) are performed at these levels to improve game performance and so are based on basketball-specific team training sessions through various types of small-sided games and scrimmages. The head coach and/or assistant coaches will run these sessions. The sessions are not designed for specific strength or neuromuscular power development; but it is essential to remember that being based on the basketball game, the drills involve neuromuscular load and sport-specific strength enhancement.

SPECIAL ORIENTATION (LEVEL IV)

This level is essential for both skill-based strength and conditioning, in the form of small-sided games (SSG) (2v2, 2vX, 3v3, 3vX, and 4vX). The decision making is complex and basketball specific. Skill-based strength and conditioning benefits include greater transfer of physiological adaptations when the exercise simulates sport-specific movement patterns. Athletes simultaneously develop technical and tactical skills under high physical loads and the higher motivation that results from performing sport-specific rather than traditional strength and conditioning sessions (32). However, careful consideration of player skill levels, current fitness, number of players, court dimensions, game rules, work-to-rest ratios, and availability of player encouragement is required (1,32,52); by modifying these factors we can manipulate the overall physiological and perceptual workload (47) (for a detailed SSGs management, see (1,32,52)).

COMPETITIVE ORIENTATION (LEVEL V)

Competitive orientation is the most specific skill-based strength and conditioning session, involving the most realistic cognitive, physical, and physiological requirements. The decision making is complex and basketball specific. Exercises are based on 4v4, 5vX, and 5v5. The value of involving a larger number of players than in SSGs lies in enhancing team-specific decision-making skills: more teammates and opponents are involved in the decision-making processes (19). In team sports, strength and conditioning training is a way to improve player's capabilities (fitness, cognition, technique, tactics, teamwork, etc.), but never a goal in itself. Players must be better at level V (playing actual basketball), not just at, for example, level 0^+ or level III. Nonetheless, training only at levels IV and V could be risky due to the tasks being "open" (less controlled): some players might not receive enough physical stimuli, losing fitness level (especially players who play fewer minutes over the season (21,46)), and other players might accentuate already existing imbalances. The design of exercises at this level should follow the considerations about SSGs. At this level it is typical to use game incentives, such as points, or to modify rules.

PERIODIZATION

In team sports such as basketball, it is common to divide the season into 3 phases: (a) pre-season, (b) competitive season, and (c) off season or transition period. We suggest designing the workout programs as follows, based on season phase requirements (competitive calendar) and individual player needs, according to biological maturation, sport-career moment, and players' strengths and weaknesses:

- Pre-season: this phase develops levels I, II and III, individualizing the programs based on the individual and team area-and-content needs, progressively reducing level I, and interspersing SSG and actual basketball (levels IV and V). However, depending on the team characteristics, the competition calendar, and player needs, it will not always be necessary to accomplish levels I and/or II.

Injury prevention and workload compensation will be a priority goal and should be carried out at levels 0^+ and 0^-.

- Competitive season: the first goal will be to compensate the high specificity provided by the competition, being that the higher the specificity, the more risk for injury (27). A workout based on level 0^-, level II and level III should be performed periodically (at least every 7–10 days). It is important to adapt different weekly strength-training schedules to the number of games per week (1, 2, 3 games per week or back-to-backs). Teams with longer microcycles (e.g., 1 game per week) may be able to perform general workouts more frequently if needed (level 0^+ and I).
- Off-season: improvements in general and maximal strength, and in maximal power production through resistance-, eccentric-, ballistic- and weightlift-training should be made mainly over off-season, and until early preseason for special player needs. Throughout this period it is also common to improve muscular imbalances and asymmetries with an eye to injury prevention.

Generally, with young team sport players (under 16 years), sport goals should be secondary; strength training should be focused on injury prevention (level 0^-), general strength (level 0^+) (4), and on deliberate play and practice (18,25) (levels III, IV, and V). In such situations, the athletes should focus more on these areas than on improving the applied strength in basketball-specific skills (contents).

SESSION DESIGN

The recommended single-workout structure, according to time efficiency and stimulus variability, is a sequence of exercises (11,17), and it can be performed in 2 ways: by (a) developing one "area" mainly, or (b) by developing several areas. Every sequence of exercises includes 2 types of exercises: (a) primary (or fundamental) and (b) secondary (complementary or compensatory). These exercises will be interspersed within the sequence, and in each sequence one set will be performed. If 4 sets are prescribed, the player will have to do the sequence 4 times. The proportion of secondary

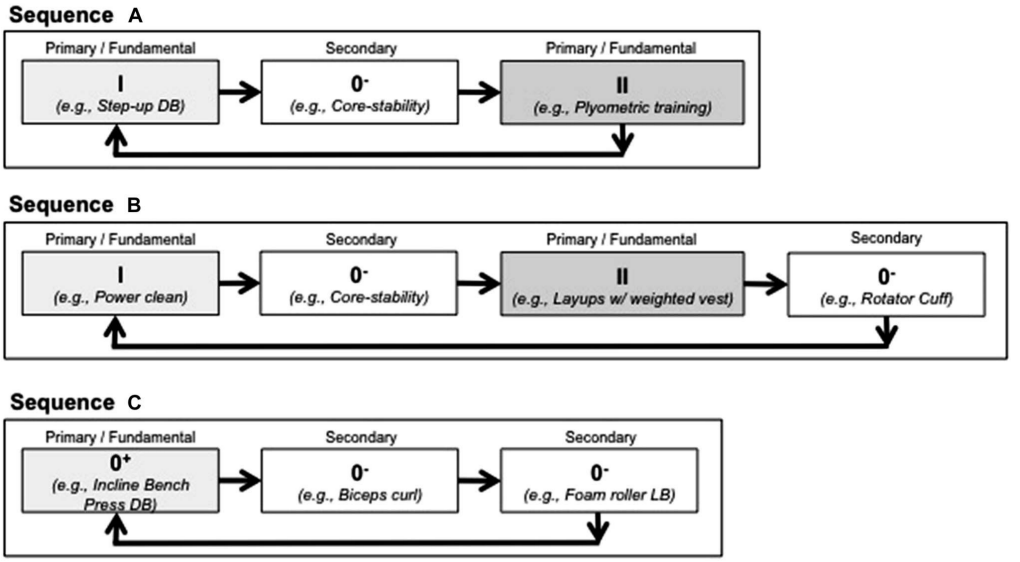

Figure 3. Session design: Sequences of exercises. "A" shows an example of 3-exercise sequence with 2 primary exercises of the same area and 1 secondary exercise (the muscle groups involved in the primary exercise have a work-to-rest ratio of 2:1), "B" shows an example of 4-exercise sequence with 2 primary exercises of the same area and content and 2 secondary exercises (the muscle groups involved in the primary exercise have a work-to-rest ratio of 1:1), "C" shows an example of 3-exercise sequence with 1 primary exercise and 2 secondary exercises (the muscle groups involved in the primary exercise have a work-to-rest ratio of 1:2). The intensity, the volume and the work-to-rest ratio of the sequence will determine the physiological adaptations. A single workout can imply as many sequences as the coach considers appropriate. There are a myriad of possible combinations using all the approaching levels (especially up to level III).

and primary exercises will depend on the physical/physiological goal (recovery needs between sets (8,54–56)). If a sequence is prescribed and focused on just one area, the athlete should perform a specificity-based progression of the primary exercises following the approaching level criterion (Figure 3).

To design the training session, we should consider:

- The individual needs (e.g., body composition, injury history, strength profile);
- Which area (or combination of areas) and contents (skill) we want to optimize (e.g., better balance on low post, faster acceleration on fast break, faster COD after crossover);
- The approaching level we want to develop (according to specificity); and
- The selection of exercises and their variations.

CONCLUSIONS

Any specific movement or action in a real sports context will depend on perception, decision-making process, motivation, and execution. The management of training specificity involving perception, decision making, and execution seems to be crucial to maximize team sports performance. In basketball, strength and neuromuscular power have an important role in performance, but players need to be not only strong but also efficient. The monitoring of strength training (i.e., force, velocity, power) through linear position transducers, accelerometers or similar devices is highly recommended. Eccentric muscle actions have been demonstrated as an effective resource for injury prevention and strength enhancement. In basketball, strength and power development will not end in the weight room, since learning how to apply strength properly throughout a game requires basketball-specific drills involving decision making.

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