Rev Esp Nutr Hum Diet. 2021; 25 (Supl. 1): e1029
Nutrition for Physical Activity and Sports

Freely available online - OPEN ACCESS

Revista Española de Nutrición Humana y Dietética
Spanish Journal of Human Nutrition and Dietetics

REVIEW ARTICLE

Dietary-nutritional needs in tennis: A narrative review

Necesidades dietético-nutricionales en el tenis: Una revisión narrativa

Raúl Domínguez[a], Antonio Jesús Sánchez Oliver[b], Sandro Fernandes da Silva[c,*], Alvaro López-Samanes[d], José Miguel Martínez-Sanz[e], Fernando Mata[f].

[a] Facultad de Ciencias de la Salud, Universidad Isabel I. Burgos, Spain.
[b] Departamento de Motricidad Humana y Rendimiento Deportivo, Facultad de Ciencias de la Educación, Universidad de Sevilla. Sevilla, Spain.
[c] Grupo de Estudos e Pesquisas em Respostas Neuromusculares (GEPREN), Departamento de Educação Física, Universidade Federal de Lavras. Lavras, Brazil.
[d] Laboratorio de Fisiología del Ejercicio, Facultad de Ciencias del Deporte, Universidad de Castilla La Mancha. Toledo, Spain.
[e] Departament d'Infermeria, Facultat de Ciències de la Salut, Universitat d'Alacant. Alicante, Spain.
[f] Nutriscience. Córdoba, Spain.
* sandrofs@def.ufla.br

Received: 18/03/2020; Accepted: 03/07/2020; Published: 24/07/2020

CITA: Domínguez R, Sánchez Oliver AJ, Fernandes da Silva S, López-Samanes A, Martínez-Sanz JM, Mata F. Dietary Nutritional in tenis: A narrative review. Rev Esp Nutr Hum Diet. 2021; 25 (Supl. 1): e1029. doi: 10.14306/renhyd.25.S1.1029

ABSTRACT

Introduction: Tennis is characterized by a large number of competitions and little recovery time between them. Thus, tennis players and coaching staff have become interested in the role that nutrition can play in maximizing sports performance. The scientific literature does not have recent narrative and/or systematic reviews about to nutrition in tennis. The aim of this study is to map, describe and discuss the state of the science of nutrition and dietetic practices for tennis players from a theoretical and contextual point of view, to enable focused future systematic reviews.

Material and methods: A narrative review through the Dialnet, Elsevier, Medline, Pubmed and Web of Science databases, through a search strategy based on keywords separated by Boolean connectors. A series of inclusion / exclusion criteria were applied to select those investigations that responded to the aim of the work.

Results: Nutritional recommendations on carbohydrate intake depend on the training load, 5-7 g/kg/day g/kg/day for normal training and 7-10 g/kg/day for competitive periods or high training load. The recommended protein intake is 1.8 g/kg/day and 1 g/kg/day of lipids. The supplements that can optimize tennis performance are caffeine, sodium bicarbonate, creatine and β-alanine. Beetroot juice can be a possible aid to consider in dietetic-nutritional planning in tennis players.

Conclusions: Performance and health of tennis player can be optimized, as well as adequate periodization of nutrients and supplements, meeting to the physiological demands of tennis.

Keywords: Tennis; Performance-Enhancing Substances; Diet, Food, and Nutrition; Dietary Supplements; Sports.

RESUMEN

Introducción: El tenis se caracteriza por una gran cantidad de competiciones y escaso tiempo de recuperación entre ellas. Por ello, los jugadores y cuerpos técnicos han empezado a interesarse por el papel que puede tener la nutrición para maximizar el rendimiento deportivo. En la literatura científica no encontramos revisiones narrativas y/o sistemáticas actualizadas sobre nutrición en el tenis. El objetivo de este estudio es mapear, describir y discutir el estado de la ciencia de la nutrición y las prácticas dietéticas para tenistas desde un punto de vista teórico y contextual, para permitir futuras revisiones sistemáticas.

Material y métodos: revisión narrativa a través las bases de datos Dialnet, Elsevier, Medline, Pubmed y Web of Science, mediante una estrategia de búsqueda basada en palabras clave separados por conectores booleanos. Se aplicaron una serie de criterios de inclusión/exclusión para seleccionar aquellas investigaciones que respondían al objetivo del trabajo.

Resultados: Las recomendaciones nutricionales sobre la ingesta de carbohidratos varían en función de la carga del entrenamiento, siendo 5-7 g/kg/día para entrenamiento normal y 7-10 g/kg/día para periodos competitivos o de mayor carga. La ingesta recomendada de proteínas se encuentra en 1,8 g/kg/día y 1g/kg/día de lípidos. Respecto a los suplementos que pueden optimizar el rendimiento en tenis encontramos la cafeína, bicarbonato de sodio, creatina y β-alanina, siendo el zumo de remolacha una posible ayuda a contemplar en la planificación dietético-nutricional en tenistas.

Conclusiones: Es posible optimizar el rendimiento y la salud del tenista mediante una periodización adecuada de nutrientes y suplementos, que cumplan las exigencias fisiológicas del tenis.

Palabras clave: Tenis; Sustancias para Mejorar el Rendimiento; Nutrición, Alimentación y Dieta; Suplementos Dietéticos; Deportes.

INTRODUCTION

Tennis is a racket sport in which two opponents face off against each other in matches of 3 or 5 sets on different types of playing surfaces such as grass, clay and hard[1]. Tennis competition is characterized by alternating short bouts of high-intensity efforts with periods of moderate to low intensity (active recovery) between points and rest during changeovers[2]. The mean point duration (high-intensity exertion) is 4-10 seconds, with a recovery time (active recovery) of 20 seconds between points during individual games and of about 90-120 seconds during changeovers and between sets. Thus, the actual playing time during a match varies from 21 to 38.5% of the match's total duration[3]. Although tennis matches take an average of 90 minutes play[4] they can last up to 5 hours[2].

At the metabolic level, carbohydrates are the main energetic substrate when playing tennis[5]; they are metabolized by both oxidative and non-oxidative processes (glycolysis), furthermore, the high intensity and duration (4-10 seconds) of the points[3] make the high-energy phosphagen system, which is the primary energy system in efforts lasting up to 6 seconds and of maximum intensity an important contributor to energy metabolism[6]. With regards to physical abilities, the key is being able to maintain high levels of strength and power output over extended periods of time[7] combined with high levels of coordination and serve velocity[8]. Thus, the inability to produce enough force to maintain powerful and precise strokes is considered to be the main limiting factor of tennis performance[9]. Factors which may lead to strength/power losses and accuracy when playing may include the depletion of phosphocreatine (PCr) and glycogen reserves, hypoglycemia, central fatigue, a decrease in pH, dehydration and hyperthermia.

High intensities during each point (i.e. 4-7 seconds of maximum intensity) can partially deplete the body's phosphocreatine reserves[10]. PCr restoration rate consists of a first phase lasting 30 seconds in which ~50% of the PCr are replenished and a second phase of 3-5 minutes in which PCr are nearly completely restored[9], which leads one to believe that the time between points and changeovers during tennis matches allow for continuous restoration of the PCr reserves. However, it is possible that restoration is incomplete and, as a match or high-intensity training session on the court progresses, significant PCr depletion occurs over time[11]. Just as with low PCr reserves, limited muscle and liver glycogen reserves may become depleted during highly demanding matches[12]. The low bioavailability of glycogen affects tennis performance by making it impossible to metabolize carbohydrates either by oxidative or non-oxidative processes[13]. One of the most obvious effects of the depletion of muscle glycogen reserves is hypoglycemia, a symptomatology which occurs in 64% of athletes when playing sports[12]. Hypoglycemia decreases both physical and mental performance and, in addition, is accompanied by catabolic processes[14].

The decrease in blood glycemia is accompanied by an increase in the levels of free fatty acids in the blood and in gluconeogenic processes[15], thus increasing the contribution of amino acids to energy metabolism, with branched-chain amino acids (BCAA) being quantitatively more important. The metabolic use of BCAA increases the tryptophan and BCAA ratio (which are bound to albumin), resulting in an increase in free-tryptophan concentrations which, after crossing the blood-brain barrier, becomes a precursor of serotonin[16], which results in an increase in the subjective perception of effort or central fatigue. In numerous studies attempts to explain this hypothesis of central fatigue produced by the displacement of free tryptophan. The BCAA can act as a neurotransmitter per se, one of their functions being the reduction of fatigue. Another function is related or to the sensitivity of the 5-HT receptor: trained athletes may develop a lower sensitivity, which may contribute to an increase in exercise tolerance.

A decrease in pH has also been identified as a factor which limits tennis performance[9]. Activation of glycolysis leads to an accumulation of H^+ ions, which leads to a progressive decrease in pH, which increases to the extent that this metabolic pathway's contribution to energy metabolism increases[6]. Intramuscular H^+ accumulation leads to the inhibition of phosphofructokinase (PFK), an enzyme which favors adenosine triphosphate (ATP) resynthesis through glycolysis and PCr. Because the two critical requirements for muscle contraction are the presence of ATP and calcium in myocyte sarcoplasm, the inhibition of phosphofructokinase caused by the increase in H^+ decreases the rate of ATP delivery through the two systems[6] as well as causing an increase in the subjective perception of the effort. So, considering the important contribution to the glycolysis to metabolism[5], as the duration of a match is increased, could set up a progressive decrease in pH that could affect to the anaerobic metabolism.

During tennis competition, tennis players rate of dehydration can lead to losses of 0.5-2.7% of his/her body weight per hour of play[17]. This rate of sweating led to set up of body weight loss to >2% that is the value which sport performance is affecting and must be avoided by a correct fluid intake[18]. This implies that tennis players may experience dehydration, another factor linked to limit tennis performance[13]. A decrease in body fluids causes a reduction in cardiac output, resulting in an increase in heart rate at a given workout intensity as well as an increase in glycolysis[5], which, in turn results in a greater decrease in pH, another factor that limits performance[9]. Moreover, dehydration causes muscle cramps[18], in addition to decreased thermoregulatory capacity, a significant increase in plasma concentrations of catecholamines, ADH, renin, cortisol, adrenocorticotropic hormone, aldosterone, angiotensin, and the natriuretic atrial peptide[19,20]. In fact, dehydration is associated with the degree of dehydration of an athlete, with the duration of matches[21], opportunities for the ingestion of fluid during competition and/or a lack of knowledge regarding the nutritional requirements of and fluid consumption by athletes. The inadequate intake of liquid or electrolytes influences the development of dehydration, which is sometimes followed by hyponatremia associated with exercise (EAH), due to excessive hypo-osmotic fluid replacement[22,23]. Since internal temperatures above 40 °C can be life-threatening and accelerate the feeling of fatigue, the nervous system sends out neurological signals aimed at getting the athlete to cease exertion, thus limiting performance[21].

Dietary intake alters adaptations to exercise and training programs[24,25]. Thus, an adequate selection of nutrients and supplements which takes into account ingestion time in relation to the exercise improves athletes' performance, as well as their state of health[25] and may represent one of the most important factors in the prevention of, and the recovery from, sports injuries[4].

According to Maughan[26], dietary intervention in athletes should take in account the performance-limiting factors of each sport modality as a first step towards establishing nutritional goals which take into account said performance-limiting factors and, subsequently, designing strategies aimed at achieving those goals. Practical nutritional recommendations for this sport were established in 2013[5], but currently, the scientific literature related to nutrition in tennis does not have recent narrative and / or systematic reviews that address this issue.

The aim of this review is to describe and discuss the state of the knowledge of nutrition and dietetic practices for tennis players from a theoretical and contextual point of view, to enable focused future systematic reviews in some subtopics.

MATERIAL AND METHODS

This narrative review was conducted through a combined English and Spanish language search in the following databases: Dialnet, Elsevier, Medline, Sport Discus, Pubmed, Web of Knowledge and Web of Science. For the search process, terms found in the thesaurus "Medical Subject Headings" (MeSH), developed by the U.S. National Library of Medicine, were used. The terms used in the search were "tennis" and "racket sport" combined with "nutrition", "sport nutrition", "ergogenic aids and supplementation". Also, relevant references related to the topic of the selected articles were searched for manually.

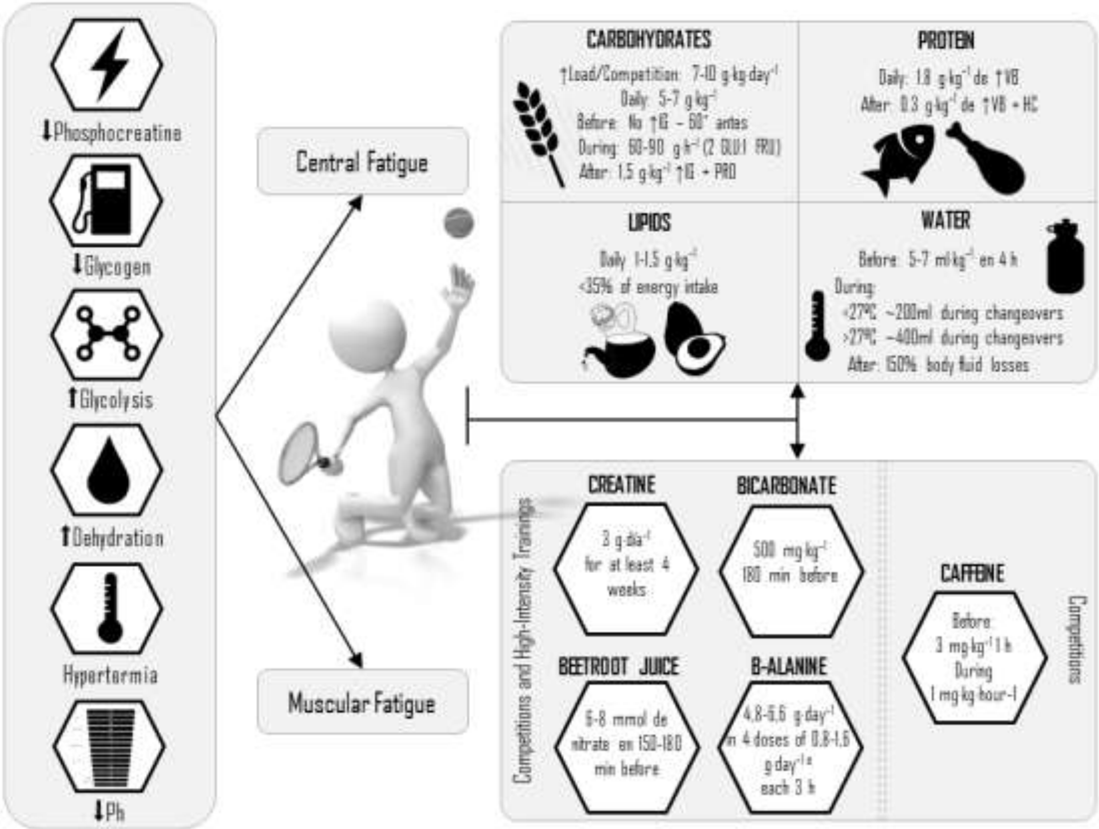
Although the manuscript is a narrative review, the process of articles selection published in Spanish, English or Portuguese was based on PICOS criteria. So, two authors independently performed the search and applied the next inclusion criteria based on PICOS: population (sample or topic -for reviews- based on tennis players), intervention (nutritional intervention, including sport supplements ingestion), comparison (in the randomized controlled trial to compare with a control condition), outcomes (analyze physical performance and/or biochemical parameters) and settings (randomized controlled studies and specific reviews of the topic). Before redacting the results and discussion sections, two authors performed a summary of each articles were registered the characteristics of the sample, the type of nutritional intervention, the tests of sport performance or biochemical parameters analyzed and the main results being all these data included in the results and discussion section.

RESULTS AND DISCUSSION

Energy Intake

One of the main objectives of athlete nutrition is to optimize performance, which lies in its contribution to an adequate energy intake where energy contribution is equal to energy expenditure[24]. This is important due to the fact that hypocaloric intake adversely affects levels of lean mass and, in the case of women, has been associated with possible changes in menstrual function and osteopenia[27]. For this reason, it is important to adjust the energy content of an athlete's diet based on the load of the different training periods and the duration and demands of a tennis match, taking into account that the estimated energy expenditure per hour of play in male athletes is 649±105 kcal/h, while in women, the estimated energy is considerably lower[5]. In addition to energy content and macronutrients, which will be discussed later, it is important that a tennis player's diet meet the daily intake requirements for all vitamins and minerals[24] (Figure 1).

Figure 1. Recommendation of macronutrients during training/competitions in tennis.



Carbohydrates

Carbohydrates, together with phosphocreatine, are considered to be the main energetic substrate when playing tennis[5]. During a tennis match, hypoglycemia and depletion of muscle glycogen reserves can be established[12]. A high-carbohydrate diet permits the replenishment of muscle glycogen reserves[28] and may prevent hypoglycemia[13,28], a performance-limiting factor in tennis which has a prevalence of ~64%[12], thus maintaining immune system health and avoiding overtraining[1].

During training periods characterized by high loads, tennis players spend about 4-6 hours a day training[5]. It has been established that players should have a carbohydrate intake of 7-10 g/kg/day during high-intensity training periods and tournaments, reducing their daily intake requirements to 5-7 g/kg/day during regular training periods[29]. However, in addition to the amount of carbohydrates ingested, the distribution of carbohydrate intake in relation to exertion is of great importance.

The pre-exercise recommendation is that the required carbohydrates be ingested prior to exertion, although nutrient intake should be avoided within 45 minutes prior to playing tennis[29]. This recommendation is due to the fact that carbohydrate intake just before exercise, either in liquid or solid form, results in a sudden and disproportionate increase in blood glucose concentrations which precede a decrease in the same due to excessive insulin production which leads to rebound hypoglycemia[12]. However recently Jeunkendrep et al.[30] reported contradictory findings to the approach.

Although some studies have found that a diet with a high carbohydrate content (65% of energy intake) is sufficient to avoid the onset of hypoglycemia[31], other studies have found that carbohydrate intake during exercise shows higher levels of blood glucose[13,15]. With regards to the effects on performance, one study has verified that carbohydrate intake while playing tennis does not affect parameters like the number of games won, aces served, efficacy during the game, the number of double faults, or faults on the first or second service[15]. However, other studies have reported a lower number of first-service faults[28], a greater effectiveness in hitting the ball during the final phase of a 2-hour workout and a higher level of intensity and lower perception of fatigue during a series of 3 matches[31], thus maintaining immune system health and avoiding overtraining[1].

During periods with a high training load, tennis players spend about 4-6 hours a day training[5]. It has been established that players should have a carbohydrate intake of 7-10 g/kg/day during high-intensity training periods and tournaments, reducing their daily intake requirements to 5-7 g/kg/day during regular training periods[29]. However, in addition to the amount of carbohydrates ingested, the distribution of carbohydrate intake in relation to exertion is of great importance. The pre-exercise recommendation is that the required carbohydrates be ingested prior to exertion, although nutrient intake should be avoided within 45 minutes prior to playing tennis[29]. This recommendation is due to the fact that carbohydrate intake just before exercise, either in liquid or solid form, results in a sudden and disproportionate increase in blood glucose concentrations which precede a decrease in the same due to excessive insulin production which leads to rebound hypoglycemia[12]. However recently Jeukendrup et al.[30] reported contradictory findings to the approach.

Although some studies have found that a diet with a high carbohydrate content (65% of energy intake) is sufficient to avoid the onset of hypoglycemia[31], other studies have found that carbohydrate intake during exercise shows higher levels of blood glucose[13,15]. With regards to the effects on performance, one study has verified that carbohydrate intake while playing tennis does not affect parameters like the number of games won, aces served, efficacy during the game, the number of double faults, or faults on the first or second service[15]. However, other studies have reported a lower number of first-service faults[28], a greater effectiveness in hitting the ball during the final phase of a 2-hour workout and a higher level of intensity and lower perception of fatigue during a series of 3 matches[31].

In cases where carbohydrates are ingested during tennis training/competitions[28,31], as greater sustained intensity[31], which may be due to a delay in the depletion of muscle glycogen reserves as well as a higher oxidation rate of exogenous carbohydrates[32]. The stimulation of carbohydrate metabolism while eating carbohydrates during exercise[31], coincides with a smaller increase in cortisol levels during exercise[15]. The efficacy of carbohydrates in reducing the cortisol response attenuates the increase of free fatty acids in blood as well as the metabolic use of amino acids, and the metabolic actions of cortisol, thus avoiding the onset of central fatigue[15].

A good type of carbohydrate to use during exercise could be a solid form added to sports drinks. With respect to this, a meta-analysis has shown that beverages with a 6-8% carbohydrate concentration improve endurance-related performance[33]. In any case, the maximum carbohydrate intake which can be ingested while playing sports is determined by the maximum absorption rate of the glucose (1.1 g/min) and fructose (0.6 g/min) (90 g/h) of carbohydrates provided that a 2:1 ratio between glucose and fructose is maintained[33].

At the end of exercise, the glycogen resynthesis rate is higher increasing replenishment to a greater extent when carbohydrates with a high glycemic index are ingested versus when carbohydrates with a low glycemic index are ingested[33]. Thus, a carbohydrate intake of 1.5 g/kg is recommended, especially during periods of high training load and in tournaments[29].

Proteins

Maintaining lean mass requires a nitrogen balance in which the rate of protein synthesis is equal to the degradation rate. Protein contribution to energy metabolism ranges from 1-1,5%[34]. However, in tennis players, protein requirements may be higher because the metabolic contribution of the same increases when glycogen reserves decrease[34]. It may be inferred that the protein intake requirements would be higher due to the fact that muscle glycogen reserves may be depleted during tennis matches[12]. Moreover, because strength and power training is a factor in tennis performance[9], tennis players include strength training sessions in their training programs; therefore, protein requirements also increase.

Protein intake recommendations often distinguish between resistance and strength modalities. The daily protein requirements for tennis have been set at 1.8 g/kg/day because tennis possesses characteristics of both types of modalities[5]. However, when proteins are ingested, as well as their co-ingestion with other nutrients, appears to be just as important as the amount of proteins ingested[5].

Protein intake at the end of exercise promotes the synthesis of new muscle proteins and a positive nitrogen balance, as well as mitochondrial adaptations and increased glycogen resynthesis capacity[34]. However, the anabolic effects of protein intake, which are associated with serum leucine concentrations and leucine thresholds at which synthesis of myofibrillar protein increases[35], are dependent on the quality and quantity of the protein source[35]. The leucine threshold would be reached with an intake of ~0.3 g/kg of protein of high biological value[36]. Which should be the recommended post-exercise protein intake, in addition to the recommended post-exercise carbohydrate intake[5].

Lipids

Due to the high-intensity exertion characteristic of tennis[37] which makes fat contribution to metabolism unimportant, intramuscular triglycerides are an important energy source in long-duration exercise which may provide a considerable metabolic contribution during recovery periods[38]. Furthermore, a fat-deficient diet makes it difficult to meet the body's intake requirements for essential fatty acids and fat-soluble vitamins in addition to being associated with the appearance of injuries in athletes of different sports modalities[37]. For this reason, the recommended daily intake of lipids for tennis players is 1-1.5 g/kg/day[5], establishing a range of 20-35% of energy intake[24,25].

With regards to omega-3 fatty acids, because they are involved in cognitive function, their supplementation has been shown to improve performance, assessed whether an omega-3 supplement of 670 mg/day would improve performance in a tennis skill test[39]. This study found that, in the population studied (pediatric population), omega-3 supplementation enhanced the improvements even though, upon analysis, the DHA content of the diet was <0.3 g/day. Because experienced tennis players present an automated technique, having passed the learning and technique acquisition stage, a diet with a lipid profile that is rich in unsaturated fatty acids and which contains nutritional sources which have high omega-3 contents, like blue fish, should be recomended[39].

Hydration

Tennis dehydration rate which has been situated between 0.5-2.7% of body mass per hour of play[17]. Dehydration equivalent to a loss of 1.5-2% of body weight is considered to be sufficient to decrease physical performance[18]. For this reason, high sweating rates when playing tennis mean that inadequate water intake leads to dehydration, which acts as a performance-limiting factor[13]. The first objective for a tennis player is to begin play with an adequate state of hydration. To meet this objective, athletes should follow general hydration guidelines, which recommend the intake of 5-7 mL/kg of fluids in the 4 hours prior to playing, to which an additional 3-5 mL/kg should be added in cases of dark-colored urine or no urine output[18]. While playing, one should try to maintain a stable body weight because, when the thirst stimulus appears, the body has already lost 1.5 L of its water[14], and performance may have already been reduced[18]. An intake of ~200 mL per changeover is recommended in environments with a temperature < 27 °C, increasing intake up to 400 mL per changeover in humid conditions and in cases where the ambient temperature exceeds 27 °C[14]. One of the supplements more utilized the tennis player is the sports drinks[40]. When finished exercising, one of an athlete's nutritional goals should be to return to a properly hydrated state as quickly as possible. It is recommended that 150% of the amount of fluids lost during exercise be ingested[1,41].

Ergogenic Aids

Sports supplementation, which is understood as additional support to normal nutrition, has been proposed as being effective in improving athletes' recovery and training capacity[4]. In addition, certain nutritional supplements, called nutritional ergogenic aids, must be considered because they can improve sports performance[41] including tennis performance (Table 1), although there is still controversy over with the possible ergogenic effects of some substances, such as beetroot juice.

Table 1. Ergogenic aids and effects in tennis.

Ergogenic aid	Effects	Dose	Recommendations
Caffeine[5,42]	Stimulator of the central nervous system (CNS), enhance muscle contractility, recruitment of motor units, reduction of subjective perception of effort and improvement of thermoregulation.	3 mg/kg one hour before competition	During competitions
Creatine[5,43]	Improvement of PCr resynthesis, regulation of acid-base balance and membrane stabilization.	3 g/day at least 4 weeks before of the event	Periods with high training loads and competitions
Sodium Bicarbonate[24,44]	Regulator of acid-base balance at extracellular level.	500 mg/kg 180 minutes before competition/training	High-intensity trainings and competitions
β-alanine[37,45]	Regulator of acid-base balance at the intracellular level and improvement of muscle contraction.	6.4 g/day in 4-8 doses de 0.8-1.6 g at 3 hours intervals	Periods with high training loads and competitions

Caffeine

Caffeine is an alkaloid of the methylated xanthine family and an adenosine receptor antagonist, which can be found in many of the typical Western diet foods like tea, coffee or cocoa. Caffeine's main effect on performance is its effects on central nervous system stimulation by adenosine antagonism and, although it also serves to increase motor unit recruitment[46], and improving thermoregulation[47].

In tennis, supplementation with a dose of 3 mg/kg of caffeine has been shown to be effective at maintaining serve speed in the final stretch of a simulated match[13] and reducing the subjective perception of effort during an extended match[5]. In addition, in another racket sport, such as badminton, supplementation with 3 mg/kg of caffeine has been shown to increase jump height in both squat-jumps (SJ) and countermovement-jumps (CMJ) and increase performance in an agility test[48]. In badminton, it has also been shown that supplementation with 4 mg/kg of caffeine together with carbohydrates (7 mL/kg of drink with 6.4% of carbohydrates) improves long and short serve accuracy after a 33-minute protocol designed to create fatigue[49]. Caffeine absorption processes are rapid, with high serum levels at 30-45 minutes post-ingestion and peak levels after 1 hour[42]. Although the effects of caffeine supplementation increase as the supplemental dose increases, there is a plateau effect from 3 to 9 mg/kg of caffeine[42]. In In order to maintain the highest possible serum levels during a match, a caffeine intake of 3 mg/kg in the hour before the start of a match is necessary, incorporating an additional 1 mg/kg per hour of match duration[42]. An excessive consumption of caffeine (≥9 mg/kg BM) can increase the risk of negative side effects: nausea, anxiety, insomnia, restlessness, diarrhea, headache and lack of concentration[50]. Lower caffeine doses, variations in the timing of intake before and/or during exercise should be trialled in training prior to competition use[51].

Creatine

Creatine is an amino acid synthesized from arginine, glycine and methionine, although, it can also be obtained through diet, primarily by consuming meat products, fish and eggs[45]. It is estimated that 50% of daily creatine requirement of 2 g per day comes from endogenous synthesis and the remaining half from dietary intake[45]. The main function of creatine is related to the rapid resynthesis capacity of phosphocreatine[51], although it has also been shown to act as a buffer in acid-base balance regulation[53].

In any case, creatine monohydrate supplementation has been shown to be effective in high-intensity, short-duration and intermittent sports, so, despite the lack of ergogenic effects in the tennis filed it has been proposed that[54], creatine supplementation may be considered an ergogenic aid of potential use in tennis due to the sport's repeated high-intensity rest-exercise transitions[5]. Because a long-term creatine intake of 3 g/day has the same effects on intramuscular creatine levels as protocols that begin with a loading phase during the first few days[43], this 3 g/day supplementation could be considered adequate[43]. Recent research has indicated no negative health effects are noted with long-term use (up to 4 years) of creatine when appropriate loading protocols are followed[24]. Future studies should be developed with creatine ingestion in the tennis field, specially studying the effects of creatine in match-play demands.

Sodium Bicarbonate (SB)

Sodium bicarbonate is the main acceptor of H^+ from glycolysis produced during exercise[6]. SB supplementation increases sodium bicarbonate levels and blood pH[55], favoring the flow of lactate and H^+ to the systemic circulation[56], permitting attenuation of the decrease in intramuscular pH; a limiting factor of performance[55].

A single study that evaluated the effect of SB supplementation on a simulated tennis match found that, at the end of exercise, lactate concentrations were higher (implying a greater contribution of glycolytic metabolism to exercise) without an increase in the subjective perception of effort[57]. In addition, that study reported a lower percentage of service errors, as well as significant improvements when combining forehand and backhand shots. These results, together with other studies which have reported ergogenic effects of SB in other types of exertion including intermittent high-intensity exercise and long-duration exercise of submaximal intensity[57-60] could make SB an ergogenic supplement for tennis[1,58].

Due to the relatively high prevalence of side effects and the fact that recommended SB intake has been established at 200-400 mg/kg[24] consumed 60–150 min prior to exercise, doses of 300 mg/kg are often used. However, research has shown that a 500 mg/kg SB supplement has a significantly greater effect, at least in a 30-second maximum-intensity test on a cycle ergometer performed by judokas[44], but this effect is likely does not apply in tennis. In spite of this, instead of decreasing the supplemental dose, an alternative is to use sodium citrate, a supplement with effects similar to SB but with reduced gastrointestinal discomfort, main adverse effects of this ergogenic aids[61]. Because sodium citrate supplementation raises the pH peak in blood at 180-215 minutes and its side effects occur at 65-95 minutes post-ingestion respectively, it is recommended that sodium citrate be administered in the 3 hours prior to exercise[44].

β-alanine (BA)

The aim of BA supplementation is to increase synthesis of carnosine, a dipeptide formed by BA and histidine which is limited by the amount of BA in the diet[62]. The main function of carnosine is related to pH regulation, being the main protein with an intracellular buffer effect, in addition to improving muscle contraction through an improvement in the calcium uptake and re-uptake processes in the sarcoplasmic reticulum[62]. BA supplementation is effective in speed tests[62] in strength and endurance tests[63]. Moreover, BA supplements have been shown to potentially enhance the effects of SB supplements, with a combination of the two improving performance to a greater extent than intake of each one separately[63]. Despite the absence of tennis-specific studies, BA supplementation could improve performance because of the intermittent dynamics of the sport[37]. The main adverse effect of BA supplementation is paresthesia[64]. The symptomatology of paresthesia originates from an increase in BA levels in the blood. This symptomatology, which appears at doses above 10 mg/kg, is proportional to the levels of BA in the blood[62]. Because BA levels in the blood normalize at 3 hours post-ingestion, it is recommended that the ergogenic dose of BA (4.8-6.4 g/day) be divided into four to eight 0.8-1.6 g/day partial doses taken with a 3-hour period in between each partial dose[53].

Beetroot juice (BJ)

BJ is a supplement containing high amounts of inorganic nitrate (NO3-) and is used in sports because of its ability to raise nitric oxide (NO) levels. Approximately 25% of NO3- is reduced to nitrite (NO2-) in the oral cavity by NO3- reductase, which is present in microorganisms found there[65]. The NO2- is partially reduced to NO by the action of stomach acids, which is subsequently absorbed in the intestines, in addition, part of the NO2- goes to the systemic circulation where it is converted to NO in situations of hypoxia[65].

NO has many physiological functions such as vasodilatation, increasing blood flow at the muscular level, improving the gas exchange processes in muscle fiber, stimulating gene expression, as well as increasing biogenesis and mitochondrial efficiency[66]. All these physiological effects allow BJ supplementation to improve performance in endurance and high-intensity modalities[67,68]. However, several studies have reported ergogenic effects of BJ supplementation on performance in resistance training[69] or intermittent high-intensity exercise[67]. In the recent study the BJ supplementation, no effect of performance the tennis players after a single dose of 70 mL of BJ, but was observed a trend to statistical differences in an agility test (p=0.071) and an isometric handgrip strength (p=0.069)[70]. So, considering that in a study was reported an ergogenic effect of BF after a single dose of 140 mL and 280 mL, but not after 70 mL[71] while another studies have observed ergogenic effect after a chronic supplementation (14[72] - 28[73] days), suggesting select chronic doses with at least 140 mL of BJ for have possible ergogenic effect of this supplement. In addition, attending to the peak levels of NO_2^- in the blood occur 2-3 hours after ingesting BJ, with the ergogenic effects of BJ supplementation observed from 150 minutes post-ingestion[74], the timing correct must be around 150 minutes before exercise. Nevertheless, actually the ergogenic effect of BJ supplementation on tennis must be taken with caution.

CONCLUSIONS

Due to the physiological demands of tennis, players have specific macronutrient requirements. As a result, carbohydrate intake should rise to 7-10 g/kg/day during periods with a high training load and tournaments versus 5-7 g/kg/day during periods of normal training. Furthermore, daily protein intake should be 1.8 g/kg/day and lipid intake should be 1 g/kg/day (not exceeding 35% of energy intake). The nutrition professionals must take into account the nutritional quality of food and supplements in the dietetic-nutritional planning for tennis players. It is also important to remember that the proper timing and dosing of caffeine, creatine, sodium bicarbonate and BA supplements may optimize performance in this sporting modality. Furthermore, the adverse effects of ergogenic aids must also be taken into account to the dietetic-nutritional planning. This review provides an update about the optimal amount and timing of fluid, carbohydrate, fat, protein and supplements intake in tennis players at different in training sessions or competitions. The authors provide an approximation of standardized, valid and reliable tennis-specific protocols. Despite the popularity of tennis worldwide, there is little scientific literature on this sport. Future research should investigate the dietary intake and effect of supplements, as beetroot juice, in professional and recreational tennis players, in addition to establishing specific protocols based on evidence of supplements.

FUNDING

This research received no external funding.

CONFLICTS OF INTERESTS

Authors state that there are no conflicts of interest in preparing the manuscript.

AUTHOR CONTRIBUTION

RD, AJSO and SFdS designed the study; JMMS, FM and ALS reviewed and supervised the study; RD, AJSO and SFS interpreted the data; SFS and ALS they wrote the manuscript; RD, AJSO, JMMS and FM they reviewed and edited the manuscript; all authors will approve the final version of the manuscript.

REFERENCES

(1) Tavío P, Domínguez Herrera R. Necesidades dietético-nutricionales en la práctica profesional del tenis: Una revisión. Nutr Clin Diet Hosp. 2014;34(2):18–28.

(2) Fernandez J, Mendez-Villanueva A, Pluim BM. Intensity of tennis match play. Br J Sports Med. 2006;40(5):387–91.

(3) Kovacs MS. Tennis Physiology. Sport Med. 2007;37(3):189–98.

(4) Kondric M, Sekulic D, Uljevic O, Gabrilo G, Zvan M. Sport nutrition and doping in tennis: an analysis of athletes' attitudes and knowledge. J Sports Sci Med. 2013;12(2):290–7.

(5) Ranchordas MK, Rogersion D, Ruddock A, Killer SC, Winter EM. Nutrition for tennis: practical recommendations. J Sports Sci Med. 2013;12(2):211–24.

(6) Chamari K, Padulo J. 'Aerobic' and 'Anaerobic' terms used in exercise physiology: a critical terminology reflection. Sport Med - Open. 2015;1(1):9.

(7) Girard O, Millet GP. Physical Determinants of Tennis Performance in Competitive Teenage Players. J Strength Cond Res. 2009;23(6):1867–72.

(8) Ulbricht A, Fernandez-Fernandez J, Mendez-Villanueva A, Ferrauti A. Impact of Fitness Characteristics on Tennis Performance in Elite Junior Tennis Players. J Strength Cond Res. 2016;30(4):989–98.

(9) Girard O, Lattier G, Maffiuletti NA, Micallef JP, Millet GP. Neuromuscular fatigue during a prolonged intermittent exercise: Application to tennis. J Electromyogr Kinesiol. 2008;18(6):1038–46.

(10) Sanchez-Oliver AJ, Mata F, Grimaldi-Puyana M, Domínguez R. Necesidades nutricionales e hídricas en el tenis. ITF Coach Sport Sci Rev. 2017;25(13):13–5.

(11) Domínguez R, Mata F, Sanchez-Oliver A. Nutrición Deportiva Aplicada: Guía para Optimizar el Rendimiento. 1ª. Editores I, editor. 2017. 405 p.

(12) Ferrauti A, Pluim BM, Busch T, Weber K. Blood glucose responses and incidence of hypoglycaemia in elite tennis under practice and tournament conditions. J Sci Med Sport. 2003;6(1):28–39.

(13) Hornery DJ, Farrow D, Mujika I, Young WB. Caffeine, Carbohydrate, and Cooling Use during Prolonged Simulated Tennis. Int J Sports Physiol Perform. 2007;2(4):423–38.

(14) Kovacs MS. A Review of Fluid and Hydratio in Competitive Tennis. Int J Sports Physiol Perform. 2008;3(4):413–23.

(15) Gomes R, Capitani C, Ugrinowitsch C, Zourdos M, Fernandez-Fernandez J, Mendez-Villanueva A, et al. Does carbohydrate supplementation enhance tennis match play performance? J Int Soc Sports Nutr. 2013;10(1):46.

(16) Yamamoto T, Azechi H, Board M. Essential Role of Excessive Tryptophan and its Neurometabolites in Fatigue. Can J Neurol Sci. 2012;39(01):40–7.

(17)Bergeron MF. Heat cramps: Fluid and electrolyte challenges during tennis in the heat. J Sci Med Sport. 2003;6(1):19-27.

(18) American College of Sports Medicine, Sawka MN, Burke LM, Eichner ER, Maughan RJ, Montain SJ, et al. American College of Sports Medicine position stand. Exercise and fluid replacement. Med Sci Sports Exerc. 2007;39(2):377–90.

(19) Urdampilleta Otegui A, Martínez Sanz J, Julia Sánchez S, Álvarez Herms J. Protocolo de hidratación antes, durante después de la actividad físico-deportiva. Eur J Hum Mov. 2013;(31):57–76.

(20) Magee PJ, Gallagher AM, McCormack JM. High prevalence of dehydration and inadequate nutritional knowledge among university and club level athletes. Int J Sport Nutr Exerc Metab. 2017;27(2):158–68.

(21) Morante SM, Brotherhood JR. Thermoregulatory responses during competitive singles tennis. Br J Sports Med. 2008;42(9):736–41.

(22) Hew-Butler T, Rosner MH, Fowkes-Godek S, Dugas JP, Hoffman MD, Lewis DP, et al. Statement of the Third International Exercise-Associated Hyponatremia Consensus Development Conference, Carlsbad, California, 2015. In: Clinical Journal of Sport Medicine. Lippincott Williams and Wilkins; 2015. p. 303–20.

(23) Thomas DT, Erdman KA, Burke LM. Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and Athletic Performance. J Acad Nutr Diet. 2016;116(3):501-28.

(24) Maughan RJ, Burke LM, Dvorak J, Larson-Meyer DE, Peeling P, Phillips SM, et al. IOC consensus statement: Dietary supplements and the high-performance athlete. Br J Sports Med. 2018;52(7):439–55.

(25) Kerksick CM, Wilborn CD, Roberts MD, Smith-Ryan A, Kleiner SM, Jäger R, et al. ISSN exercise & sports nutrition review update: Research & recommendations. J Int Soc Sports Nutr. 2018;15(1):1–57.

(26) Maughan RJ. Nutritional status, metabolic responses to exercise and implications for performance. Biochem Soc Trans. 2003;31(Pt 6):1267–9.

(27) Łagowska K, Kapczuk K, Friebe Z, Bajerska J. Effects of dietary intervention in young female athletes with menstrual disorders. J Int Soc Sports Nutr. 2014;11(1):21.

(28) Hargreaves M, Hawley JA, Jeukendrup A. Pre-exercise carbohydrate and fat ingestion: effects on metabolism and performance. J Sports Sci. 2004;22(1):31–8.

(29) Kovacs MS. Carbohydrate intake and tennis: are there benefits? Br J Sports Med. 2006;40(5):e13.

(30) Jeukendrup AE, Killer SC. The myths surrounding pre-exercise carbohydrate feeding. Ann Nutr Metab. 2010;57(Suppl. 2):18–25.

(31) Peltier SL, Leprêtre P-M, Metz L, Ennequin G, Aubineau N, Lescuyer J-F, et al. Effects of Pre-exercise, Endurance, and Recovery Designer Sports Drinks on Performance During Tennis Tournament Simulation. J Strength Cond Res. 2013;27(11):3076–83.

(32) Clarke ND, Drust B, Maclaren DPM, Reilly T. Fluid provision and metabolic responses to soccer-specific exercise. Eur J Appl Physiol. 2008;104(6):1069–77.

(33) Jeukendrup AE. Carbohydrate intake during exercise and performance. Nutrition. 2004;20(7–8):669–77.

(34) Tarnopolsky M. Protein requirements for endurance athletes. Nutrition . 2004;20(7–8):662–8.

(35) Devries MC, Phillips SM. Supplemental protein in support of muscle mass and health: Advantage whey. J Food Sci. 2015;80(S1):A8–15.

(36) Moore DR, Churchward-Venne TA, Witard O, Breen L, Burd NA, Tipton KD, et al. Protein Ingestion to Stimulate Myofibrillar Protein Synthesis Requires Greater Relative Protein Intakes in Healthy Older Versus Younger Men. Journals Gerontol Ser A Biol Sci Med Sci. 2015;70(1):57–62.

(37) López-Samanes A, Ortega Fonseca JF, Fernández Elías VE, Borreani S, Maté-Muñoz JL, Kovacs MS. Nutritional Ergogenic Aids in Tennis. Strength Cond J. 2015;37(3):1–11.

(38) López-Samanes Á, Moreno-Pérez D, Maté-Muñoz JL, Domínguez R, Pallarés JG, Mora-Rodriguez R, et al. Circadian rhythm effect on physical tennis performance in trained male players. J Sports Sci. 2017;35(21):2121–8.

(39) Seferoglu F. The effect of n - 3 LC - PUFA supplementation on tennis skill acquisition. Biol Sport. 2012;29(3).

(40) Sánchez-Oliver AJ, Mata-Ordoñez F, Domínguez R, López-Samanes A. Use of nutritional supplements in amateur tennis players. J Phys Educ Sport. 2018;18(2):775–80.

(41) Rodriguez NR, DiMarco NM, Langley S, American Dietetic Association, Dietitians of Canada, American College of Sports Medicine: Nutrition and Athletic Performance. Position of the American Dietetic Association, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and athletic performance. J Am Diet Assoc. 2009;109(3):509–27.

(42) Goldstein ER, Ziegenfuss T, Kalman D, Kreider R, Campbell B, Wilborn C, et al. International society of sports nutrition position stand: Caffeine and performance. J Int Soc Sports Nutr. 2010;7(1):5

(43) Phillips SM, Van Loon LJC. Dietary protein for athletes: From requirements to optimum adaptation. J Sports Sci. 2011;29(sup1):S29–38.

(44) Douroudos II, Fatouros IG, Gourgoulis V, Jamurtas AZ, Tsitsios T, Hatzinikolaou A, et al. Dose-related effects of prolonged NaHCO3 ingestion during high-intensity exercise. Med Sci Sports Exerc. 2006;38(10):1746–53.

(45) Cooper R, Naclerio F, Allgrove J, Jimenez A. Creatine supplementation with specific view to exercise/sports performance: an update. J Int Soc Sports Nutr. 2012;9(1):33.

(46) Bazzucchi I, Felici F, Montini M, Figura F, Sacchetti M. Caffeine improves neuromuscular function during maximal dynamic exercise. Muscle and Nerve. 2011;43(6):839–44.

(47) Juan DC, Estevez E, Mora-Rodriguez R. Caffeine during exercise in the heat: Thermoregulation and fluid-electrolyte balance. Med Sci Sports Exerc. 2009;41(1):164–73.

(48) Abian P, Del Coso J, Salinero JJ, Gallo-Salazar C, Areces F, Ruiz-Vicente D, et al. The ingestion of a caffeinated energy drink improves jump performance and activity patterns in elite badminton players. J Sports Sci. 2015;33(10):1042–50.

(49) Clarke ND, Duncan MJ. Effect of carbohydrate and caffeine ingestion on badminton performance. Int J Sports Physiol Perform. 2016;11(1):108–15.

(50) Burke LM. Caffeine and sports performance. In: Applied Physiology, Nutrition and Metabolism. Appl Physiol Nutr Metab. 2008. p. 1319–24.

(51) Maughan RJ, Griffin J. Caffeine ingestion and fluid balance: A review. J Hum Nutr Diet. 2003;16(6):411-20.

(52) Manjarrez-Montes De Oca R, Farfán-González F, Camarillo-Romero S, Tlatempa-Sotelo P, Francisco-Argüelles C, Kormanowski A, et al. Effects of creatine supplementation in taekwondo practitioners. Nutr Hosp. 2013;282828(2).

(53) Domínguez R, Hernández Lougedo J, Maté-Muñoz JL, Garnacho-Castaño MV. Efectos de la suplementación con ß-alanina sobre el rendimiento deportivo. Nutr Hosp. 2015;31(1):155–69.

(54) Pluim BM, Ferrauti A, Broekhof F, Deutekom M, Gotzmann A, Kuipers H, et al. The effects of creatine supplementation on selected factors of tennis specific training. Br J Sports Med. 2006;40(6):507–11.

(55) McNaughton LR, Siegler J, Midgley A. Ergogenic Effects of Sodium Bicarbonate. Curr Sports Med Rep. 2008;7(4):230–6.

(56) Price MJ, Simons C. The Effect of Sodium Bicarbonate Ingestion on High-Intensity Intermittent Running and Subsequent Performance. J Strength Cond Res. 2010;24(7):1834–42.

(57) Wu C-L, Shih M-C, Yang C-C, Huang M-H, Chang C-K. Sodium bicarbonate supplementation prevents skilled tennis performance decline after a simulated match. J Int Soc Sports Nutr. 2010;7(1):33.

(58) Carr BM, Webster MJ, Boyd JC, Hudson GM, Scheett TP. Sodium bicarbonate supplementation improves hypertrophy-type resistance exercise performance. Eur J Appl Physiol. 2013;113(3):743–52.

(59) Grgic J, Garofolini A, Pickering C, Duncan MJ, Tinsley GM, Del Coso J. Isolated effects of caffeine and sodium bicarbonate ingestion on performance in the Yo-Yo test: A systematic review and meta-analysis. J Sci Med Sport. 2020;23(1):41-47.

(60) Grgic J, Rodriguez RF, Garofolini A, Saunders B, Bishop DJ, Schoenfeld BJ, et al. Effects of Sodium Bicarbonate Supplementation on Muscular Strength and Endurance: A Systematic Review and Meta-analysis. Sports Med. 2020;50(7):1361-1375.

(61) Urwin CS, Dwyer DB, Carr AJ. Induced Alkalosis and Gastrointestinal Symptoms After Sodium Citrate Ingestion: a Dose-Response Investigation. Int J Sport Nutr Exerc Metab. 2016;26(6):542–8.

(62) de Salles Painelli V, Roschel H, de Jesus F, Sale C, Harris RC, Solis MY, et al. The ergogenic effect of beta-alanine combined with sodium bicarbonate on high-intensity swimming performance. Appl Physiol Nutr Metab. 2013;38(5):525–32.

(63) Tobias G, Benatti FB, De Salles Painelli V, Roschel H, Gualano B, Sale C, et al. Additive effects of beta-alanine and sodium bicarbonate on upper-body intermittent performance. Amino Acids. 2013;45(2):309–17.

(64) Sale C, Saunders B, Harris RC. Effect of beta-alanine supplementation on muscle carnosine concentrations and exercise performance. Amino Acids. 2010;39:321–33.

(65) Lundberg JO, Weitzberg E, Gladwin MT. The nitrate–nitrite–nitric oxide pathway in physiology and therapeutics. Nat Rev Drug Discov. 2008;7(2):156–67.

(66) Pinna M, Roberto S, Milia R, Marongiu E, Olla S, Loi A, et al. Effect of Beetroot Juice Supplementation on Aerobic Response during Swimming. Nutrients. 2014;6(2):605–15.

(67) Domínguez R, Garnacho-Castaño MV, Cuenca E, García-Fernández P, Muñoz-González A, de Jesús F, et al. Effects of Beetroot Juice Supplementation on a 30-s High-Intensity Inertial Cycle Ergometer Test. Nutrients. 2017;9(12).

(68) Domínguez R, Cuenca E, Maté-Muñoz JL, García-Fernández P, Serra-Paya N, Estevan MCL, et al. Effects of beetroot juice supplementation on cardiorespiratory endurance in athletes. A systematic review. Nutrients. 2017;9(1):43.

(69) Mosher SL, Sparks SA, Williams EL, Bentley DJ, Mc Naughton LR. Ingestion of a Nitric Oxide Enhancing Supplement Improves Resistance Exercise Performance. J Strength Cond Res. 2016;30(12):3520–4.

(70) López-Samanes Á, Pérez-López A, Moreno-Pérez V, Nakamura FY, Acebes-Sánchez J, Quintana-Milla I, et al. Effects of Beetroot Juice Ingestion on Physical Performance in Highly Competitive Tennis Players. Nutrients. 2020;12(2):584.

(71) Wylie LJ, Kelly J, Bailey SJ, Blackwell JR, Skiba PF, Winyard PG, et al. Beetroot juice and exercise: Pharmacodynamic and dose-response relationships. J Appl Physiol. 2013;115(3):325–36.

(72) Jo E, Fischer M, Auslander AT, Beigarten A, Daggy B, Hansen K, et al. The effects of multi-day vs. Single pre-exercise nitrate supplement dosing on simulated cycling time trial performance and skeletal muscle oxygenation. J Strength Cond Res. 2019;33(1):217–24.

(73) Wylie LJ, Ortiz De Zevallos J, Isidore T, Nyman L, Vanhatalo A, Bailey SJ, et al. Dose-dependent effects of dietary nitrate on the oxygen cost of moderate-intensity exercise: Acute vs. chronic supplementation. Nitric Oxide - Biol Chem. 2016;57:30–9.

(74) Vanhatalo A, Bailey SJ, Blackwell JR, DiMenna FJ, Pavey TG, Wilkerson DP, et al. Acute and chronic effects of dietary nitrate supplementation on blood pressure and the physiological responses to moderate-intensity and incremental exercise. Am J Physiol Integr Comp Physiol. 2010;299(4):R1121–31.