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Nutrition-related considerations for health and performance in female basketball players: a narrative review

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Abstract Basketball is a popular team sport worldwide. Nutrition is one of the key aspects for the optimization of performance and subsequent recovery. Female athletes have unique nutritional requirements as a result of daily training and competition, in addition to the specific demands of gender-related physiological changes. However, inadequate, or erroneous nutritional behaviours are commonly observed. Thus, the aim of our work is to provide concise nutritional recommendations for female basketball players. Based on a review of the literature, there is limited evidence that comprehensively assesses health attributes as well as behaviours, habits, and nutritional knowledge of physical activity by gender in basketball players. Recent research highlights the need for nutritional strategies to develop tools to help manage energy deficiency in women's sports. We suggest that individual adjustment of dietary energy value is the key factor in the physical performance of female basketball players; information that could be used to optimize the training process and health maintenance. The recommended intake for athletes involved in moderate levels of training, such as elite basketball players (2-3 h/day for 5-6 times/week), is 50-80 kcal·(kg·day)$^{-1}$, with specific recommendations of 1.6-1.8 g·(kg·day)$^{-1}$ protein. For physically active women, it is recommended that 1.2-2 g·(kg·day)$^{-1}$ of protein be consumed, with fat intake of 20-35% of total kilocalories and 5-8 g·(kg·day)$^{-1}$ of carbohydrate to adequately meet performance demands.
Keywords : basketball, women, nutrition, health, team sport

Introduction

Team sports and, in particular, basketball, present characteristics of high (Mouche, 2022)[1)] intensity activities of an intermittent character that require very intense movements and technical gestures of great specificity, interspersed with moments of active and passive recovery (Scanlan et al., 2015[2)]; Calleja-González et al., 2016[3)]; Stojanović et al., 2018[4)]), which, in turn, require players to adequately develop a strong physical condition for successful performance on the court (Castillo et al., 2021)[5)]. In this sense, an analysis of physical condition (Mancha-Triguero et al., 2019)[6)] is important in the training process to detect deficits in players and, consequently, to prescribe appropriate training strategies (Mancha-Triguero et al., 2019)[6)].

Performance of this type of action involves resynthesizing ATP in the muscle fibre predominantly by anaerobic means, involving existing glycogen (Elliott-Sale et al., 2021)[7)] reserves. This resynthesis has to be supported by adequate nutritional strategies so that the energy needs of athletes are covered (Burke et al., 2006)[8)], a demand that needs to be known on an individual basis since a continued energy deficit could result in various physiological alterations, compromising the health and performance of the athlete (Holway & Spriet, 2011)[9)]. Unfortunately, there is a lack of research specific to women in basketball, leading to a potentially incorrect transfer of findings from male studies to female athletes (Costello et al., 2014)[10)]. In turn, these energy needs are reflected in the work performed by the athlete, irrespective of their internal characteristics (Wallace et al., 2009)[11)].

A study by Stojanović et al. (2018)[4)] found that, during a game, a female basketball player runs approximately 5-6 km, with blood lactate concentrations of 2.7-6.8 mmol/l, at an average intensity of 85% of maximum heart rate and performing a total of approximately 750-2,750 actions. Concerning energetic level, basketball is often played at intensities above the "maximum lactate steady state" (MLSS) (Gualdi-Russo & Zaccagni, 2001)[12)]. In relation

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to this aspect, Dragonea et al. (2019)[13] have concluded that elite basketball athletes have an MLSS (physiological variable that measures aerobic physical condition) with an average heart rate equal to 88% of the maximum heart rate. This would be the maximum work intensity at which the blood lactate concentration remains stable, with an average concentration of 3.7 mmol/l. Although anaerobic metabolism is quantitatively much lower than aerobic metabolism, it is decisive in phases of high/maximal speed running. In this situation of high physiological demand (Gualdi-Russo & Zaccagni, 2001)[12], marked by an insufficient supply of oxygen to the muscle, anaerobic metabolism (anaerobic glycolysis) represents an essential means of maintaining ATP resynthesis, for which it is essential to have a well-supplied storage of glycogen (Escribano-Ott & Ibáñez-Santos, 2020)[14]. A study of the types of actions performed by players during basketball games using video analysis and global positioning technology with accelerometers and gyroscopes puts the energy expenditure of a basketball game at least 8 metabolic rate (MET) (Scribbans et al., 2015)[15] units, with players performing between 750 and 2,750 individual actions of an explosive nature (Gualdi-Russo & Zaccagni, 2001)[12]. Thus, a European League or Endesa League game will involve an energy expenditure of approximately 10.5 kcal/min (Salgado-Sánchez et al., 2015)[16] in the case of a 75 kg player. This fact should be taken into account in the planning of typical seasonal training and its subsequent application to competitive performance (Delextrat et al., 2012)[17].

If female athletes follow general nutritional advice in their diet, it has been shown that up to 47% of them will be at risk of having an inadequate calorie intake for their needs (Bratland-Sanda & Sundgot-Borgen, 2013[18]; Ackerman et al., 2019[19]). In addition, we must consider the menstrual cycle as a uniquely female physiological process that causes predictable (but inconsistent) hormonal alterations in female athletes and has contributed to researchers' reluctance to design specific studies for women (Elliott-Sale et al., 2021)[7]. Therefore, the purpose of this paper is to provide concise nutritional recommendations for women who play basketball at a competitive level.

The fact that no two matches are the same creates additional difficulties for scientists trying to establish personalized (Jeukendrup, 2014)[20] nutritional strategies to increase athlete performance and maintain health, so it is necessary to create a standard scenario in which to measure the conditions of exertion (Hopkins et al., 1999)[21]. In addition, much of the information obtained in team sports is drawn from studies with exercise protocols that do not resemble real competition (American Academy of Pediatrics, 2000)[22].

Methods

Sources of information. This article is a narrative review focusing on nutrition-related considerations for health and performance in female basketball players.

The review was conducted following the Preferred Reporting Items for Systematic Review and Meta Analyses (PRISMA) guidelines (Liberati et al., 2009)[23]. A structured search was conducted in WoS (Web of Science), PubMed, SciELO Citation Index, MEDLINE, Current Contents Connect, KCI-Korean Journal Database and Scopus.

Study inclusion and exclusion criteria. The PICOS model was used to determine the inclusion criteria referred to by O'Connor et al. (2008)[24]: P (Population): "female basketball players", I (Intervention): "nutrition and health", C (Comparators): "identical conditions for experimental trials", O (Outcome): "nutritional intake", and S (study design): "randomised controlled design".

Accordingly, the studies included in this systematic review had to meet the following inclusion criteria (I) study population consisted of female basketball players; (II) articles examined nutritional intake and health; and (III) study designs were randomized.

The following exclusion criteria were applied to the experimental research protocols: (I) studies conducted with participants who had some type of previous disorder, (II) articles pertaining to other team sport populations with no included or duplicate articles, and (III) abstracts, non-peer-reviewed articles and book chapters.

Selection of studies. Titles and abstracts of publications identified by the search strategy were screened for further full-text review and cross-referenced to identify duplicates. All trials assessed for eligibility and classified as relevant were retrieved. In addition, the reference section of all relevant articles was examined using the snowball strategy of Gentles et al. (2015)[25]. Based on information contained in the full articles, inclusion and exclusion criteria were used to select eligible trials for inclusion in this systematic review.

Results

An initial search of the scientific literature noted 511 articles related to basketball, but excluded 258 articles as not related to nutrition and health in female basketball players (did not meet inclusion criteria) (Fig. 1).

Energy demands in women's Basketball

According to the American College of Sports Medicine (ACSM, 2000)[26], adequate calorie intake is necessary to maintain lean tissue mass, immune and reproductive function, and optimal athletic performance because, when calorie intake is inadequate, the body will use fat and lean tissue mass as fuel and, as a result, muscle mass will be lost and strength and endurance will be compromised (ACSM, 2000)[26].

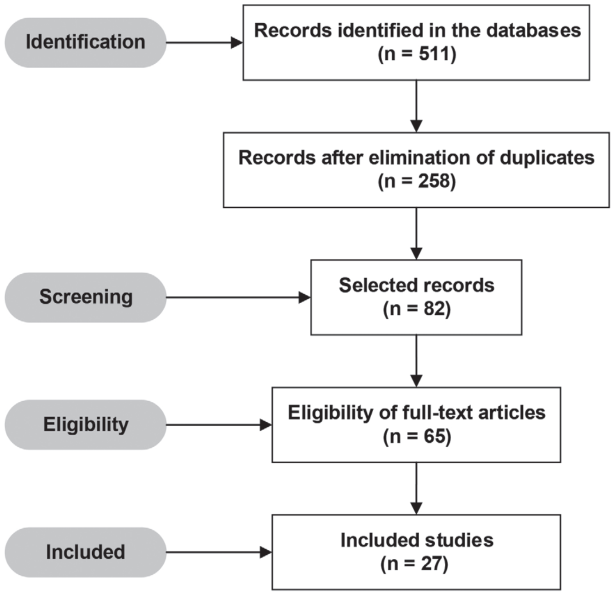

Fig. 1 Study selection flowchart

The current scientific literature presents conflicting results on energy requirements, body composition and other measures of performance over the course of an entire basketball season (Bolonchuk et al., 1991[27]; González et al., 2012[28]; Silva et al., 2012[29]). Specifically, it has been shown that low energy availability is particularly prevalent during pre-season and mid-season, suggesting that athletes do not adequately ensure their nutritional intake (Silva et al., 2017)[30]. Significant increases in the lean body mass (LBM) of female basketball players have also been observed over the course of a season, which could be interpreted as an adequate nutrient intake (Mancha-Triguero et al., 2019)[6]. Although there are studies that have addressed energy balance over the course of an entire sporting season, most of these only complete measurements before and after the period under study. Such measurement frequency may be insufficient to accurately assess changes over the course of a season (Stojanović et al., 2018[4]; Mouche, 2022[1]).

In that sense, achieving energy balance (EB) is a critical aspect of meeting adequate energy requirements and levels (Hausswirth & Le Meur, 2011)[31]. This is particularly important among female athletes, although it has been observed that rates of energy expenditure and energy intake remain more or less stable throughout the season, with the exception of the last months of the season (Zanders et al., 2021)[32]. This is important as negative EB and/or low energy availability (EA) have been associated with low iron intake in this type of sport (Ahmadi et al., 2010)[33]. Low EA may result from low energy intake (EI) and/or a high total energy expenditure (TEE) to activity energy expenditure (ExEE) ratio (Nattiv et al., 2007)[34]. Martinchik et al. (2003)[35] estimated the TEE of the Russian women's Olympic team to be no less than 12,958 kJ·day^{-1} (3,100 kcal·day^{-1}), which is not far from the values reported by

Table 1. Evolution of recommended energy intake

	Energy Intake (kcal/day)
Hinton (2004)	2200
Ahmadi (2010)	2049.79
Silva (2012)	2097.514
Silva (2013)	3500

Silva et al. (2013)[36] of 14,630 kJ·day^{-1} (3,500 kcal·day^{-1}). It should be considered that inadequate energy intake (EI) in relation to TEE compromises performance and other benefits of sports training (Burke et al., 2006)[8].

Nutrition in team sports

Nutrition is among one of the most important aspects necessary for any athlete to maintain their competitive level and health throughout the season (Mielgo-Ayuso et al., 2015)[37]. In fact, Kreider et al. (2010)[38] state that nutrition is an important aid in attenuating fatigue by providing the necessary energy, restoring intramuscular triglyceride (IMT) storage, and maximizing muscle protein synthesis. In addition, adequate nutrition during the competitive season has been shown to improve body composition (BC) (Cheng et al., 2010)[39]. Therefore, since performance is a primary goal during the competitive season, it is essential to monitor dietary intake to assess whether there is adequate total energy intake, as well as sufficient, proportional, and appropriate utilization of each macronutrient.

Team sports have intermittent activity patterns with periods of highly competitive intensity followed by rest breaks or periods of low activity (Gabbett et al., 2008)[40]. This situation means that both aerobic (carbohydrate [CHO] and fat) and anaerobic systems (Burke et al., 2006)[8] are used, with CHO intake being the main dietary priority as it is the fuel used in both energy systems (Celejowa, 2008)[41]. From a physiological perspective, these sports are characterized by distances covered by athletes at medium to high speed, which places a burden on glycogen replenishment and hydration strategies (Burke & Hawley, 1997)[42], with variable activity patterns such as walking, jogging, sustained running, sprinting, supporting, jumping, crashing or charging, actions that show that the ability to perform repeated sprints in a chained fashion is an important determinant of performance in intermittent team sports such as basketball (Burke & Hawley, 1997)[42].

In particular, basketball is characterized by back-and-forth running, blocking, passing and shooting, involving both the lower and upper extremities. Also, specific movements such as jumping, where high values of adipose mass (AM) increase energy demand and accelerate the onset of fatigue (Burke & Hawley, 1997)[42], as BC can have a critical impact on athletic performance (Hallberg, 2001)[43]. Andreoli et al. (2003)[44] have highlighted LBM as an indicator of enhanced performance in specific high-intensity activities. On the other hand, an increase in LBM may indicate growth in muscle mass, resulting in an increase in the potential to produce force during exercise (Hallberg et al., 1993)[45], so monitoring changes in LBM, indicative of nutritional status, can provide insight into the effectiveness of the training programme being undertaken on (Zapolska et al., 2014)[46] an overall level and also on an individual basis (Schelling et al., 2015)[47].

It has been commonly recommended that the energy intake of athletes involved in moderate levels of training, such as elite basketball players (2-3 h/day for 5-6 times/week), should be 50-80 kcal·(kg·day)$^{-1}$ (Scanlan et al., 2015)[2], with specific recommendations of 1.6-1.8 g·(kg·day)$^{-1}$ for protein (Phillips & Van Loon, 2011)[48]. The ASCM recommends that physically active women consume 1.2-2 g·(kg·day)$^{-1}$ of protein (Thomas et al., 2016)[49], while fat intake should be 20-35% of total kilocalorie intake (Rodríguez et al., 2009)[50] and 5-8 g·(kg·day)$^{-1}$ of CHO (Scanlan et al., 2015)[2] to adequately meet performance demands.

Protein recommendations for training. The position of the International Society of Sports Nutrition (ISSN) (Campbell et al., 2007)[51] documents the benefit of protein intake before and after exercise. This position is similar to that of other studies (Kreider, 1999[52]; Kreider et al., 2003[53]; Baker et al., 2014[54]) which present evidence of improvements in body composition, strength, power and agility, and highlight the benefit of protein intake at the appropriate time in conjunction with a strength training programme.

These results are very similar for men and women, although most other studies on protein intake and exercise have been conducted in men, so confirmation of its influence on body composition and performance improvements in the female athlete population is an important step towards completing the body of knowledge.

On the other hand, Wilborn et al. (2013)[55] found no significant gender differences in the type of protein intake on overall performance gains during an eight-week conditioning and undulating resistance training programme, similar findings to those observed by Tipton et al. (2004)[56].

In team sports, there are limited and inconsistent data showing that protein supplementation can improve physical performance recovery despite attenuation of indirect markers of muscle damage (Poulios et al., 2019)[57]. In basketball, it has recently been reported that female basketball players consuming 48 g/day of whey protein isolate (WP) or casein for 8 weeks show a 1.5 kg increase in LBM, ±1-2% decrease in body fat percentage, and a 90 kg increase in leg press strength and a 4.3-7.5 kg increase in upper body strength (Taylor et al., 2016)[58].

WP supplementation has also been shown to moderately increase LBM in female basketball players who work on their aerobic endurance exercise. These results are consistent with other studies, which suggest that, in addition to increasing muscle mass, WP supplementation is able to increase strength (Cribb et al., 2006)[59], and which reported that WP supplementation in conjunction with training increases fat loss and muscle mass. In addition, several studies have shown that increasing protein intake in CHO-based supplementation improves recovery from fatigue, as assessed by endurance performance (Betts et al., 2007)[60].

Table 2. Recommended protein intake

	Protein
Kreider (1999)	1.3-1.8 (g/kg)
Hinton (2004)	55-83 (g/day)
Volek (2006)	1.4-1.8 (g/kg)
Campbell (2007)	1.4-1.7 (g/kg/day)
Kreider (2010)	1-1.5 g/kg/day
Phillips (2011)	1.6-1.8 (g/kg/day)
Silva (2012)	93 (g/day)
Zanders (2012)	87.08 (g/day)
Silva (2013)	82.0 (g/day)
Thomas (2016)	1.2-2 (g/kg/day)
Kerksick (2017)	0.25-0.40 (g/kg)

Therefore, it is essential that athletes consume sufficient amounts of protein and, at the same time, properly time their protein intake to experience positive nitrogen balance, enhanced muscle hypertrophy (Kreider et al., 2003)[53], improved recovery from exercise (Calleja-González et al., 2018)[61], and better immune function during periods of intense training (Kerksick & Leutholtz, 2005[62]; Betts et al., 2007[60]; Willoughby et al., 2007)[63].

CHO requirements for training and competition. Compared to endurance sports, relatively few studies have tested the impact of CHO supplementation during practice or competition on athletic performance in basketball. In addition, the complex nature of the sport makes accurate and reliable measurements of performance difficult, and the many methodological differences between studies confound the ability to interpret results. Previous reviews on the effects of CHO intake on intermittent sports performance have focused primarily on individual performance factors in intermittent sports and what recommendations can be derived for CHO intake before/during exercise in intermittent sports based on available evidence.

Existing literature indicates that after exercising it is recommended to consume ≥ 1.2 g·(kg·day)$^{-1}$ of CHO in the hours following exercise (Kerksick et al., 2017)[64]. For team sport events of < 90 minutes, a specific CHO load is not necessary, and storages of glycogen can be replenished with regular consumption of 7-10 g·(kg·day)$^{-1}$ of CHO (Burke et al., 2011)[65]. In terms of recovery, the consumption of CHO and protein afterwards could be beneficial for athletes participating in multiple training or

Table 3. Literature summary: Effect of carbohydrate intake during exercise on basketball. Adapted from Baker et al. (2015)[73]

		Literature Summary	AdditionalComments
Intermittent high-intensity exercise capacity	(Papadopoulu et al., 2002)	Consistent performance enhancement	This finding is perhaps not surprising, given the well-established benefit of carbohydrate intake on endurance exercise capacity
Sprinting	(Papadopoulu et al., 2002) (Jeukendrup, 2014) (Baker et al., 2015)	Mixed results	3 out of 4 basketball studies report a benefit of carbohydrate ingestion on sprint performance in the 4th quarter of a simulated game.
Jumping	(Papadopoulu et al., 2002) (Jeukendrup, 2014) (Baker et al., 2015)	Minimal effects	Limited data available.
Skill	(Jeukendrup, 2014)	Mixed results	Studies in basketball have found mixed results. Skill is difficult to measure, and many different tests have been used. More validation work is needed for measurement of skill in court-based and other sports.
Change of directionspeed	(Jeukendrup, 2014)	Mixed results	Limited data available for pre-planned change of direction speed. No studies involving changes in direction in response to a stimulus. Difficult to measure. More validation work is needed.
Cognition: Attention and response time	(Papadopoulu et al., 2002) (Baker et al., 2015)	Minimal effects	Limited data available. Difficult to measure. Most cognitive tests are not specific to team sports. More validation work is needed.

competition sessions on the same day or on consecutive days (Beelen et al., 2010[66]; Williams & Rollo, 2015[67]). The extent to which team sportswomen follow these recommendations was also evaluated (Baker et al., 2014)[54], as it was found that many of these athletes restrict their intake of CHO, not complying with the recommended dietary allowances (RDA) (Hinton et al., 2004)[68].

From a nutritional point of view, basketball players use CHO as their main source of fuel during exercise, given the type of training they do and the characteristics of the competition. A few studies have measured the impact of CHO intake on vertical jump performance during a simulated basketball model (Welsh et al., 2002[69]; Winnick et al., 2005[70]; Baker et al., 2007[71]), and only one study (Baker et al., 2015)[72] found a benefit of CHO intake on performance in this parameter. Attention, in basketball, is a fundamental aspect of performance, and it has been observed (Kindlon, 1998)[73] that CHO ingestion before/during training protocols has no impact on improving or maintaining athlete attention (Papadopoulu et al., 2002[74]; Baker et al., 2015)[73].

Welsh et al. (2002)[70] conducted a laboratory study to determine the effects of CHO intake on various physical and mental tasks in an exercise protocol designed to mimic the demands of a basketball game-like situation (Papadopoulu et al., 2002)[74]. The main findings of this study (Papadopoulu et al., 2002)[74] can be seen in Table 3. This experiment was designed to determine the benefit of CHO nutrition on physical function and central nervous system functioning during a high-intensity intermittent exercise protocol that mimicked the physical demands of team sports such as basketball.

Table 4. Carbohydrate intake recommendations

	Carbohydrates
Hinton (2004)	330 (g/day)
Volek (2006)	>8 (g/kg/day)
Willoughby (2006)	20 (g/day)
Kreider (2010)	5-8 (g/kg/day)
Silva (2012)	280 (g/day)
Zanders (2012)	272.5 (g/day)
Silva (2013)	218.8 (g/day)
Scanlan (2015)	5-8 (g/kg/day)
Kerksick (2017)	8-12 (g/kg/day)

Generally, female basketball athletes are recommended to consume around 60% of energy from CHOs, assuming that energy intake is adequate to meet existing needs, which translates into a range of 6-10 g CHO/kg body weight per day to achieve optimal muscle glycogen storage (Martinchik et al., 2003)[35]. Results are found to be in line with data obtained from several women's basketball teams (Papadopoulu et al., 2002)[74].

Ideally, nutritional support should be tailored to the needs of the individual player to enable him or her to cope with training and competition (Jeukendrup, 2014)[20]. However, future studies should look at CHO intake in combination with protein at different doses to determine which dose will improve post-recovery, specifically in female basketball players.

Fat requirements for training and competition. Although fat is a valuable source of energy, high fat diets have not been shown to be beneficial for sports performance, especially in the presence of inadequate CHO intake (Jeukendrup, 2003)[75].

It is important to note that gender specifications are much needed, as it has been observed that women may consume higher protein and fat intake than men, but less CHO and total energy (Volek et al., 2006)[76]. This gender difference in specific dietary intake may be due to a variation in substrate utilization (i.e., less glycogen and greater reliance on IMT), possibly due to the difference in sex hormone secretion (Braun & Horton, 2001)[77]. Furthermore, without sex-specific recommendations, female athletes may have an incorrect intake of the specific macronutrients they need to achieve optimal substrate utilization during the competitive season (Frestedt et al., 2008)[78].

Indeed, if dietary intake is monitored in conjunction with training, a proper assessment can be made to determine whether intake is sufficient in these athletes to meet the rigorous demands of training and competition, as well as to determine whether they meet the necessary nutritional guidelines (Rodríguez et al., 2009[50]; Cheng et al., 2010[39]). Furthermore, to the authors' knowledge, it remains unclear whether these athletes must adhere to current energy intake guidelines to improve BC and performance during the competitive season or whether an alternative strategy may yield more beneficial results.

Therefore, to manage the repeated stressors of a season (Montero et al., 2002)[79] and not diminish the performance of athletes in a frequently fatigued state, it seems necessary to monitor nutrition along with training throughout the season (Taylor et al., 2016)[58]. Indeed, it has been reported that when elite female athletes are not provided with specific nutritional guidelines, many of them show a negative EB during the competitive season (Hassapidou & Manstrantoni, 2001)[80] and their intake needs to be monitored. Schröder et al. (2002)[81] established that, in their daily practice, basketball players consumed CHO (12.7%) with other nutrients such as amino acids (14.5%) and protein (12.7%) during one season (Schröder et al., 2002)[82].

Table 5. Recommended fat intake

	Fat
Hinton (2004)	<73 (g/day)
Kreider (2010)	0.5-1 (g/kg/day)
Silva (2012)	67.5 (g/day)
Zanders (2012)	100.94 (g/day)
Silva (2013)	64.1 (g/day)

Risks related to nutritional status of female athletes. Female athletes, as a group, have special nutritional needs based on their age, gender, BC and, most importantly, the type, intensity, frequency and duration of activity required for their sport. The nutritional intake of elite female athletes is a major determinant of their athletic performance and their ability to compete both physically and mentally (American Dietetic Association, 2000)[82].

In fact, many female athletes, especially those in leaner sports, have suboptimal energy and nutrient intake and are at risk of compromised nutritional status (Sundgot-Borgen, 1996[83]; Beals & Manore, 1998[84]). Thus, this type of female athlete may attempt to lose weight or body fat by developing eating disorders. This aberrant behavior may lead to menstrual dysfunction and subsequent osteoporosis. These three distinct but interrelated conditions are known as the female athlete triad (Yeager et al., 1993[85]; Nattiv et al., 1994[86]; West, 1998[87]).

Thus low energy availability, functional hypothalamic amenorrhea and osteoporosis, alone or in combination, pose significant risks to the health of physically active girls and women (Nattiv et al., 2007[34], and is related to impaired immunocompetence, which increases their susceptibility to infections and limits their prospects of achieving goals (Montero et al., 2002)[80].

Dietary intake of basketball athletes

The nutritional intake of athletes is determinant for performance and the ability to compete both physically and mentally (Economos et al., 1993)[88].

An adequate performance by athletes is the multifactorial result of good training, BC, and nutritional status, so an adequate intake of macro and micronutrients affects these aspects and, consequently, sporting performance (Jeukendrup, 2017)[89]. Currently there are reports that indicate that many athletes do not develop nutritional practices/habits to optimize their sporting performance (Bytomski, 2018)[90].

Performance can be defined as *the attainment of set objectives by meeting or exceeding predefined levels* (Portenga et al., 2017)[91], referring to both individual and collective patterns. It is determined by the development of specific skills, abilities and conditions to adapt to unexpected environmental influences and competitive situations (West, 1998[88]; Kellmann & Beckmann, 2018[92]), and can be affected by both physiological aspects (such as endurance, strength, speed or flexibility) (Lambert, 2012[93]; Halson, 2014[94]) and psychological factors (such as concentration, motivation or will) (Beckman & Elbe, 2015[95]).

In relation to the intake of female team athletes, we can observe that, in general, it is below the established recommendations, both in terms of macro and micronutrients. This will have an influence in the short or medium term on sports performance and, in the longer term, on the health of the female athlete (Beals & Manore, 1998)[85].

Initially, health was developed as a reductionist concept based on the absence of disease or infirmity and defined by physical parameters (Larson, 1999[96]; Tinetti & Fried, 2004[97]). Later, a revolution in this definition was brought about by the World Health Organization (WHO) and health was redefined as a "state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (World Health Organization, 1946)[98]. However, it has now been shown that this definition has also become obsolete (Saracci, 1997[99]; Bok, 2004[100]; Jadad & O'Grady, 2008[101]; Huber et al., 2011[102]; Goodle, 2011[103]; Huber et al., 2016[104]) and health needs to be considered as more than a state of complete well-being (Larson, 1999)[98]. Thus, health is now understood *as a dynamic state of well-being characterized by physical, mental and social potential that meets the demands of a life in accordance with age, culture and personal responsibility* (Bircher, 2005)[105].

In terms of fluid intake, the general target for female basketball players has been set at 600-1,000 ml·hr^{-1} (Broad et al., 1996)[106]. However, there is a need to collect data on the dietary intake of female athletes on match days, as most of the published data refer to training days. In this way, a relevant comparison between the two situations could be established.

Supplements and sports nutrition in women's basketball

Team athletes are interested in the ergogenic potential that could be obtained by means of special supplements even though most of them do not have level 1A (NIH evidence-based medicine) evidence (Bishop, 2010)[107].

Currently, based on scientific evidence (Maughan et al., 2018)[108], only caffeine, creatine, citrate, beta alanine and nitrates have been scientifically proven to have some kind of proven results (Escribano-Ott et al., 2021 & 2022)[109,110].

Caffeine. Caffeine intake is one of the most popular supplements (Spriet & Gibala, 2004)[111]. As far as basketball is concerned, caffeine has been shown to generally improve performance (Mielgo-Ayuso, 2019; a, b)[112,113].

According to a review of the literature, the effect of caffeine supplementation on linear sprinting and change of direction speed is not yet clear in team sports because there are not a significant number of studies available (Chia et al., 2017)[114]. But some team sport-specific skills have already been examined following caffeine ingestion (Abian-Vicen et al., 2014)[115].

To date, five studies have examined the ergogenic effect of caffeine supplementation on performance-related variables indicative of success in female basketball players [vertical jump (Abian-Vicen et al., 2014[117]; Puente et al., 2017[116]; Stojanović et al., 2019)[117], change of direction speed (Abian-Vicen et al., 2014[117]; Scanlan et al., 2019)[118], linear sprint speed (Abian-Vicen et al., 2014)[117] and dribbling speed (Abian-Vicen et al., 2014[117]; Scanlan et al., 2019)[120]].

The results of Stojanović et al. (2019)[119] indicate that acute caffeine supplementation may be an effective method of improving anaerobic performance including vertical jumping, change of direction speed, single sprinting, and repeated sprinting in professional female basketball players. Although the ergogenic effects of caffeine vary in magnitude between individuals. Therefore, it is recommended to determine whether pre-exercise caffeine supplementation is ergogenic at the individual level, as well as its effects on performance enhancement. Furthermore, the performance-enhancing effects of caffeine supplementation were accompanied by lower RPE and higher perceived performance, with no adverse side effects. This is consistent with other research reporting the benefits of caffeine supplementation on vertical jumping (Scanlan et al., 2019[120]; Gómez-Bruton et al., 2021[119]).

Puente et al. (2017)[118] reported that caffeine increased the number of free throws attempted, while it did not improve free throw accuracy. Furthermore, caffeine intake did not influence two- and three-point field goal shooting, which reinforces the lack of a positive/negative effect of caffeine on sport-specific accuracy (Gómez-Bruton et al., 2021)[121].

The results of Scanlan et al. (2019)[120] are the first to indicate precise effects of caffeine supplementation on dribbling speed in elite female basketball players, in addition to improvements in upper body strength (ball speed), CMJ, single sprint performance and body impacts during a game (game intensity) (Gómez-Bruton et al., 2021)[121]. Improvements in Abalakov jump shot, number of free throws made and attempted, offensive manuevers, and total rebounds, and total number of assists (Scanlan et al., 2019)[120] were also observed. Furthermore, the performance-enhancing effects of caffeine supplementation were accompanied by lower RPE and higher perceived performance without adverse side effects (Abian-Vicen et al., 2014)[117].

It is important to examine the effect of caffeine supplementation independently in female and male players, given that gender-related differences in physiological and performance responses to caffeine ingestion have been reported (Scanlan et al., 2019[120]; Gómez-Bruton et al., 2021[121]).

Creatine. Creatine monohydrate supplementation is a popular strategy for its physical performance enhancing effect when it comes to repeated sprinting, as well as increasing LBM, muscle strength and power, which helps to support greater training loads and improve physical performance in competition (Mielgo-Ayuso et al., 2019[115]; Fernández-Landa et al., 2019[120]).

It is commonly used in team sports and has also been the subject of extensive research in relation to these types of sports as its purported ergogenic action (enhanced PC recovery) matches their activity profile (Lemon, 2002)[121)], and research indicates that both acute and chronic creatine supplementation may contribute to improved team performance (Fernández-Landa et al., 2019)[122)].

The potential interest of creatine supplementation in basketball may be related to an increased ability to perform repeated high-intensity exercise sessions, during training or during competition in sports where repeated efforts are required (e.g., basketball), but this possibility needs to be scientifically confirmed (Mujika & Padilla, 1997)[122)].

ß-alanine and Bicarbonate. Although β-Alanine supplementation has been shown to improve high-intensity exercise performance and capacity, and its use (Trexler et al., 2015)[123)] may provide benefits in team sports, no clear scientific results have yet been presented on its ergogenic effect on team performance (Bishop & Claudius, 2005)[124)] (including basketball).

However, sodium bicarbonate ($NaHCO_3$) supplementation has been extensively studied as a strategy to delay metabolic acidosis in muscles during high-intensity, short-duration (<10 min) (McNaughton et al., 2016)[125)] exercise. Significant improvements in repeated sprint ability (RSA) performance were observed following acute doses of $NaHCO_3$ (Mujika & Padilla, 1997[124)]; Bishop et al., 2004[126)]); but as women are often characterized as having a higher resistance to fatigue during repeated sprints (Laurent et al., 2010)[127)], this may suggest that women may not benefit from buffering systems as much as men.

The results also showed that $NaHCO_3$ supplementation resulted in significant improvements in mean jump height (Narazaki et al., 2009[128)]; Matthew & Delextrat, 2009[129)]; Delextrat et al., 2015[130)]), an interesting result for the discipline under discussion here.

In conclusion, $NaHCO_3$ intake improved sprint and jump performance (Delextrat et al., 2018)[131)]. Other studies should investigate whether these observed benefits transfer to basketball exercise performed throughout the duration of a game, as well as identify the optimal dose-response of $NaHCO_3$ supplementation alone or combined with other buffers such as ß-alanine.

Nitrates. Recent studies indicate that dietary nitrate supplementation, most commonly administered in the form of beetroot juice, can (a) improve muscle efficiency and thus improve endurance exercise performance and (b) improve muscle power and sprint exercise performance (Jones et al., 2018)[132)]. However, these results have not been fully supported by previous studies (Martin et al., 2014)[133)] nor considered significant in actual competition (Buchheit, 2018)[134)].

Several studies in basketball have proven that the ergogenic effects of NO_3^- supplementation positively affect physiology and performance, but its usefulness is still unclear or unknown (López-Samanes et al., 2020)[135)].

Therefore, further research is needed to confirm the findings and to determine the possible effects of NO_3^- supplementation on the performance of team athletes.

Future studies should also investigate whether a balanced diet rich in NO_3^- could produce comparable effects on physical performance to those observed after acute or chronic supplementation.

Other supplements. The prevalence of vitamin D insufficiency in female basketball players has been studied extensively in the last decade (Bellows et al., 2013[136)]; Fields et al., 2019[137)]; Fields et al., 2020[138)]; Sekel et al., 2020[139)]), as female basketball players may be more susceptible to hypovitaminosis D due to reduced exposure to sunlight from training [and competing] indoors.

Despite the growing interest in quantifying and correcting vitamin D insufficiency in female basketball players, a critical synthesis of these data to overcome the poor generalization of results from individual studies has not yet been undertaken (Mielgo-Ayuso et al., 2018)[140)].

Twenty-three studies were synthesised, but only one exclusively included female basketball players (Farrokhyar et al., 2015)[141)]. The pooled analyses suggested that vitamin D supplementation was effective in improving serum 25(OH)D concentrations and correcting vitamin D insufficiency [insufficiency and deficiency (Sekel et al., 2020)[141)]] in female basketball players, although data regarding the positive impact of vitamin D supplementation on optimising sports performance in female basketball players remain scarce.

Farrokhyar et al. (2015)[143)] confirmed non-significant effects of vitamin D supplementation on physical performance. Therefore, further intervention trials are required to determine whether optimisation of vitamin D status improves athletic performance in female basketball players.

And while, overall, the results demonstrated vitamin D insufficiency in female athletes playing indoor sports, interestingly, no relationship was found between vitamin D status and bone health. Further research is recommended to investigate the relationship between 25(OH)D, vitamin D binding protein, bioavailable 25(OH)D, bone mineral density and LBM in high-level female athletes (Farrokhyar et al., 2015)[143)].

In relation to health, the introduction of bovine colostrum, with documented immunomodulatory activity (Rak & Bronikowska, 2014)[142)], into the diet may be one element of a gentle and safe intervention to restore balance to the immune system. To our knowledge, no work has been published to date on the use of bovine colostrum supplementation in athletes involved in team sports that has been analysed in terms of its ability to reduce immune suppression after exercise.

The ambiguous results of the research (Skarpańska-Stejnborn et al., 2020)[143)] suggest that future research should indicate which biologically active ingredients should be consumed at what dose to achieve the intended effect of protection against infection.

At the level of hydration, post-exercise rehydration with alanine-glutamine dipeptide (Hoffman et al., 2012)[144] appears to maintain basketball skill performance and visual reaction time to a greater extent than water alone.

Data obtained in the study of Szczepańska & Spałkowska (2012)[145] in basketball conclude that 48% of respondents used dietary supplements with vitamin and mineral preparations. Of the other supplements used, joint regeneration preparations (12%), creatine (9%) and fat reducers (8%) were most frequently observed. Supplementation is also indicated by the results of studies by other previous authors (Holway & Spriet, 2011[9]; Spiteri et al., 2015[146]).

Supplementation should provide nutritional support and may be of benefit if an athlete is unable to meet their body's needs through a balanced diet (Rodríguez et al., 2009)[50]. Otherwise, supplementation may be pointless or may adversely affect health (Szczepańska & Spałkowska, 2012)[147]. Therefore, supplements should be used in justified cases (e.g., in the case of anemia), as long as adequate knowledge about them is available. We cannot lose sight, in any case, that several studies on the effects of dietary supplements are still ongoing.

Conclusions

Based on the fact that the dietary habits of basketball athletes, specifically female athletes, are not as well studied as the dietary habits of individual sports, it is obvious that team sports nutrition requires additional knowledge of sport-specific physiology during training and competition. In general, the huge difference in energy expenditure observed in the dietary records of female athletes is mainly due to a lack of information, recommending 50-60 kcal·$(kg\cdot day)^{-1}$, with values of 2,000 kcal/day maintained over time. Low energy availability (with or without eating disorders) has been shown to be a trigger for the development of amenorrhoeic and osteoporotic processes.

All previous studies have shown why it is necessary to consume sufficient energy to achieve optimal performance. However, it is a well-known fact that in many female athletes in team sports, an insufficient energy supply is a main problem, with a negative energy balance of 567 ± 362 kcal/day.

Currently available research suggests that there is some potential for CHO intake to improve performance in tests that simulate the high-intensity intermittent nature and skills of intermittent sports. CHO ingestion consistently improves high-intensity intermittent exercise capacity; however, studies have shown mixed results (improvement or no effect) in terms of effects on sprinting, dexterity and change of direction or dribbling and minimal effects on jumping and cognition (attention and response time). Review of the studies used suggests that many participants do not meet current energy recommendations for physically active women during non-competitive periods. On the other hand, the current data confirm (Ho et al., 2018)[147] previous studies indicating that increasing the proportion of protein in CHO-based supplementation for exercising individuals improves recovery from fatigue in high-intensity endurance performance.

In conclusion, dietary and nutritional monitoring in elite female basketball team athletes over the course of the competitive season revealed lower total energy and CHO intake and higher fat and protein intake than recommended guidelines.

Practical recommendations. We recommend that more attention be paid to the nutrient intake (especially calorie and micronutrient intakes) of female athletes because, while increasing the theoretical levels of micronutrients and vitamins through supplementation does not result in improved athletic performance (Beck et al. 2021)[148], not reaching these theoretical levels does result in decreased athletic performance as this is directly related to a decrease in the overall health of the athlete and the possible occurrence of disorders and injuries of various kinds.

In summary, we can infer that in sports such as basketball, athletes must show speed, strength, endurance, and attention. But although basketball is an all-round discipline, we must adopt a gender-based approach that meets the nutrition and hydration needs of each athlete individually.

After analyzing the above-mentioned studies, we can conclude that, in the vast majority of cases, the nutritional behavior of female basketball athletes is still widely deficient.

Future lines of research. In the future, researchers should measure and report on the reliability, validity and sensitivity of basketball-specific skill tests and protocols and direct these investigations to determine the most important sport performance skills that are particularly relevant to the real needs of the game.

Furthermore, to the authors' knowledge, it remains unclear whether these types of athletes must adhere to current energy expenditure guidelines to improve BC and performance during the competitive season, or whether there are alternative strategies that may produce more beneficial outcomes.

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Authorship principles

All authors whose names appear in the submission:
1) made substantial contributions to the conception or design of the work, or the acquisition, analysis, or interpretation of data, or the creation of new software used in the work;
2) drafted the work or critically reviewed it for important intellectual content;
3) approved the version to be published; and
4) agreed to be responsible for all aspects of the work to ensure that questions regarding the accuracy or completeness of any part of the work are properly investigated and resolved.

Conflict of Interests

The authors declare that they have no conflicts of interest.

Author Contributions

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