

## A Review of the Physiological Demands and Nutritional Strategies for Canoe Polo Athletes

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### Abstract

Canoe polo is an emerging and growing sport. Canoe polo athletes are characterized by low body-fat percentages with high levels of upper body aerobic and anaerobic power. Canoe polo is a high intensity intermittent team sport consisting of two 10 min halves. Average heart rates during game play ranged from 146 to 159 bpm. Sixty-nine per cent of a canoe polo game is played above ventilator threshold. Due to the intensity and intermittent nature, ATP re-phosphorylation occurs via non-oxidative and oxidative energy systems. A high carbohydrate diet ( $>6 \text{ g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$ ) is recommended to support non-oxidative ATP re-phosphorylation during training and competitions. Following training, a rapidly digested and complete protein (e.g., whey protein; 20-40 g) provided in close proximity may maximize the muscle protein synthetic response.  $\beta$ -Alanine, sodium bicarbonate, creatine, caffeine, and nitrates are purported ergogenic aids to improve high intensity exercise performance and may be beneficial for canoe polo athletes.

**Keywords:** Team sports, Diet, Performance, Macronutrients, Supplements

### Introduction

Canoe polo is an emerging sport and is growing in popularity [1-3]. The International Canoe Federation first sanctioned canoe polo in 1989 and the first World Championships were held in 1994. There were 24 and 18 countries competing in the men's and women's divisions, respectively, at the most recent International Canoe Federation World Championships held in Italy in 2016. Canoe polo is a competitive ball sport played on water, in a defined pitch (35 m in length by 25 m wide). There are 2 teams of 5 players, each in a specialized kayak. In addition, each team has up to 3 players behind the goal line who can substitute in at any time. The objective of the game is to score goals by throwing a canoe polo ball into the opponent's net (measuring 1.0 m in height by 1.5 m wide) that is suspended 2 m above the water. A player acts as a goalie to defend the goal with their paddle blade. During game play, the ball is passed among the players by hand or with some use of the paddle or thrown out of reach from the player and then regaining possession (dribbling); however, the player may only have the ball in their possession for a maximum of 5 s. Furthermore, there is a 60 s shot clock, which is reset after a foul by the defensive team, a change in team possession, or after a shot on net. The game is 20 min in length split into two 10-min halves separated by 3 min and begins with a sprint start to gain possession of the ball at the center line [4]. For further information about the sport the reader is encourage to visit (Figure 1).

The growth of canoe polo and the introduction of the International Canoe Federation sanctioned World Championships have led to an increased competitiveness and systematic training. A typical annual training plan consists of a general preparation phase (September to April), a specific preparation phase (April to June), a competitive phase (June to August), and a transition phase (September; Table 1). Training during the general and specific preparation phases typically consist of resistance training 3 to 4 times per week for 60-90 min each session, running twice a week (60 min per session), and indoor tactical paddling 1 to 2 sessions per week (60 min per session). The physiological goals during the general and specific preparation phases are to enhance aerobic and anaerobic power and capacity, increase

strength and muscular endurance, and to improve canoe polo specific skills. During the competitive phase canoe polo athletes are engaged in 3 to 5 paddling and tactical training sessions (1-2+ h in duration), 2 to 3 resistance training sessions (60 min per session), and 1 to 2 cross training (typically running) sessions. The physiological goals during the competition phase are to improve game-specific intensity and neuromuscular power development. The transition phase varies from complete rest to 1 to 2 paddling sessions per week. The focus is on physiological and psychological recovery.

With the increase in training volume and competitiveness, there



Figure 1: A photograph of Canoe Polo.

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**Received** November 23, 2016; **Accepted** December 23, 2016; **Published** December 30, 2016

**Citation:** Forbes SC, Sheykhloovand M (2016) A Review of the Physiological Demands and Nutritional Strategies for Canoe Polo Athletes. Sports Nutr Ther 1: 116. doi: [10.4172/2473-6449.1000116](https://doi.org/10.4172/2473-6449.1000116)

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| Periodized training phase   | Training/competition focus   | Nutrition focus  | Daily macronutrient targets                                      |
|-----------------------------|--|--|--|
| <b>General preparation</b>  | High training volume (5-12+h/week).<br>Focus on aerobic development.<br>Training includes resistance, cross training, and on-water endurance sessions.                       | Higher caloric intake to support training volume.<br><br>Dietary intake must support desired changes in body composition.        | ~6-12 g CHO/kg/day, ~1.5-1.7 g PRO/kg/day, ~1.5-2.0 g FAT/kg/day |
| <b>Specific preparation</b> | Lower volume (4-10+h/week).<br>Focus on anaerobic development and canoe polo specific skills.<br>Training includes more specialized training.                                | Dietary intake to support high intensity training.<br><br>Dietary intake must support recovery and canoe polo specific training. | ~6-10 g CHO/kg/day, ~1.5-1.7 g PRO/kg/day, ~1.0-1.5 g FAT/kg/day |
| <b>Taper/competition</b>    | Lower volume (3-8 h/week) including high intensity training.<br><br>Focus on game-specific intensity and neuromuscular power development.<br><br>Competitions are the focus. | Dietary intake to support high intensity games.<br><br>Dietary intake must support recovery and canoe polo game play.            | ~6-10 g CHO/kg/day, ~1.5-1.7 g PRO/kg/day, ~0.8-1.2 g FAT/kg/day |
| <b>Transition</b>           | Volume and intensity are both low and/or complete rest (2-4 h/week).<br><br>Focus is on physiological and psychological recovery.  | Total caloric intake to match training volume.<br><br>Some weight gain is expected.  | ~4-6 g CHO/kg/day, ~0.8-1.2 g PRO/kg/day, ~1.0-1.5 g FAT/kg/day  |

**Table 1:** Nutritional and training periodization for canoe polo athletes.

is a need for scientific evaluation. Recent literature has examined the anthropometric, physiological, performance and dietary assessments of high level canoe polo athletes [1-6]. The purpose of this brief review is to 1) summarize the physiological and energetic demands of canoe polo training and games, 2) examine the physiological and anthropometric characteristics of high level canoe polo players, and 3) provide nutritional recommendations for training and competition and discuss potential ergogenic aids for canoe polo.

## Methods

### Data sources and search strategy

Literature searches were performed in October 2016 on Medline, Embase, CINAHL, and Google Scholar. For the Medline search the MeSH terms (exploded) *Canoe Polo, Kayak, and Paddling*, were combined with the terms *Nutrition Assessment, Nutrition Therapy, Diet, Micronutrients* and *Food plus Nutrition* as a keyword. A supporting keyword search was done using (kayak polo\* or canoe polo\* or paddling) AND (food\* or diet\* or nutrition\* or micronutrient\* or mineral\*). The other databases were searched by similar strategies using terms from their specific thesauri.

### Physiological demands of canoe polo

The quantification (e.g., frequency, duration) of common movements and the assessment of the physiological demands (e.g., heart rates, lactates) of canoe polo have important implications for the development of more appropriate and specific training regimes. Having an understanding of the physiological demands allows for better monitoring of programs through sport-specific fitness assessments to optimize physical preparations for competitions, and may assist in providing nutritional recommendations. Time-motion analysis data (work-to-rest ratios, and sprints times) have been assessed during a single simulated game [1] and following three games at the World championships in 2008 [2]. Average heart rates during the simulated game were  $146 \pm 11$  bpm (representing ~76.4% of maximum heart rate) and during the World Championships was  $\sim 158 \pm 16$  bpm. A total of  $69 \pm 22\%$  of the first half and  $68 \pm 29\%$  of the second half of the games were played at a mean heart rate intensity above a heart rate

that occurred at ventilatory threshold [2]. The heart rate at ventilatory threshold was determined during an incremental arm crank protocol. A total of  $93 \pm 3.0\%$  of the game was defined as “effort” time whereas only  $6.9 \pm 3.0\%$  of the game was recovery time [1]. “Effort” was considered as any action involving paddling as well as rolling, passing, and shooting regardless of its intensity. The predominant movements during a canoe polo game were slow to moderate forward paddling (29%), contesting for position (28%), and resting/gliding (27%), while sprinting, backwards paddling, turning, and dribbling contributed to the remaining 16% [2]. Sprinting and contesting for position are associated with a higher intensity and predominantly fueled via non-oxidative ATP re-phosphorylation (~30% of the games) and these high intensity movements were interspersed with less intensive activities (~70% of the games), such as slow to moderate paddling or resting and gliding [2]. The number and duration of sprints during a simulated game were  $n=9.6 \pm 4.4$  and  $4.6 \pm 1.5$  s, respectively [1]. Blood lactates significantly increased from ~1 to ~7 mmol/L during a single game [1].

In summary, canoe polo is an intermittent sport that requires high physiological demands (based on game play heart rates and post-game blood lactates). Alves et al. [1] states that aerobic metabolism is the main source of energy during a canoe polo game, however, it is important to note that given the high intensity and explosive actions, ATP re-phosphorylation may depend on the ATP-phosphocreatine and non-oxidative (“anaerobic”) glycolytic systems [1-3,5]. The understanding of the different energy systems and the fuels required to re-phosphorylate ATP must be taken into consideration when making nutritional recommendations [7].

### Anthropometric and physiological profiles

The anthropometric and physiological profiles of elite level canoe polo athletes are shown in Table 1. Canoe polo athletes are  $\sim 180.0 \pm 5.0$  cm and have a body mass of  $\sim 80 \pm 8$  kg, with a relatively low percent body fat ( $\sim 12 \pm 3\%$ ); however, there is high individual variability. This variability may be associated with specific positions and tactical players. For example, a taller stature is better suited for the goal tender position requiring a high reach; however, no studies have reported positional specific anthropometric and physiological characteristics.

Due to the highly intermittent nature of canoe polo, players require ATP re-phosphorylation via non-oxidative and oxidative energy systems. To assess the non-oxidative (e.g., anaerobic) energy system, a common tool was an upper body Wingate [1-5]. The power output achieved during the first 5 s has been used to indicate the peak rate of energy supply from intramuscular ATP and phosphocreatine, and the 30 s mean power output has been used to estimate the rate of energy contribution primarily from anaerobic glycolysis [8]. Canoe polo athletes possess high peak and average power outputs (Table 1); however, there was high variability between studies (peak power outputs ranged from 313 to 518 Watts). These differences may be associated with the relative loading factor and or ergometer used [8]. Due to the high intensity and intermittent nature of canoe polo, it would be hypothesized that canoe polo athletes demonstrate high maximal oxygen consumption. Average relative  $\text{VO}_2$  max ranged from 39.2 to 44.3  $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$  (Table 1). These values are lower than elite sprint kayakers (ranged from 53.8-58.8  $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$  [9,10]. They are higher than mean values for upper exercise reported in a systematic review in recreationally active participants [11]. Ventilatory thresholds are an indicator of aerobic fitness because it indicates an exercise intensity up to which exercise may be performed without rapid accumulation of blood lactate. Blood lactate is a marker of accelerated anaerobic metabolic contribution [12]. Canoe polo athletes achieved ventilatory threshold at 69% of peak  $\text{VO}_2$  [2] and was similar to international level wheelchair basketball players [13]. Sheykhloouand et al. [3] found a higher ventilatory threshold in national level players (80.2% of peak  $\text{VO}_2$ ). Therefore, Canoe polo players may have high levels of aerobic and anaerobic fitness derived from their participation in the sport itself [3]. To support this, Sheykhloouand et al. [3], examined the effects of various high intensity training protocols used by canoe polo athletes

and demonstrated a significant increase in  $\text{VO}_2$  peak, ventilatory threshold, and upper body peak and average power output (Table 2).

### Nutrition for training

**Caloric intake:** Dietary intake must provide sufficient calories to maintain optimal body composition and energy resources to support training intensity and duration [7]. The average energy intake in canoe polo athletes ranged from 3269 to 3571 kcals or 41.2 to 42.8  $\text{kcal}\cdot\text{kg}^{-1}$  of body mass (Table 2). These energy intakes are lower than other power sport athletes [7,14]. Power athletes typically report 55  $\text{kcal}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$  [14].

A relatively new approach to sport nutrition is to provide periodized nutrition to match training periodization and specific goals of each training phase [7]. Traditional periodization sequences for canoe polo training are separated into four main macro-cycles of general preparation, specific preparation, competition, and transition phases. The training load (i.e., training intensity and duration) is different in each phase (as outlined earlier), therefore, the fuels and the amount of energy required to re-phosphorylate ATP during these phases need to be addressed through a periodized nutritional approach [15]. Table 1 outlines the various phases, training goals, and nutritional recommendations for each phase (adapted for Canoe Polo athletes) [7].

**Dietary protein intake recommendations:** To date, no studies have evaluated the effects of protein on recovery and training adaptations in canoe polo athletes; and very few studies have been conducted in power sports. Several studies have demonstrated the importance of sufficient protein in the diet for strength performance. During stable training periods, protein intakes greater than 1.7  $\text{g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$  have been shown to induce an increase in protein oxidation, therefore, it is suggested that elite athletes who undertake a large and intense training load meet their

| First author (year) | Study population (N)  | Design and duration  | Anthropometrics  | Performance profile   | Physiological  |
|---------------------|---|--|--|---|--|
| Alves 2012          | 10 male Brazilian National Team Athletes (age =26.7 ± 4.1 years)  | Descriptive single time point  | Height (cm)=177.1 ± 6.5; Body mass (kg)=76.8 ± 9.0; Sum of 8 skinfolds (mm)=95.4 ± 34.2; Body fat (%)=12.3 ± 4.0 | Upper-body peak power (W)=518.4 ± 82.3; 1-RM bench press (kg)=99.1 ± 11.7; 1-RM leg press (kg)=303.6 ± 68.2; Handgrip (kgf)=47.6 ± 8.7; Flexibility (cm)=35.9 ± 5.9; Vertical jump height (cm)=35.0 ± 2.7;  | Peak $\text{VO}_2$ (L/min)=3.4 ± 0.4; Relative peak $\text{VO}_2$ (mL/kg/min)=44.3 ± 5.8; Running speed at peak $\text{VO}_2$ (km/h)=17.6 ± 1.7; Running speed at second ventilatory threshold (km/h)=15.6 ± 1.2; heart rate max (bpm)=192 ± 5 |
| Forbes 2013         | 8 male Canadian National Team Athletes (age=25 ± 1 years; years experience=6.2 ± 3.9)                                 | Descriptive single time point  | Height (cm)=182 ± 4.0; Body mass (kg)=81.9 ± 10.9; Body fat (%)=9.9 ± 1.7  | Upper-body peak power (W)=377 ± 45; Upper-body mean 30 sec power (W)=289 ± 29; Grip Strength (kg)=119 ± 14; Sit and Reach Flexibility (cm) =30.1 ± 11.7   | Peak $\text{VO}_2$ (L/min)=3.25 ± 0.35; Relative peak $\text{VO}_2$ (mL/kg/min)=39.2 ± 4.2; VT (L/min)=2.2 ± 0.3; VT (% of $\text{VO}_2$ max)=68 ± 6   |
| Sheykhloouand 2015a | 21 male professional canoe polo athletes (10 of which were on the national Iranian Canoe Polo team; age=24 ± 3 years) | Randomized controlled trial; 3 week training study; 3 groups-control, High intensity interval training (HIIT-1) ↑ intensity; HIIT-2 ↑ volume | Height (cm)=181 ± 4; Body mass (kg)=85 ± 6; body fat (%)=12.9 ± 2.7  | Pre-peak power (W): Control=420.8 ± 23; HIIT-1=416 ± 37.2; HIIT-2=313.5 ± 85.9. Mean Power output (W)=Control =272 ± 22; HIIT-1=294.6 ± 34.1; HIIT-2=212.5 ± 53.8. Post-Peak Power (W): Control=440.5 ± 10; HIIT-1=456.4 ± 42; HIIT-2=361.6 ± 90.7; Mean Power output (W)=Control=282 ± 28; HIIT-1=327.3 ± 50.5; HIIT-2=250.7 ± 53.0. | Pre-peak $\text{VO}_2$ (L/min): Control=3.14 ± 0.37; HIIT-1=3.27 ± 0.37; HIIT-2=2.77 ± 0.51. Post-Control=3.21 ± 0.35; HIIT-1=3.56 ± 0.53; HIIT-2=3.01 ± 0.44  |
| Sheykhloouand 2015b | 15 elite Iranian canoe polo athletes (age=24.8 ± 2.1 years)   | Descriptive single time point  | Height (cm)=178.5 ± 4.4; Body mass (kg)=83.9 ± 5.2; Body fat (%)=13.2 ± 3.0                                      | Upper body peak power (W/kg)=1.76 ± 0.52; 1RM bench press (kg)=107.8 ± 16.2; ball throwing velocity (m/sec)=22.1 ± 0.45; Grip strength (N)=616 ± 96; Flexibility (cm)=38.8 ± 5.2  | Relative Peak $\text{VO}_2$ (mL/kg/min)=41.8 ± 4.2; $\text{VO}_2$ at lactate threshold (L/min)=2.7 ± 0.4; Heart rate max (bpm)=198.3 ± 1.9   |
| Vastola 2012        | 2 male Italian canoe polo athletes (age=26-27 years)  | Descriptive single time point  | Height (cm)=179 ± 18; Body mass (kg)=80-82   |   | Heart rate max=197 and 200 bpm   |

Table 2: Anthropometric, performance and physiological data of canoe polo athletes.

protein requirements with 1.3–1.8 g·kg<sup>-1</sup>·day<sup>-1</sup> [16]. Canoe polo athletes are achieving these daily total protein intake recommendations, average protein intake =1.8 g·kg<sup>-1</sup>·day<sup>-1</sup> [1].

In addition to total daily protein intake, the muscle adaptive response is modulated by the per meal protein dose [17-19], protein type [20,21] and timing of protein [17]. Due to the intermittent nature of the canoe polo, consuming 20 g of protein at breakfast, lunch, dinner and pre-sleep [22,23] might help to improve recovery and training adaptations. This may be especially of importance in the high-volume general preparation phase.

**Dietary carbohydrate intake recommendations:** Bergstrom et al. [24] was the first to show that a high carbohydrate diet led to augmented glycogen stores, resulting into improved time to exhaustion compared to a low carbohydrate diet. Due to the highly intermittent nature of canoe polo and thus the varying intensity and duration, the precise amount of carbohydrate that is oxidized varies. However, carbohydrate oxidation provides the majority of ATP when exercising above 75% of VO<sub>2</sub> peak [7]. During the specific preparation and competition phases, the relative amount of recommended carbohydrate is high (>6 g·kg<sup>-1</sup>·day<sup>-1</sup>). Due to the large training load during the general preparation phase, the absolute requirement for carbohydrate remains high (>6 g·kg<sup>-1</sup>·day<sup>-1</sup>). Carbohydrate rich foods must provide the majority of energy throughout the training to maintain training intensity, since the rate of fat oxidation is not sufficient for high intensity exercise [7]. General recommendations, depending on individual training volume and intensity, are to ingest a high carbohydrate diet of ~6-12 g·kg<sup>-1</sup>·day<sup>-1</sup> to maintain immune function, recover glycogen storage and reduce over-reaching [7,14]. Canoe polo athletes on average failed to meet these dietary recommendations (average carbohydrate intake ranged from 5.0 to 5.79 g·kg<sup>-1</sup>·day<sup>-1</sup> (Table 3).

**Dietary fat intake recommendations:** Although the majority of fuel for canoe polo athletes is in the form of carbohydrate, fat also plays several important roles and is a crucial fuel source during endurance training (e.g., moderate intensity exercise up to 85% of VO<sub>2</sub> max) [25]. The general preparation phase features considerable amounts of endurance training where dietary fats are a significant source of fuel. The amount of dietary fat required for daily intramuscular triacylglyceride repletion after prolonged (>2 h) endurance training has been estimated at 2 g·kg<sup>-1</sup>·day<sup>-1</sup> [26]. Average fat intake in canoe polo athletes ranged from 1.39 to 1.7 g·kg<sup>-1</sup>·day<sup>-1</sup> (Table 2). Fat intake greater than 2 g·kg<sup>-1</sup>·day<sup>-1</sup> may compromise muscle glycogen recovery and muscle tissue repair

by displacing the intake of adequate amounts of carbohydrates and protein [7].

### Fueling during training

Canoe polo games are only 20 min in duration with a 3 min half time, therefore there is limited time to fuel with fluids or carbohydrates. However, given that some training sessions during the general preparation phase may exceed 2 h in length, there is sufficient opportunity to benefit from carbohydrate and fluid intake during training. Current recommendations suggest that 30-60 g·h<sup>-1</sup>, with greater amounts for exercise exceeding 2.5 h. For recent reviews see refs. [27,28]. Briefly, they report that the need for more specific and more personalized advice with regards to carbohydrate ingestion during exercise is required. The new guidelines take into account the duration (and intensity) of exercise and provide advice on amount of carbohydrate and the type of carbohydrate. Jeukendrup [29] suggest that combining multiple carbohydrate sources (i.e., fructose and glucose) can increase carbohydrate oxidation higher than 1 g·min<sup>-1</sup> (which is the upper limit for a single transportable carbohydrate). Multiple transportable carbohydrates are only required during long training sessions (>2.5 h). The form of carbohydrate does not seem to be a major factor with liquid, semisolid, or solid being equal. Lastly, carbohydrate intake guidelines are independent of body weight and training status [29]. A review by Phillips, Sproule, Turner [30] on carbohydrate intake on team sport performance, concluded that when protocols designed to mimic the demands of team sports are employed, the body of research clearly shows a benefit of carbohydrate intake on intermittent high-intensity exercise capacity.

Since canoe polo is a highly tactical and skill oriented sport, cognitive function is of importance. Carbohydrate supplementation can improve neuromuscular function via the attenuation of cognitive fatigue, which can reduce technical errors and enhance skill development [31]. A systematic review on soccer skill performance [32] concluded that 6 of 8 studies demonstrated that ingestion of 30-60 g of carbohydrate per hour with a 6 to 8% solution of glucose, sucrose, or maltodextrin was associated with an enhancement of at least one aspect of soccer skill performance (i.e., dribbling, shooting, passing, and heading).

### Nutrition to optimize recovery

Due to the variable nature and diversity of canoe polo training and competition, an individualized post training nutritional recovery plan needs to be implemented. Glycogen re-synthesis can be achieved by

| Variable                  | Alves et al. 2012      | Sheykhloovand (unpublished) |
|---------------------------|------------------------|-----------------------------|
|                           | Mean ± SD (range)      |                             |
| Energy (kcal)             | 3269 ± 527 (2745-4551) | 3571 ± 409 (2986-4024)      |
| Energy (kcal/kg)          | 42.8 ± 8.6 (33.5-62.5) | 41.2 ± 4.6 (36.4-49.0)      |
| Protein (g)               | 150 ± 19 (118-173)     | 147 ± 19 (121-171)          |
| Protein (g/kg)            | 1.9 ± 0.1 (1.6-2.2)    | 1.75 ± 0.16 (1.57-2.0)      |
| Protein (% of total kcal) | 19.0 ± 2.8 (12.4-22.8) | 16.4 ± 1.46 (14.2-18.3)     |
| CHO (g)                   | 377 ± 91 (238-568)     | 483 ± 104 (312-615)         |
| CHO (g/kg)                | 5.0 ± 1.5 (2.6-7.8)    | 5.79 ± 1.28 (3.42-7.22)     |
| CHO (% of total kcal)     | 46.5 ± 6.8 (31.9-54.0) | 53.9 ± 8.8 (37.6-63.7)      |
| Fat (g)                   | 130 ± 32 (87-190)      | 117 ± 35 (80-164)           |
| Fat (g/kg)                | 1.7 ± 0.4 (1.2-2.6)    | 1.39 ± 0.36 (0.93-1.58)     |
| Fat (% of total kcal)     | 35.3 ± 4.8 (27.6-42.7) | 29.5 ± 8.6 (18.4-43.9)      |

Note: 10 Brazilian (Alves et al. 2012) and 15 Iranian national team athletes (Sheykhloovand, unpublished) conducted food intake assessments using the means of three 24-h dietary recalls (two weekdays and one weekend day). CHO=carbohydrate

Table 3: Nutritional profile of canoe polo athletes.

1.2-1.5 g·kg<sup>-1</sup> body mass of carbohydrate ingested in close proximity to the training session [7,33]. Van Loon et al. [34] demonstrated that combining creatine (20 g/day for 5 days) in combination with exercise increase glycogen stores by ~20%. With regards to protein synthesis, 0.3 g·kg<sup>-1</sup> of body mass is recommended in close temporal proximity to the exercise bout to maximize the anabolic response to training [35].

### Nutrition for competition

Canoe polo tournament schedules vary greatly from competition to competition. At the previous World championships, each team played ~2 to 4 games per day over a 4 day period. In combination with the general and recovery recommendations highlighted above, several practical recommendations must be taken into account. It is important to be prepared for limited access to food at competition sites and to have snacks available to achieve carbohydrate and protein requirements.

### Potential ergogenic aids for canoe polo

Due to the high intensity and intermittent nature of canoe polo, glycolysis is the most likely predominant source of ATP re-phosphorylation. Glycolysis produces lactate and hydrogen ions (H<sup>+</sup>). The large increase in H<sup>+</sup> results in a decrease in muscle pH which inhibits phosphofructokinase, skeletal muscle contraction, re-synthesis of phosphagens, and the creatine phosphagen equilibrium [36]. β-Alanine provided in a dose of 3-6 g·day<sup>-1</sup> over 4-8 weeks (for a total intake of >120 g) results in an increase of muscle carnosine of about 40-50%, and will lead to a positive anaerobic performance outcomes in intense exercise lasting 1-6 min [37]. An extracellular buffer that has shown positive findings is sodium bicarbonate (NaHCO<sub>3</sub>). Edge, Bishop, and Goodman [38] found positive effects (increase lactate threshold and endurance capacity) of utilizing NaHCO<sub>3</sub> supplementation (0.2 g·kg<sup>-1</sup> at two time points; 90 and 30 min) before intense interval training (3 times a week for 8 weeks) in moderately trained females.

Creatine (Cr), a nitrogen-containing compound, is widely used to enhance high intensity exercise performance [39]. Creatine supplementation improves performance through increasing PCr, PCr recovery, and muscle buffering which may facilitate higher training intensities and therefore greater training adaptations. To date, there have been two studies investigating the performance effects of creatine combined with high intensity interval training with preliminary positive results [40,41]. There is emerging evidence that the timing of creatine supplementation may be an important consideration [42]. Creatine ingested in close temporal proximity to training appears to be an effective strategy to increase the anabolic response [43], with slightly enhanced benefits when creatine is consumed after exercise [42,44].

Caffeine acts as a central nervous system stimulant as an adenosine receptor antagonist and may improve short duration exercise. For detailed reviews, see [45,46]. Caffeine provided in a relatively small dose (2 mg·kg of body mass in a Redbull drink) improved upper body muscular endurance exercise [47]. Future research is warranted in canoe polo athletes.

There are several other nutritional supplements (such as beetroot juice [48], arginine, citrulline) which may improve high intensity intermittent performance, however research is limited.

### Future research directions

This review provides a review of the physiological demands and energetics of canoe polo and provided nutritional recommendations. This information can be used immediately by athletes, coaches, and sport practitioners to enhance training and competition performance.

With the growing interest and popularity of canoe polo, there is a greater need for further scientific evaluation. There is limited data published to date, future research in female players and position specific research is required.

### Acknowledgements

The authors have no potential conflicts of interest that are directly relevant to the content of this review.

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**Citation:** Forbes SC, Sheykhloovand M (2016) A Review of the Physiological Demands and Nutritional Strategies for Canoe Polo Athletes. *Sports Nutr Ther* 1: 116. doi: [10.4172/2473-6449.1000116](https://doi.org/10.4172/2473-6449.1000116)

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