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SCOPING REVIEW

Integrating physical and cognitive approaches: A scoping review of advanced training methods in basketball

Asaf Shalom[1]✉, Aviad Levy[2], Yoav Meckel[4], Julio Calleja-Gonzalez[3], and Roni Gottlieb[4]

[1]Department of Physical Education, Tel Hai Academic College, Qiryat Shemona, Israel; [2]Under 16 Israeli Men National Team (Basketball), Tel Aviv, Israel; [3]Department of Physical Education and Sports, Faculty of Education and Sport, University of the Basque Country, UPV/EHU, Vitoria-Gasteiz, Spain; and [4]School of Human Movement and Sport Sciences, The Levinsky-Wingate Academic College, Netanya, Israel

Abstract

Background: Basketball is a sport characterized by dominant anaerobic physiological demands, requiring high explosive power in combination with advanced psychomotor abilities. **Objective:** The primary aim of this scoping review was to examine advanced evidence-based training methods in basketball, focusing on their impact on physiological and psychomotor functions. The review explored methods to enhance performance qualities aligned with the physiological, cognitive, and sport-specific demands of professional players, to identify methods supported by scientific evidence for systematic on-court implementation and to examine whether such evidence suggests future research directions. **Methods:** A structured search was conducted across four electronic databases (PubMed, Scopus, Web of Science, and Google Scholar), along with backward citation screening. Extracted data included training type, participant characteristics, context, and reported outcomes. **Results:** A total of 10 studies published between 2014 and 2024 met the inclusion criteria. Seven advanced training methods were identified as relevant and applicable to professional basketball performance: plyometric training, sprint training, specific training, contrast training, complex training, multi-component training (MCT), and cognitive-motor dual-task training (CMDT). **Conclusions:** The combination of CMDT and MCT offers a promising new way to improve both explosive power and cognitive performance in basketball. Using these methods as part of warm-up routines has not been studied enough and should be explored further. Future research should test how effective this approach is and explore how it can be combined with other methods to create effective training programs for professional basketball players.

Keywords: innovation in sports science, basketball, training methods, physiological systems, psychomotor components, sports performance

Introduction

Basketball, a sport marked by its rapid pace and intermittent high-intensity activities (Gottlieb et al., 2021; Narazaki et al., 2009), requires a comprehensive array of physiological attributes for optimal performance, including anaerobic power, recovery from explosive short actions, strength, agility, and neuromuscular coordination (Mancha-Triguero et al., 2020; Ostojic et al., 2006; Shalom et al., 2023a). These physiological demands are primarily supported by three energy systems: the anaerobic alactic system, known as adenosine three phosphate – creatine phosphate system (ATP-CP); the anaerobic lactic (glycolysis) system; and the aerobic system (Apostolidis et al., 2004; Boone & Bourgois, 2013; Narazaki et al., 2009). The ATP-CP system predominates, providing immediate energy for short-duration, high-intensity activities such as sprints, jumps, and rapid directional changes (Gottlieb et al., 2021). The muscles energy storage for this system, however, is rapidly depleted, requiring brief periods of rest for replenishment (Delextrat & Cohen, 2008). The contribution of the anaerobic glycolysis system in basketball is secondary to the ATP-CP system, as it functions as a major energy supplier during prolonged high-intensity efforts (Delextrat & Cohen, 2008; Gottlieb et al., 2021). Indeed, given the game's intermittent activity nature, basketball does not typically impose high levels of blood lactate accumulation (Shalom et al., 2023a). Finally, the aerobic energy system, though less dominant in high-intensity efforts, is essential for recovery (Gottlieb et al., 2022, 2023). The primary contribution of this system is reflected by an athlete's maximal oxygen uptake (VO_{2max}), which supports sustained performance throughout the game by enhancing recovery between high-intensity actions (Stojanovic et al., 2012).

In addition to the aforementioned physiological demands, basketball is also dependent on psychomotor skills, as it requires the players to respond dynamically to rapidly changing scenarios in a sometimes-unpredictable environment (Chaiken et al., 2000; Habay et al., 2021; Lakhno et al., 2020). As success in basketball often hinges on the integration of various psychomotor components, cognitive skills are crucial in the game, classifying it as a

✉ **Corresponding author:** A. Shalom et al., e-mail dr.asafshalom@gmail.com, ORCID® record https://orcid.org/0000-0001-5148-5536

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sport involving open skills (Lucia, Digno, et al., 2023; Lucia et al., 2021; Taatgen, 2013). The psychomotor skills involved in basketball include agility, reaction time, coordination, balance (both static and dynamic), and kinesthesia (Habay et al., 2021; Hassan et al., 2022; Lakhno et al., 2020; Mancha-Triguero et al., 2020; Muntianu et al., 2022; Portaz et al., 2024; Rosker & Sarabon, 2010). Brief descriptions of these skills are provided below.

Reaction time is defined both as a physical measure expressed in units of time and as a broader cognitive-motor ability involving the rapid processing of stimuli and execution of responses. Reaction time is critical in basketball because the ability to quickly process and respond to external stimuli, such as an opponent's actions or the trajectory of the ball, may dictate whether a team gains or loses ball possession (Badau et al., 2022; Hassan et al., 2022; Lakhno et al., 2020; Sheppard & Young, 2006). This combined temporal and cognitive-perceptual capacity is crucial in scenarios such as intercepting a fast pass, contesting a shot, or making a quick defensive adjustment (Lucia, Bianco, & Di Russo, 2023; Lucia et al., 2021).

Balance is another fundamental element, both in its static form, which enables players to maintain stability in stationary positions (such as holding a defensive stance or setting a screen), and in its dynamic form. The latter involves control during movements such as driving to the basket, pivoting, or performing a layup under defensive pressure. Effective balance allows players to maintain their center of gravity and reduce the risk of injury during rapid, multidirectional movements (Halabchi et al., 2020; Lucia, Digno, et al., 2023; Stojanović et al., 2023).

Coordination involves the smooth integration of multiple body parts to execute complex skills, often simultaneously or in quick succession, such as dribbling while scanning the court for passing options or shooting accurately under defensive pressure (Lucia, Aydin, & Di Russo, 2023; Lucia, Bianco, & Di Russo, 2023; Lucia, Digno, et al., 2023; Shalom et al., 2023b, 2024). Coordination is critical for the fluid execution of these skills.

Agility is defined as a rapid whole-body movement with a change of velocity or direction in response to a stimulus. It is indispensable for the quick and efficient changes in direction and speed that are necessary in both offensive and defensive basketball contexts (Lucia, Bianco, & Di Russo, 2023; Scanlan et al., 2014; Sekulic et al., 2017; Sheppard & Young, 2006). Whether executing a crossover dribble to evade a defender or recovering quickly to contest a shot, agility underpins the ability to perform rapid, controlled movements that are crucial to high-level performance in basketball (Lucia et al., 2021; Lucia, Bianco, & Di Russo, 2023; Lucia, Digno, et al., 2023).

Finally, *kinesthesia*, or the awareness of the position and movement of the body in space, allows players to make precise adjustments to their movements in real-time, enhancing their ability to navigate through opponents, perform complex footwork, and maintain control of the ball under pressure (Chaiken et al., 2000; Habay et al., 2021; Lakhno et al., 2020; Muntianu et al., 2022; Rosker & Sarabon, 2010). Kinesthetic awareness is particularly important in scenarios where players must rely on their sense of body positioning, such as during blind pass or fadeaway jump shot (Habay et al., 2021; Lakhno et al., 2020).

Psychomotor skills and adaptability are essential for high-level basketball performance, yet often insufficiently addressed in training. Their integration in training methods supports more complete player development and enhances performance (Lucia, Bianco, et al., 2023; Lucia et al., 2021; Portaz et al., 2024).

Table 1 outlines the specific psychomotor components directly related to the game of basketball (Habay et al., 2021; Lucia, Bianco, & Di Russo, 2023; Lucia, Digno, et al., 2023; Shalom et al., 2023b; Sheppard & Young, 2006).

Objectives of the scoping review

The primary aim of this scoping review was to examine a range of advanced and evidence-based training methods used in basketball, focusing on their effects on physiological and psychomotor functions involved in players' performance. Specifically, we sought to review training methods designed to enhance performance qualities that align directly with the physiological, cognitive, and sport-specific demands of professional basketball players. In doing so, we aimed to identify training methods that are supported by scientific evidence and can be practically and systematically implemented in on-court training environments. Furthermore, this review aimed to examine whether such scientific evidence could provide valuable insights for developing new directions in performance enhancement,

Table 1 Specific psychomotor components involved in basketball

Component	Description	Skill examples
Reaction time	The ability to quickly process and respond to external stimuli	• Intercepting a fast pass • Contesting a shot • Making a quick defensive adjustment
Balance	The ability to maintain one's center of gravity and reduce the risk of injury during rapid multidirectional movements	• Holding a defensive stance or setting a screen (static balance) • Maintaining control during movement, such as driving to the basket, pivoting, or performing a layup under defensive pressure (dynamic stability)
Coordination	The integration of multiple body parts to execute complex skills	• Dribbling while scanning the court for passing options • Shooting accurately under defensive pressure
Agility	Rapid whole-body movement with change of velocity or direction in response to a stimulus	• Evading from defender • Recovering quickly to contest a shot
Kinesthesia	The awareness of the position and movement of the body in space, which allows players to make precise adjustments to their movements in real-time	• Navigating through opponents • Performing complex footwork • Maintaining control of the ball under pressure • Performing fadeaway jump shots

promoting innovation in training methods, and advancing research within the field of basketball performance and sports science.

Methods

This scoping review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement, ensuring a systematic and transparent procedural process (Tricco et al., 2018).

Eligibility criteria

The inclusion criteria for this scoping review included a study publication date between 2014 and 2024. Additionally, foundational studies published prior to 2014 were also included if they were deemed critical to the topic. The year 2014 was chosen to capture the most recent decade of research reflecting significant innovations in basketball training methods and sports performance science. To be eligible, studies had to be published in English and address basketball-specific training methods or closely related sports training methods, emphasizing investigations into physiological, psychomotor, or cognitive skills relevant to performance optimization in professional basketball players. Only peer-reviewed empirical studies, systematic reviews, and theoretical frameworks that provided insights into advanced training methods were included. Studies that considered variables such as age, gender, and playing position were also included, so as to acknowledge the importance of these factors in the context of basketball-specific training and performance development.

Exclusion criteria included studies that focused on non-basketball sports or failed to align with the unique demands and requirements of basketball, such as those unrelated to the sport's specific physiological, psychomotor, or tactical needs. Studies that did not analyze the targeted components or that were non-empirical in nature, including conference abstracts or opinion pieces, were also excluded. This approach ensured that the review focused exclusively on high-quality, relevant studies that contribute to the understanding and advancement of basketball training methods.

In accordance with the purpose and methodology of scoping reviews, no formal quality assessment of the included studies was conducted, as the objective was to map the breadth and scope of the available literature, not to critically appraise individual studies.

Search strategy

A comprehensive search of four electronic databases (PubMed, Scopus, Web of Science, and Google Scholar) was performed using the default field search setting within each database. The search terms included „Basketball Training Methods" OR „Physiological Systems" OR „Psychomotor Components" AND „Exercise Physiology" OR „Sports Performance". The last search was conducted in January 2025 by the lead author (A.S). These terms were chosen based on the opinion of the authors (A.L, Y.M., J.C-G., and R.G.), professional judgement, the scientific literature review, and controlled vocabulary where applicable. Synonyms and related terms were incorporated to maximize the retrieval of relevant studies. Additionally, the reference lists of all included studies were examined to ensure comprehensive identification of pertinent literature. The search strategy followed a structured and reproducible approach, using predefined inclusion and exclusion criteria; systematic screening of titles, abstracts, and full texts by multiple reviewers; and alignment with PRISMA recommendations to ensure transparency and methodological rigor.

The following search string on the PubMed database represents one of the structured queries used to identify relevant studies, with additional searches and variations conducted across databases to ensure comprehensive coverage of the topic: (*"Basketball Training" OR "Physiological Systems" OR "Psychomotor Components") AND ("Exercise Physiology" OR "Sports Performance") [Title/Abstract]*. A core set of keywords and search principles guided this query and was adapted with minor variations across databases (Scopus, Web of Science, and Google Scholar) to ensure comprehensive coverage of the topic.

Selection of sources of evidence

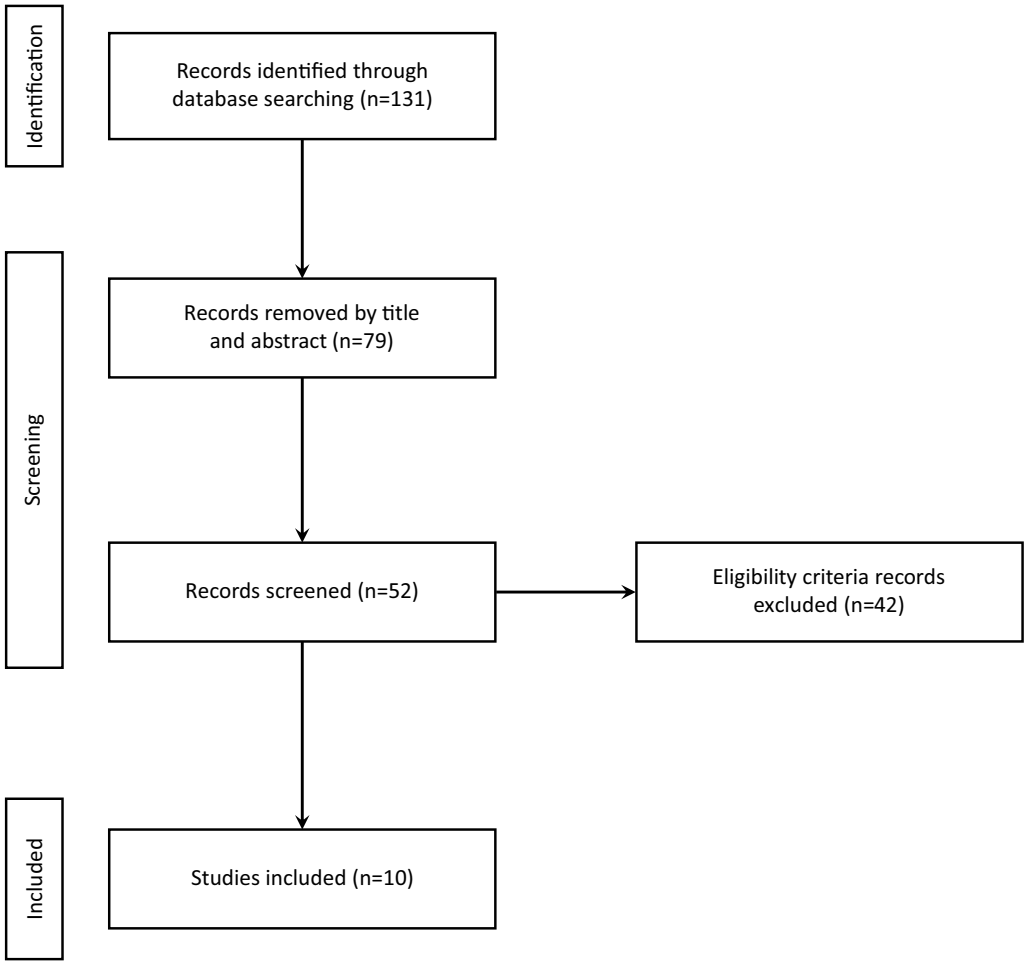
The study selection process followed a systematic approach, as illustrated in Figure 1. Exact numbers from each database were not systematically preserved; therefore, only the overall total is reported, and this limitation is also noted in the Results section. After the initial search across the four databases, duplicate records were removed. The remaining records were then screened for relevance based on title and abstract, followed by a full-text review against the eligibility criteria. Only studies that were most relevant and innovative, and that aligned with the objectives of this scoping review, were included in the final analysis. The screening process was conducted independently by two reviewers in two rounds (titles/abstracts and full text). Duplicate records were removed manually using Microsoft Excel 2019 and Microsoft 365 (Microsoft, Redmond, WA, USA) prior to the initial screening. Discrepancies were resolved through discussion and consensus.

Data charting process

Before initiating data extraction, we conducted a general evaluation of the methodological quality of the included studies. While formal risk of bias assessment is not mandatory in scoping reviews, this evaluation considered factors such as study design, sample size, relevance to advanced basketball training methods, and clarity of reported outcomes.

A standardized data extraction template was developed and implemented using Microsoft Excel 2019 and Microsoft 365 (Microsoft, Redmond, WA, USA). This template was utilized to systematically collect and organize relevant details from the included studies. Extracted data included the author(s), the publication year, the type of article, the population studied, and key information relevant to the objectives of the review. This structured approach ensured consistency and accuracy in documenting the most critical aspects of each study, facilitating a clear understanding of their contributions to this scoping review.

Figure 1 The PRISMA flowchart illustrating each stage of the literature search



Synthesis of results

The data were collected and analyzed descriptively using a systematic scoping review approach. This process aimed to identify key trends, knowledge gaps, and emerging practices in basketball training methods. The findings were systematically classified based on the unique physiological and psychomotor demands of basketball performance, as well as by the type of specific training methods employed. The review specifically focused on competitive, high-performance basketball contexts, reflecting the demands of professional-level play. This structured approach facilitated a comprehensive analysis of how these training methods contribute to players' conditioning and skill development, while addressing the specific requirements of basketball performance on the court.

Results

Study characteristics

An initial search across the four databases yielded approximately 1000 records before duplicate removal. Exact numbers by database were not systematically retained, and this limitation is acknowledged for the sake of transparency. After this step, the remaining records were screened for relevance (title and abstract), with 131 retained for further review. Of these, 79 were excluded due to irrelevance to the research objectives. Subsequently, 52 articles underwent a full-text review against the eligibility criteria, of which 42 were excluded. At the end of the screening process, 10 studies were included in this scoping review and are listed in Table A1 . Notably, the included studies comprised both review articles, which offered a broader context within the field, and empirical studies that provided direct evidence relevant to physiological and psychomotor aspects of advanced basketball training. These 10 studies represent the most relevant and innovative research aligned with the objectives of the review, with each study linked to a specific training method.

Principles of training methods for optimal basketball performance

Seven training methods were identified in our literature review as the most effective for developing the unique abilities of basketball players. While other training methods are available, the seven methods highlighted in this scoping review are particularly applicable on the basketball court. These methods, proven to enhance key performance attributes, are described below, followed by a focused discussion that includes conclusions and practical applications.

Plyometric training

Plyometric training, which involves the stretch-shortening cycle (SSC), is critical for enhancing muscle power and speed (Gottlieb et al., 2014). The SSC is a natural muscle function whereby a rapid eccentric contraction (muscle lengthening) is immediately followed by a concentric contraction (muscle shortening; Gottlieb et al., 2014; Ramirez-Campillo et al., 2022). During plyometric exercises, the SSC is exploited to maximize force production in a minimal amount of time (Ramirez-Campillo et al., 2022; Sánchez-Sixto et al., 2021). This process not only increases muscle power but also enhances the speed at which a player can generate force. By repeatedly engaging in these explosive movements, players can improve their neuromuscular efficiency, coordination, and overall kinetic performance, leading to greater speed and power in their athletic endeavors (Gottlieb et al., 2014; Ramirez-Campillo et al., 2022).

On the basketball court, various forms of plyometric training are integral to optimizing athletic performance. A prominent example is depth jumps, wherein a player descends from an elevated platform and immediately performs a vertical leap upon ground contact, thereby exploiting the SSC to augment explosive power (McCormick et al., 2016; Ramirez-Campillo et al., 2022). Selective drills and unique devices may be used to execute appropriate plyometric-type training sessions. Another example is box jumps, which involves repetitive leaps onto and off a raised surface, serving to enhance vertical jump capacity and neuromuscular coordination. Tuck jumps, characterized by a player jumping and drawing their knees to their chest mid-air before landing, are effective in bolstering lower body strength and agility. Bounding drills, which entail exaggerated leaping strides, aim to improve horizontal propulsion and dynamic equilibrium (Brini et al., 2023; Khlifa et al., 2010; Ramirez-Campillo et al., 2022; Verma et al., 2015). Incorporating these exercises in a basketball-specific training program can substantially elevate players' proficiency in executing high-intensity, explosive maneuvers, such as rebounding, rapid sprints, and swift directional changes (Gottlieb et al., 2014; McCormick et al., 2016). It is essential to note that this training method is highly intense and requires the establishment of a foundational movement base and preliminary strength to ensure efficacy and reduce the risk of injury (Berton et al., 2018).

Sprint training

Sprint training, a method involving repeated short sprints in a straight line, is fundamental for enhancing explosive power in basketball (Attene et al., 2014; Freeman et al., 2019; Song et al., 2023; Young et al., 2001). This training technique is grounded in sports science principles that emphasize the development of anaerobic energy systems, particularly the ATP-CP system (Shalom et al., 2023a; Song et al., 2023). By performing all-out short sprints, players can increase their muscle fiber recruitment, particularly of the fast-twitch fibers responsible for explosive movements (Shalom et al., 2023a). This form of training also enhances the efficiency of neuromuscular coordination, allowing for quicker and more forceful muscle contractions.

On the basketball court, sprint training can be integrated through drills that simulate game scenarios, such as fast breaks and defensive transitions, ensuring that improvements in speed and power are directly applicable to in-game performance (Attene et al., 2014; Fang & Jiang, 2024; Shalom et al., 2023a). Additionally, depending on sprint repetition frequency and length, sprint training may improve cardiovascular capacity and lactic acid tolerance. While the requirement for lactic acid tolerance is less significant, it may still play a role in enhancing endurance in certain situations, depending on the team's game tactics, (Gottlieb et al., 2021, 2022). Sprint training may also serve as a way to improve the aerobic capacity needed for recovery, while simultaneously maintaining high explosive power and training fast-twitch muscle fibers (Ben Abdelkrim et al., 2010; Gottlieb et al., 2023; Mancha-Triguero et al., 2020; Shalom et al., 2023a). The repetitive nature of sprint training conditions the central nervous system to better handle the demands of rapid acceleration and deceleration, which are critical for effective play in basketball.

Basketball-specific training

A particularly effective training method in basketball, which emphasizes game-specific movements, involves executing a series of short sprint drills interspersed with rapid directional changes to mirror the dynamic nature of in-game scenarios (Gottlieb et al., 2014). This approach typically involves performing unique movements in a closed skill environment where the planning of actions is predetermined (Brini et al., 2023; Fang & Jiang, 2024). These drills can be conducted both with and without a basketball, thereby enhancing both basketball-specific technical skills and physical conditioning (Gottlieb et al., 2021; Shalom et al., 2023a). For instance, shuttle runs and cone drills can be designed to simulate defensive slides, offensive cuts, and transition movements (Gottlieb et al., 2014). Incorporating ball-handling or passing elements during these drills further replicates the multi-tasking demands of actual gameplay, fostering improved spatial awareness, and quality of movement (Lucia et al., 2021; Lucia, Digno, et al., 2023).

This training method enhances the anaerobic alactic system by requiring short bursts of high-intensity effort followed by brief recovery periods, thereby improving the body's capacity to generate and utilize energy rapidly (Shalom et al., 2023a). Additionally, this type of training significantly boosts explosive power, enabling players to execute quick and forceful movements essential for successful performance in basketball (Gottlieb et al., 2014; Shalom et al., 2023a). However, it is important to note that the unique movements relevant to the game are often practiced in a controlled environment, where the focus is on the intensity and speed of these movements, particularly in the horizontal plane, without the added complexity of significant external stimuli or reactive demands (Gottlieb et al., 2014).

Complex and Contrast training

Post-activation potentiation (PAP) mechanism

Both contrast and complex training methods utilize the principle of PAP, a procedure that leads to more forceful muscle contractions following pre-activation of resistance exercises (Docherty & Hodgson, 2007; Gepfert et al., 2020; Seitz & Haff, 2016). This pre-activation results in an elevated neural drive and increased recruitment of muscle fibers, thereby enhancing the execution of subsequent explosive movements (Cormier et al., 2020; Gołaś et al., 2016). The PAP is a fundamental mechanism in both contrast and complex training, as it contributes significantly to the efficacy of these methods in enhancing athletic performance, particularly in sports that demand rapid and powerful movements, such as basketball (Cormier et al., 2020).

Complex training

Complex training involves alternating between biomechanically similar high-load strength exercises and similar lighter load explosive power exercises within the same training session. For example, a set of heavy squats may be immediately followed by a set of plyometric jumps (Comyns et al., 2006; Ebben, 2002). This method capitalizes on the PAP mechanism, wherein heavy resistance exercises such as squats induce PAP, subsequently enhancing the effectiveness of ensuing power exercises such as jumps (Cormier et al., 2020). This combination allows players to maximize power output during the lighter, explosive movements, making it particularly beneficial for sports requiring rapid force production (Cormier et al., 2020; Ebben, 2002). By immediately transitioning from strength to explosive power exercises, the gains in strength are directly transferred to the explosive movements required in basketball, enhancing neuromuscular coordination and efficiency (Cormier et al., 2020; Santos & Janeira, 2008). Consequently, this leads to improvement in key performance such as vertical jumping, sprinting, and agility, which are crucial for success in the sport (Cormier et al., 2020).

Complex training can be seamlessly integrated into on-court drills, thereby closely mimicking the demands of actual gameplay (Freitas et al., 2019). For instance, following a set of heavy goblet squats performed at the baseline, a player might immediately transition to executing explosive jump shots or rebounding drills (Comyns et al., 2006; Cormier et al., 2020; Ebben, 2002; Freitas et al., 2017). The heavy squats effectively augment the player's vertical power output, which can then be directly applied to the jump shot or rebound, simulating the explosive demands encountered during a game (Freitas et al., 2017; Santos & Janeira, 2008). Additionally, the pairing of heavy lateral lunges with lateral bounds or shuttle sprints can enhance agility and change of direction capabilities, which are critical skills for both defensive and offensive maneuvers on the basketball court (Cormier et al., 2020; Freitas et al., 2017; Santos & Janeira, 2008).

Given that complex training alternates between strength and explosive power exercises within the same session, it is particularly suitable for in-season or late pre-season periods when maintaining a high level of both attributes is essential. This training method is often considered more advanced and may provide superior performance-specific benefits for experienced and high-level basketball players (Comyns et al., 2006; Cormier et al., 2020; Ebben, 2002; Santos & Janeira, 2008).

Contrast training

Contrast training is structured differently from complex training, as all high-load strength exercises are performed together at the beginning of the training session, followed by lighter load explosive power exercises performed towards the end of the session (Mujika et al., 2009; Pagaduan et al., 2019). In other words, unlike complex training, where strength and explosive power exercises are alternated within the same set, contrast training groups these exercises sequentially (Latorre Román et al., 2018; Pagaduan et al., 2019). The initial heavy-load exercises induce PAP, priming the muscles for enhanced performance in the subsequent power exercises. However, unlike complex training, in contrast training, the PAP effect is intended to carry over to the lighter exercises performed later in the session (M. Hammami et al., 2019; Latorre Román et al., 2018; Pagaduan et al., 2019).

In the context of basketball, a contrast training session might, for instance, commence with heavy squats and deadlifts (forming the strength phase), followed by sprint drills and plyometric exercises in the explosive power phase. This ensures that the strength gained from heavy lifts is immediately followed by exercises that demand the application of this strength in a fast and explosive manner (Cormier et al., 2020).

The sequential nature of contrast training allows for a more targeted development of strength before moving on to explosive power, which can be particularly advantageous for basketball players needing to build a solid strength base prior to focusing on explosive power (Cormier et al., 2020; Pagaduan et al., 2019). This approach enables coaches to tailor the training session to better address specific weaknesses, such as developing raw strength or converting existing strength into explosive movements required in gameplay. Contrast training is especially beneficial during the off-season or early pre-season, where there is a need to prioritize foundational strength building before transitioning into explosive power development (M. Hammami et al., 2019; Latorre Román et al., 2018; Mujika et al., 2009; Pagaduan et al., 2019).

Multi-component training (MCT)

In open-skill sports, the synchronization of technical, physical, and psychological elements presents a formidable challenge for coaches and sport scientists (Lucia, Digno, et al., 2023). MCT addresses this complexity by incorporating multiple exercise modalities within a single training session, aiming to simultaneously enhance physical fitness, technical skills, cognitive performance, and overall athletic performance (Brunner et al., 2019; Lucia et al., 2021; Lucia, Digno, et al., 2023). Typically, MCT sessions include a

combination of components such as agility, balance, speed, strength, and technique. Exercises within an MCT framework might involve agility drills, balance exercises, plyometrics, strength training circuits, and sport-specific skill drills (Lucia, Digno, et al., 2023).

MCT has been predominantly utilized in basketball as a warm-up strategy to mitigate injury risk. However, its integration in comprehensive training programs remains limited, and cognitive components are rarely included. Nonetheless, recent evidence highlights the efficacy of MCT in improving various performance metrics among basketball players, such as anaerobic power and capacity, agility, and vertical jump height. The inclusion of cognitive tasks within MCT protocols could further augment these benefits by enhancing decision-making and reaction time, thus providing a holistic approach to athletic development (Brunner et al., 2019; Lucia, Digno, et al., 2023).

Cognitive-motor dual-task training (CMDT)

CMDT emerges as a cutting-edge approach in sports science, integrating technical, physical, psychomotor, and mental components within a single training session (Lucia, Aydin, & Di Russo, 2023; Lucia, Bianco, et al., 2023; Lucia, Digno, et al., 2023). By simultaneously training cognitive and motor skills, CMDT has been shown to enhance both cognitive and motor performance more effectively than when these skills are trained independently (Lucia, Digno, et al., 2023). Recent studies on CMDT reveal that it significantly improves anticipatory brain functions and sport performance, particularly in basketball players (Lucia, Aydin, & Di Russo, 2023; Lucia et al., 2021; Lucia, Bianco, et al., 2023; Lucia, Digno, et al., 2023). CMDT exercises designed for basketball players often include dribbling drills combined with cognitive tasks such as responding to verbal cues or solving mathematical problems. An example could involve players dribbling through a series of cones while a coach provides random auditory signals or numerical sequences that the players must recall or respond to (Bianco et al., 2017; Lucia et al., 2021; Moreira et al., 2021; Taatgen, 2013). This approach not only enhances technical skills like dribbling but also improves cognitive aspects such as attention and memory, which are crucial for game situations (Lucia, Digno, et al., 2023). Additionally, CMDT frequently incorporates visuomotor response tasks, such as reacting to visual stimuli while performing complex motor tasks (Lucia, Bianco, & Di Rosso, 2023; Lucia, Digno, et al., 2023). For example, a drill might involve players shooting from different spots on the court while simultaneously tracking moving targets on a screen. This helps refine the integration of cognitive and motor skills, improving overall performance in dynamic game situations (Lucia, Digno, et al., 2023).

The utilization of technological devices is integral to CMDT, as they facilitate exercise pacing and provide immediate performance feedback, thereby maximizing training efficacy (Lucia, Bianco, & Di Rosso, 2023; Lucia, Digno, et al., 2023). Technologies such as virtual reality systems or computerized reaction time tests can simulate game scenarios (Kołodziej et al., 2018; Lucia et al., 2021), allowing players to practice under conditions that closely mimic actual gameplay (Lucia, Digno, et al., 2023).

Cognitive-motor dual-tasks can be combined in training on the basketball court to create a comprehensive regimen that enhances both explosive power and cognitive components (Lucia, Digno, et al., 2023). Such a regimen contributes to the development of players' ability to apply their strength and power in high-pressure, game-like scenarios. This training method represents the most innovative of those reviewed and has been found over the past year to significantly improve the explosive power performance of basketball players when combined with cognitive demands in open-skill scenarios, particularly when integrated with MCT (Lucia, Digno, et al., 2023).

Table 2 summarizes the principles of the training methods and exercises presented in this scoping review for optimizing performance in basketball (Cormier et al., 2020; Freeman et al., 2019; Gottlieb et al., 2014; Lucia, Digno, et al., 2023; Young et al., 2001).

Discussion

The main aim of this scoping review was to shed light on modern training methods that have demonstrated effectiveness in enhancing the unique performance attributes of professional basketball players, based on an understanding of the energy systems activated, movement patterns used, and the cognitive demands in basketball as an open-skill sport. Through an extensive review of field-based practices and scientific research, seven specific training methods have been identified and analyzed: plyometric training, sprint training, specific training, contrast training, complex training, MCT, and CMDT. Other training methods, such as strength training methods in the gym and methods that place greater emphasis on secondary physiological systems in basketball (ie, the aerobic and glycolytic energy systems) were not reviewed. Instead, the methods that we focused on primarily emphasize anaerobic alactic fitness variables, often involving short, explosive high-intensity efforts in combination with additional sport-specific elements.

CMDT has not been explored sufficiently in the context of basketball training, and the only studies that did so looked into CMDT combined with MCT rather than CMDT combined with other advanced training methods. A recent study that looked into the integration of cognitive components within MCT in professional basketball players revealed promising results (Lucia, Digno, et al., 2023). The study compared MCT training with and without CMDT training, and found that players who trained with CMDT using interactive devices showed significant improvements in sprinting, agility, and decision-making speed, compared to those who trained with MCT alone. The superior performance detected in the experimental group who engaged in CMDT was likely due to increased cortical plasticity stimulated by the cognitive tasks (Lucia et al., 2021; Lucia, Digno, et al., 2023). A study that examined the differences between the contrast training method and the sprint training method reported significant differences in performance in favor of the contrast training method (Cormier et al.,

Table 2 Principles of training methods and exercises

Method	Goals	Exercise examples
Plyometric training	Improve player's proficiency in explosive maneuvers involving stretch-shortening cycle, such as rebounding, rapid sprints, and change of direction movement	Box jumps Tuck jumps Depth jumps Bounding
Sprint training	Increase the recruitment of fast-twitch fibers responsible for explosive movements Enhance the efficiency of neuromuscular coordination Improve cardiovascular capacity and lactic acid tolerance[a]	Linear maximal effort sprints or game scenarios (fast breaks and defensive transitions)
Specific training	Mimic the dynamic nature of in-game scenarios with game-specific movements to enhance technical skill and physical performance	Shuttle runs and cone drills (designed to simulate defensive slides, offensive cuts, and transition movements) Incorporating ball-handling or passing elements during these drills (further replicates the multi-tasking demands of actual gameplay)
Complex and Contrast training (post-activation potentiation)	Elevate neural drive and increase recruitment of muscle fibers, thereby enhancing the execution of subsequent explosive movements	Heavy strength exercise (back squat above 80% one-repetition maximum) followed by explosive power exercises (counter movement jump)
Multi-component training	Incorporate multiple exercise modalities within a single training session, aiming to simultaneously enhance physical fitness, technical skills, cognitive performance, and overall athletic performance	Agility drills Balance exercises Plyometrics Strength training circuits and Sport-specific skill drills in the same practice
Cognitive-motor dual-task training	Integrate technical, physical, psychomotor, and mental components within a single training session	Dribbling drills combined with cognitive tasks such as responding to verbal/visual cues or solving mathematical problems Responding to light color and performing several dribbling hand changes (i.e., crossover, between legs or between legs + behind back) depending on the target color

Note. [a]If recovery is limited via repeated sprints.

2020; Mujika et al., 2009). While both methods are effective, when the goal is to enhance explosive power specific to basketball, complex training is more likely to be chosen due to its superior efficacy in this area (Cormier et al., 2020).

Among professional youth basketball players aged 15 to 17 years, these findings underscore the potential benefits of integrating CMDT with MCT, highlighting its ability to foster both physical and cognitive development within a relatively short training period (Lucia, Digno, et al., 2023). This observation aligns well with the in-depth analysis of basketball-specific demands presented throughout this review. Unfortunately, the limited number of studies on CMDT/MCT integration currently available restricts the possibility of conducting a meaningful thematic analysis at this stage.

Although the review emphasizes the importance of integrating CMDT/MCT into basketball training, it is important not to overlook the potential value of other advanced training methods discussed. There is a clear need to further investigate CMDT-based combinations not only with MCT, as explored so far, but also with other evidence-based methods that have demonstrated effectiveness in enhancing basketball performance. At the same time, it is important to note several limitations that also apply to the original studies included in this review. In competitive sports, and particularly in basketball, conducting large-scale studies is difficult due to tight schedules and the demanding nature of professional competition, especially at the elite level among adult players. Such research is more feasible in youth settings, though still limited when involving elite-level athletes. In addition, studies in this field often require considerable time, which may interfere with training and competition preparation. Another limitation concerns the availability of technology and practitioners with applied expertise, which can limit both research and practical applications. It should also be noted that while most included studies explicitly reported receiving ethical approval and informed consent from participants (and parents when relevant), some did not provide such details, and it was assumed that standard institutional protocols had been followed. Despite these challenges, progress in the field depends on ongoing efforts, and leading researchers and coaches are actively working, especially on developing innovative training methods to improve performance in the areas covered by this scoping review.

Practical applications and future research lines

Basketball requirements have led strength and conditioning coaches, exercise physiologists, biochemists, and sport researchers to develop special preparation procedures for training and competitions (A. Hammami et al., 2017; Stojanović et al., 2023; Vretaros, 2023). These procedures aim to optimally prepare players for the specific and unique performances highlighted in this scoping review by incorporating elements such as PAP, sprints, and specific movements (Cormier et al., 2020; Docherty & Hodgson, 2007; Gołaś et al., 2016; Gottlieb et al., 2014). MCT, in particular, integrates seamlessly in the preparatory phase of basketball training (Brunner et al., 2019; Stojanović et al., 2023).

CMDT combined with MCT offers a novel and comprehensive basketball training approach, effectively covering a wide set of specific and unique components that are required within a short and inclusive timeframe.

To the best of our knowledge, the specific combination of elements from MCT and CMDT has not yet been directly tested as part of a warm-up routine for basketball training or competition. Given the positive results shown in this review, future research should explore how using

MCT and CMDT during warm-up may influence players' readiness, both physically and mentally. This could include comparing these methods to standard warm-up routines and may provide practical recommendations for improving pre-performance preparation. Furthermore, considering the unique physical and cognitive demands of basketball as an open-skill sport, it would be useful to investigate how CMDT can be combined with other effective training methods reviewed in this paper. It is essential that upcoming research not only examines such combinations but also considers differences between age groups, genders, and playing positions, as well as compares professional and non-professional basketball players. This could help create more complete and targeted training methods that support the specific needs of professional basketball players.

Although the methods presented in this scoping review have been shown to be effective for improving basketball performance, as training is an art, we suggest that coaches and practitioners are not confined to a single method. Instead, creative integration of multiple methods can be applied while maintaining core principles and combining field experience with the existing literature, including the application of updated research in the field to guide method integration and adaptation. This approach should always consider individual adaptations for players with injury histories or inadequate training backgrounds and is particularly important when coaching heterogeneous groups, as is often the case in basketball teams. In other words, the selection of appropriate training methods should be a strategic decision, tailored to the specific needs and contexts of players. By leveraging the advantages of each method and considering the recent research findings, coaches can optimize training programs to enhance the overall performance of basketball players. The ongoing exploration and adaptation of these training techniques will be essential in meeting the evolving demands of the sport.

Importantly, while the scientific literature increasingly underscores the importance of adapting training methods to the specific demands of each sport, this scoping review did not identify any studies that incorporated background noise as a variable within training environments despite its increasing relevance to competitive basketball. Crowd noise, a specific form of background noise common in competitive basketball settings, naturally occurs across all levels of play and may significantly influence both cognitive and physical performance under pressure. The distractions it creates mirror the dynamic and often unpredictable nature of real-game scenarios, and therefore, crowd noise represents an important, yet underexplored, dimension in the pursuit of training specificity. For this reason, incorporating distractions in training methods may offer a novel research direction that contributes to achieving higher training specificity and improving alignment with real competitive conditions.

Lastly, the impact of combining training methods, as discussed in this review, should be explored in other ball games, particularly those classified as open-skill disciplines. Applying comparative analysis across different ball games may generate practical insights for training design and transferability. Preparation before training and competition is also a critical phase, and the use of CMDT as part of warm-up protocols represents a promising avenue for future investigation.

Conclusions

This scoping review mapped advanced, evidence-based training methods in basketball, focusing on the integration of physiological and psychomotor components. Taken together, the evidence indicates that CMDT combined with MCT offers a novel and comprehensive approach that addresses the sport's specific and unique demands. While the current evidence base is limited and heterogeneous, this review offers a foundation for the continued development of advanced training methods within an integrative framework and the formulation of innovative future research directions. These efforts should be aligned with the latest scientific advancements and integrated with real-world applications in order to promote a deeper, more tailored, and relevant approach to basketball-specific and unique training programs.

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Conflict of interest

The authors report no conflict of interest.

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Appendix

Table A1 Articles included in the scoping review

Article	Article type	Population	Key information extracted
Cormier et al. (2020)	Systematic review and meta-analysis	Team sports	An in-depth understanding of the post-activation potentiation mechanism, with a focus on contrast training and complex training in team sports, and their contribution to enhancing athletic performance
Fang and Jiang (2024)	Randomized controlled trial	Basketball	An in-depth understanding of sprint training methods in basketball
Gottlieb et al. (2014)	Original research	Basketball	An in-depth understanding of training methods aimed at enhancing basketball performance, with a focus on comparing plyometric training methods to sport-specific training methods
Gottlieb et al. (2021)	Review	Basketball	An in-depth understanding of the physiological energy systems in basketball
Lucia et al. (2021)	Original research	Basketball	An in-depth understanding of the importance of cognitive demands in basketball as an open-skill sport
Lucia, Digno, et al. (2023)	Original research	Basketball	An in-depth understanding of the multi-component training and cognitive-motor dual-task training methods and the effectiveness of their combined implementation in training
Ramirez-Campillo et al. (2022)	Meta-analysis	Basketball	An in-depth understanding of the importance of implementing sport-specific training
Shalom et al. (2023)	Narrative review	Basketball	An in-depth understanding of the dominant physiological energy system in basketball and the unique, sport-specific demands placed on basketball players
Shalom et al. (2024)	Original research	Basketball	An in-depth understanding of the uniqueness of basketball in the context of movement demands, comparisons between male and female players, and differences across playing positions
Song et al. (2023)	Original research	Basketball	An in-depth understanding of straight-line sprint training and sport-specific training, emphasizing the importance of applying the principle of specificity to basketball