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REVIEW ARTICLE

Approaches on physiological changes in the performance of elite female basketball players: Literature summary

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ABSTRACT

The international level of elite women's basketball is in great contrast with the Albanian reality regarding the sports performance of the players. The purpose of this literature review is to focus on physiological changes in sports performance during a season in elite female basketball players. Methods: This literature review used a structured methodology to examine the impact of different training loads on the physiological responses of elite female basketball players over 20 years of age during a season. To collect the data for our study, 4 bibliographic databases (PubMed, Scopus, Web of Science and Pro Quest) were used using the Jab Ref program. According to a hybrid of sports scientific methods, we found 60 scientific articles that matched our requirements, integrating anthropometric analysis, body composition, strength tests and speed tests. Conclusions; At the end of this literature review, a more in-depth understanding of the complex effects of training loads on physiological responses and sports performance in female basketball players during competitive sports seasons has been formed. It is for you emphasized the lack of studies on elite women's basketball in Albania in performance evaluation.

Keywords: Female basketball, Elite, Physiological responses, Performance.

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INTRODUCTION

Elite women's basketball has experienced a significant increase in global attention, posing a continuous challenge for coaches and training staff to enhance player performance throughout a season. However, there is a stark contrast between the demands of competitive activities in elite European women's basketball competitions and the reality in Albania. Limited studies provide statistics on elite women's basketball teams in the Albanian National Championship, analysing anthropometry, physiological requirements, and the level of performance of elite female basketball players in Albania compared to their international counterparts. Research on basketball indicates that players tend to be taller and heavier, with higher levels of athletic performance. The game has become more strategic due to the development of teams with multiple offensive plays and sophisticated defence strategies (Calleja-González et al., 2015). One particular aspect influencing differences in body height among athletes from different parts of the world is genetics, where certain anthropometric and body composition characteristics of players are linked to specific population characteristics of a particular geographic region. Genetics also influence the anthropometric characteristics of players, which can be associated with athletic performance (Leonardi et al., 2018). Many studies in basketball refer to body composition assessed using sophisticated equipment such as the BodPod. According to authors (Gibson et al., 2009), changes in body composition during a sports season are reported, highlighting the importance of assessing body composition as a key component of physical abilities and high metabolic demands. In basketball, a player's body size largely determines their position on the team (Carling & Orhant, 2010). Berdejo-del-Fresno (2013) analysed body composition among elite British female basketball players and found that they had lower fitness levels and body composition values compared to women's basketball teams from countries where basketball is more popular and developed, possibly due to significant differences in the number of training hours per week.

Basketball is characterized by fast and repetitive movements that require both aerobic and anaerobic energy systems to perform various physical actions such as displacements, jumps, sprints, changes of direction, technical and tactical executions throughout the game, according to authors (Abdelkrim et al., 2010; Metaxas et al., 2009). With the increasing demand for optimal sports performance in basketball, different researchers are constantly trying to discover new ways to gain a competitive advantage, leading to significant advancements in the field of basketball science, as stated by Huyghe et al. (2022). In recent years, exercise physiology research has emphasized the physiological characteristics and differences between females and males, where it has been reported that female basketball players aged between 18 and 32 years have anthropometric and physical parameters linked to sports performance, according to García-Gil et al. (2018). Considerable differences in the analysed variables based on age and gender of athletes have been shown by Mancha-Triguero et al. (2020), mainly due to factors related to natural maturation and anthropometric development at different ages, which influence the efficiency and technical and tactical demands of the performed tests and, consequently, the results obtained from the tests. The authors Vaquera et al. (2015) indicate that the anthropometric characteristics of elite basketball players significantly contribute to their profiling as professional athletes and play a crucial role in the selection process, as these characteristics can have a significant impact on performance. Similarly, García-Gil et al. (2018) demonstrate that certain anthropometric and physical fitness characteristics of female elite basketball players are associated with parameters related to sports performance.

Various studies aim to explore the impact of different training loads on physiological responses and sports performance in elite female basketball players during a season. In the context of basketball, a player's training preparation throughout the different phases of a season has a significant influence on the development of physical abilities, tactics, and emotional resilience of the players (Bali, A. 2015). In this context, analysing

training loads is critical to understand how training adapts to the diverse demands of a basketball season, as stated by (Petway et al., 2020). As knowledge advances regarding the periodization of physical loads, it has been observed that periodized training in team sports is of great importance and is a concept that all coaches should be familiar with. The beginning phase of the season is characterized by a relative interruption after the rest and rehabilitation period following the previous season. Studies have shown that careful preparation during this phase can improve fundamental abilities, including basic strength, flexibility, and overall body capacity, according to (Luo et al., 2023). During this time, it is important for coaches to utilize training preparation methods that enhance the foundations of physical abilities, including elements of rehabilitation in case of possible injuries, as indicated by (Bahir et al., 2023). In the mid-season period, when the intensity of the game increases, it is necessary to adapt training programs to address tactical challenges and high game loads. Additionally, it is important to monitor physiological responses during this phase, including heart rate, oxygen consumption, and acidity levels, to ensure continuous adaptation to the game's demands. Authors (Ladwig et al., 2013) have shown changes in body fat percentage before and after a sports season, with an average decrease in BF% of -1.83%, indicating a significant correlation between having a low BF% and game time. As the season approaches its end, where the importance of each match increases, coaches must pay attention to fatigue management and adjust the training program. Carefully managed training loads can influence performance improvement during the peak period of the season, according to (Sansone et al., 2021). Additionally, it is important to consider off-field factors, such as the impact of psychological stress and players' health aspects, as indicated by (Bauman, 2015).

Thus, monitoring each training period provides the coach with relevant information when planning a match, resulting in a positive relationship between improved physical ability and better performance of the athlete in the game, as shown by McGill et al. (2012). To optimize performance in women's basketball, it is necessary to respect the principles of sports training, such as individuality and specificity, as highlighted by Mancha-Triguero et al. (2020). Studies have demonstrated that a carefully tailored program, focused on developing core muscles and motor coordination, has influenced the enhancement of necessary skills for good basketball performance (Luo et al., 2023). Research has observed that incorporating game situations during training, including tactical meetings and improvised scenarios, has aided in the development of tactical awareness and the ability to make quick decisions on the field (Mancha-Triguero et al., 2020; Gabbett et al., 2009; Scalan et al., 2014). In conclusion, this literature review provides a comprehensive understanding of the impact of different training loads on physiological responses and sports performance in elite female basketball players during a season. The results of this analysis offer a solid foundation for the development of personalized training strategies, thereby improving the preparation and performance of players at the highest levels of competition. To achieve this goal, it is important to continue studying and researching in this field, including other aspects.

METHODS

Is used a structured methodology to examine the impact of different training loads on the physiological responses of elite female basketball players during a season. The study integrates various methods from sports science, including anthropometric measurements, body composition analysis, strength tests, and speed tests. The research focuses on monitoring the physiological responses during training and competition at different levels of competition.

The study identified relevant scientific articles using databases such as PubMed, Science Direct, Google Scholar, Scopus, and Web of Science. The selected articles primarily focused on elite female basketball players and explored the aspects of training loads, physiological responses, and performance within the

context of a season. The data from the selected articles were analysed, categorized, and grouped based on common themes and key aspects to facilitate comparisons and synthesis.

The extracted data included anthropometric characteristics, body composition, strength test protocols (such as squat jump, countermovement jump, drop jump 40cm, and explosive force endurance test), and speed tests (such as the 505 Agility Test, Illinois Agility Run Test, and 20m shuttle run VO_2). The structured methodology aims to provide a comprehensive and accurate analysis of the impact of training loads on the physiological responses of elite female basketball players during a season. This hybrid approach will enable a precise assessment of player performance, assist in the development of personalized training protocols, and enhance their performance at the elite level. Through the literature review, it has been evident that previous studies and analyses have provided a clear understanding of the impact of training loads on the physiological responses of elite female basketball players. The following section will present some of the key findings obtained through the analysis of the selected literature.

RESULTS

From this selection process of scientific articles that we identified through database searches (keywords) and that were reviewed based on titles, abstracts and full studies, we focused on considering only 60 studies for the full evaluation of eligibility according to our criteria. Table 1 presents the details of all the processes and results obtained from the search strategy for this literature review for each of the categories analysed and that were adapted to the data on the physiological changes of sports performance during the sports season in elite female basketball.

Table 1. Results of literature review.

Analysed Category Estimated Parameters	**Author, Year of Publication Title of the article**	**Key Findings**
Anthropometry Body Height (cm) Body Weight (kg) Body Composition (%)	***(Miguel-Ortega et al., 2023)*** "Comparison of sports performance and anthropometric profiles of elite female basketball and volleyball players during a competition".	Lean body mass is an important predictor of exercise performance intensity. Excess fat mass is detrimental to the development of strength and endurance.
	(Bravo et al., 2021) "Anthropometric analysis of an elite women's basketball team during the first half of a regular season".	The results show a favourable anthropometric evolution, in contrast to the fact that the main anthropometric changes occur during the regular season.
	(Drinkwater et al., 2008). "Design and interpretation of anthropometric and fitness tests of basketball players".	A battery of specific physical tests can be used to assess body composition, aerobic capacity & strength, practical methods of interpreting changes between players have been identified, to assess the effectiveness of training programs
Force, Speed, Vertical Jump Squat Jump (SJ) (cm) Countermovement Jump (CMJ) (cm) (DJ40cm) (cm) T drill agility test Drop Jump 40cm	***(Alemdaroğlu, 2012).*** "The relationship between muscle strength, anaerobic performance, agility, sprint ability and vertical jump performance in professional basketball players".	Positive correlation between explosive strength and speed on the field. Players with a higher CMJ tend to have high court speeds. Performance in explosive strength tests is related to speed and manoeuvrability. Players with a higher CMJ tend to have high court speeds.
	(Lleshi, 2019). "Plyometric assessment of women's basketball-volleyball performance".	Through the Drop Jump test, it is possible to evaluate high and low performances not only from the height of the vertical jump development but also from the phase of staying in the air

Speed, Agility, Jump 505 Agility Test (s)	***(Horníková & Zemková, 2021).*** "The relationship between physical factors and variation in running speed in team sports".	It showed the relationship between CODS and linear sprint speed, jumping ability and muscle strength. CODS correlated significantly with sprint time for 10 m, 20 m, and 30 m, but not with time for the shortest sprint (5 m).
	(Sugiyama et al., 2021). Change of Direction Speed Tests in Basketball Players: A Brief Review of Test Varieties and Recent Trends".	The results suggest that while CODS performance in basketball players is studied with different tests, recent studies give equal weight to the three types of tests characterized by cutting-type incremental adaptation to assess CODS-specific performance.
Illinois Agility Run Test (sec)	***(Vescovi & McGuigan, 2008).*** "Relationships between sprinting, agility and jumping ability in female athletes".	The results suggest that sprinting, agility and jumping ability are common physiological and biomechanical determinants. The findings of the study show a significant relationship between jumping ability and agility performance and sprint time in young basketball players
20 m Shuttle Run VO_2 (s)	***(Stanković et al., 2023).*** "Effects of high-intensity interval training (HIIT) on physical performance in women's team sports: A systematic review.	HIIT has significant effects on VO_{2max}, RSA, and change in running speed, speed and explosive strength in women's team sports regardless of competition level.
Physiological Adaptation Heart Rate in jump (bpm)	***(Batalla-Gavalda et al., 2023).*** "A new database of the analysis of physiological needs in amateur women's basketball during official matches".	High heart rate levels have been associated with better fitness in intense dance training sessions.
	(McInnes et al., 1995). "Physiological load placed on basketball players during the competition".	In this study, it was concluded that through the analysis of heart rate data, coaches can identify the intensity and duration of physical activity during games, enabling the development of more effective training programs.
Oxygen Consumption (VO_{2max})	***(McInnes et al., 1995).*** "Physiological load placed on basketball players during the competition".	Basketball players with a high VO_{2max} tend to have an improved capacity to sustain the high intensity of the game. The study concludes that the physiological demands of soccer players are high, placing significant demands on the players' cardiovascular and metabolic capacities.
The yield of Metabolism Anaerobic Lactic Acidity (mmol/L)	***(Norkowski, 2002).*** "Anaerobic power of handball players representing different sports levels".	High levels of lactic acid are associated with actions and the ability to perform intense efforts.
Motor Ability Vertical Jump (cm)	***(Shalfawi et al., 2011).*** "The relationship between running speed and vertical jump measure in professional basketball players: a field test approach".	The results of this study show that while there is a strong and pronounced relationship between the 10-, 20-, and 40-m sprints, there is also considerable variation in the factors that contribute to performance at these distances. This may indicate that specific training strategies can be implemented to improve running speed over these distances.
Motor Coordination	***(Chaouachi et al., 2009).*** "Maximum dynamic strength and determinants of lower limb agility in elite basketball players".	A significant negative correlation was observed between the performance of the t-test and the 5-jump test ($r = -0.61$, $p = .02$). Squat 1RM was significantly related to 5-, 10-, and 30-m sprint times.
	(Šalaj & Marković, 2011). "Specification of the motor skills of jumping, sprinting and changing the speed of running".	Stepwise correlation analysis showed that body fat percentage was the single best predictor ($p < 0.05$) of agility. Squat 1RM performance was the single best predictor of 5-m and 10-m sprint times ($p < 0.05$). In light of the findings of the current study, flexibility should be considered a physiological ability in itself for elite basketball players.

Stability and Body Strength Plank Fitness Test	***(Cronin & Hansen, 2005).*** "Predictors of Strength and Power in Sports Speed".	It was suggested that improving power-to-weight ratio as well as plyometric training involving countermovement and loaded jump-squat training may be more effective for increasing athletic speed in elite players.
	(Bissas & Havenetidis, 2008). "The use of different power tests as predictors of sprint running performance".	The present findings suggest that the ability to produce force quickly, as measured by the time to reach 60% of maximal voluntary contraction, is related to running performance, with the coefficient of determination accounting for 53% of the variance. These data also show that sprinting ability is related to DJ performance, particularly in the 30 cm drop jump. It is suggested that the above tests may be useful in preparing and testing sprint ability.
Leg Muscle Strength	***(Young et al., 2011).*** "What jumping variables should be used to assess explosive leg muscle function?"	The results show that if an integrated system including a position transducer and a force platform is available for CMJ assessment, jump height and peak power/weight are useful variables to describe explosive leg muscle function for athletes performing sprint.

DISCUSSIONS

The discussion of the data in this literature review can focus on several main themes that arise from the results of the included studies. This discussion will be based on anthropometric data, strength, speed, physiological adaptation, and body stability and strength. Based on these key points, the data from the articles included in this literature review are presented as follows:

Anthropometry and evolution throughout the season

According to the study by Miguel-Ortega et al. (2023), positive results were shown in anthropometric evolution during the season, focusing on female basketball and volleyball players, resulting in changes in body composition throughout the season. Similarly, the study by Bravo et al. (2021) focused on the initial analysis of a specific period of the sports season, where there may be variations in anthropometric characteristics compared to the previous study by Miguel-Ortega et al. (2023). The study by Drinkwater et al. (2008) focuses on the design and interpretation of anthropometric and physical fitness tests in basketball players and provides recommendations for the use of anthropometric tests in the training of basketball players.

Explosive strength and speed

The study by Alemdaroğlu (2012) demonstrates a positive relationship between explosive strength and speed on the field, where the Countermovement Jump (CMJ) test is used as one of the key indicators for explosive strength, and it is found that players with higher CMJ tend to have higher speed. The study by Lleshi (2019) also reported that tests of explosive strength are used to assess the performance of female basketball and volleyball players, which is related to speed and jumping ability.

Speed and jumping ability

According to the study by Horníková & Zemková (2021), there is a relationship between the 505 Agility test and linear sprint speed, which aims to determine the relationship between physical factors and speed in basketball. Similarly, the study by Sugiyama et al. (2021) shows the connection between change of direction speed (CODS) and sprint speed, including an analysis of trends and the use of various tests to assess

CODS performance. According to Pojskić et al. (2015), their study concluded that strength and aerobic and anaerobic capacities can be good differentiating variables among players with different roles based on positions.

Physiological adaptation

Analysis of heart rate during official female basketball games according to the authors (Batalla-Gavalda et al., 2023) has led to the identification of high levels of heart rate and fitness during intense dance sessions. The possibility of identifying the intensity and duration of physical activity during games has also been reflected by the authors (McINNES et al., 1995) in the analysis of the physiological demands of basketball during competitions as well as the yield of anaerobic metabolism, and they determine that the metabolic demands are high in basketball. The study of (Norkowski, 2002) argues that aerobic and technical potential as well as tactical ability are also important for the quality of a team where motor adaptability and motor coordination are also needed. Strong correlation between sprint speed and jump height has been shown in the authors' study (Shalfawi et al., 2011) in the use of jump and speed tests in the preparation and testing of sports speed. But according to the authors (Chaouachi et al., 2009) a negative correlation is shown between the performance in the Plank test and the ability to perform sprint times, which includes the analysis of factors that contribute to jumping and sprinting performance. According to the authors (Plasa & Koci, 2023) in a study with the National women's team in Albania, it was concluded that the RAST test (Running Anaerobic Sprint Test) is an excellent indicator of measuring hyper lactate and through it anaerobic performance is evidenced. The most common demand analysis in basketball has been internal load analysis through heart rate and subjective scales and external load analysis by time motion analysis according to the authors (Reina et al., 2020). Physiologically, the body's responses to training loads vary across the phases of the season. Studies have identified changes in heart rate, oxygen consumption and muscle acidity during intense exercise (Montgomery et al., 2010). Off-court factors, including nutrition, environmental influence and psychological stress, are also essential for the preparation and performance of female elite basketball players according to (Stojanović et al., 2017). (Cronin & Hansen, 2005)'s study focuses on strength and speed predictors and proposes that improving power-to-weight ratio and plyometric training may be more effective. The authors (Bissas & Havenetidis, 2008) in their study propose that performance in the 5-jump test is the best predictor of 5-m and 10-m sprint times.

Training loads

The control and monitoring of the training load requires scientific information for the creation of different protocols to evaluate sports performances. Testing and monitoring the skills and performance of players can have multiple purposes, but we need to evaluate the effectiveness of training programs or monitor actual levels of sports performance. In our framework, knowledge gaps have appeared in the analysis of training load, body composition and fitness level in elite women's basketball in Albania, so a proper assessment and periodization of training loads are essential in the development of sports performance. Analysis of internal and external load by means of a test of anaerobic and aerobic capacities is not a common practice for players in the training phases. Recently, there has been an increase in interest in the management and monitoring of internal and external loads to reduce the risk of injury and improve sports performance according to (Weiss et al., 2017). There are two types of loads: (1) external load, or the amount of work done in a period of time or period of activity, and (2) internal load, or the psycho-physiological response to the external load. Rating of perceived exertion (RPE) has emerged as a widely used method for monitoring workload in several team sports according to (Bourdon et al., 2017) including basketball (Russell et al., 2020). On the other hand, the internal load depends on the internal psycho-physiological factors of the athlete, such as motivation, stress, fatigue, cognitive capacity, age, gender, sports experience and physical condition. Monitoring internal loading in basketball can be used to understand the effects and possible

physiological adaptations caused by external loading. McLaren et al. (2017) report that measures of internal load derived from perceived exertion and heart rate show consistent positive associations with external loads and intensity derived from running and accelerometer during training and competition in team sports, but the magnitude and uncertainty of these relationships depend on the amount and method of training. Monitoring training loads in basketball is particularly important within team members as different individuals respond in different ways to training sessions, which involves quantifying external and internal load. External load monitoring presents one of the most unique challenges due to the cost and accessibility of methods commonly used in other team sports according to a review by (Fox et al., 2017). Many tests are used for selection methods and procedures, to screen candidates, or to monitor the effectiveness of training programs by (Norkowski, 2002). According to (Legg et al., 2017) that aimed to quantify changes in jump performance and variability in elite female basketball players, it shows that in-season loads not only impair jump performance, but also movement variability in basketball players. De Freitas Cruz et al. (2018) showed that the results of the study highlight the importance of using a comprehensive and multivariate approach to effectively monitor the physical performance of young athletes. The RAST was also used to assess anaerobic fitness exclusively in professional players, prohibiting the ability to compare performance between levels of competition. Insufficient studies were noted to draw conclusions regarding positional changes in RAST performance in basketball players. According to the authors (Plasa & Koci, 2023) in a study with the National women's team in Albania, it was concluded that the RAST test (Running Anaerobic Sprint Test) is an excellent indicator of measuring hyper lactate and through it anaerobic performance is evidenced. Monitoring fitness at each training session provides the coach with relevant information when planning a competition, with a positive relationship then existing between better fitness and better athlete performance in competition (McGill et al., 2012). . It is important to identify what are the obstacles encountered in cargo monitoring so that practical solutions can be found to alleviate the needs of practitioners according to (Fox et al., 2019). Assessment of players' physical fitness during an entire basketball season allows monitoring the effectiveness of conditioning programs and quantifying changes in player fitness status at different stages of the season (Drinkwater et al., 2008). The greatest improvement in the physical fitness of athletes usually occurs during the preparation period, when players begin to perform a physical activity after a relatively long period of complete or almost complete rest (Hoffman, 2000). Despite the fact that the preparatory period represents a crucial phase for optimizing the performance of athletes, information about the appropriate level of load and training, in the volume and intensity that they are carried out during this period, the relationships between the training load and changes in the fitness levels of players is limited, they have not yet been researched in elite women's basketball in Albania.

CONCLUSIONS

This literature review provides a rich perspective on the factors that influence the sports performance of elite female basketball players. However, it is important to note that discontinuities and variations between studies may be the result of a variety of factors, including initial skill levels, training methods, and seasonal conditions. All of the aforementioned findings play an important role in the ongoing research of elite women's basketball. This review collects a good portion of the tests and outcome variables used to assess the physical characteristics of basketball players in the literature to date. The number of tests and outcome variables identified confirm that a test battery is needed for the assessment of physical characteristics of basketball players. Training that focuses on body strength and stability can be important for improving their performance. The development of test batteries at the level of elite female basketball in Albania would enable the longitudinal evaluation of players and the establishment of minimum physical standards for playing positions and levels of competition. Evaluation methods often change in relation to the new technologies used. Given the limited amount of research in elite women's basketball that assesses physical parameters of sport

performance: further research is needed to explore potential differences between players across playing positions and levels of competition to develop efficient testing and training-based scientific research. In conclusion, load management in basketball requires a scientific approach to evaluate and analyse the internal and external load of players for the development of analytical evaluation protocols. For more, there is a need for updated research that includes studies on female players, given the growing interest in women's basketball.

AUTHOR CONTRIBUTIONS

The contribution to this review is joint, where Salvator Kurti is a PhD candidate and Enkeleida Lleshi is her scientific leader.

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