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Review

AYUDAS ERGOGÉNICAS EN JUGADORES DE BALONMANO DE COMPETICIÓN. UNA REVISIÓN NARRATIVA

ERGOGENIC AIDS IN COMPETITIVE HANDBALL PLAYERS: A NARRATIVE REVIEW

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RESUMEN

El balonmano es un deporte de equipo caracterizado por esfuerzos de alta intensidad combinados con periodos de recuperación. Debido a las altas exigencias físicas del balonmano, los jugadores de este deporte suelen utilizar ayudas ergogénicas con el objetivo de mejorar el rendimiento deportivo, mejorar la capacidad para realizar entrenamiento efectivo y/o aumentar el ritmo de la recuperación. Aunque el uso de ayudas ergogénicas está generalizado en todo el espectro de los niveles competitivos del balonmano (e.g. desde jugadores amateurs hasta jugadores profesionales), en la literatura científica solo se ha investigado la efectividad de unas pocas ayudas ergogénicas para las características específicas del rendimiento físico en balonmano. Por otro lado, ningún trabajo ha resumido la información para determinar qué ayudas ergogénicas son efectivas en el balonmano competitivo. Así, el objetivo de esta revisión narrativa fue describir la información científica existente en relación a la prevalencia en el uso de ayudas ergogénicas en jugadores de balonmano así como analizar esta información para identificar las ayudas ergogénicas que pueden aumentar el rendimiento físico en un deporte de carácter intermitente como es el balonmano.

Palabras clave: suplementos nutricionales, deportes de equipo, atleta élite; rendimiento deportivo

ABSTRACT

Handball performance is a team-sport characterized by high intensity efforts interspersed with recovery periods. Due to high demands of handball performance, the use of ergogenic aids is a common strategy of handball players with the aim of enhancing handball performance, to allow more effective training, and to increase the rate of recovery. Although the use of ergogenic aids is generalized in the whole spectrum of competitive handball (e.g., from recreational to professional players), only a few ergogenic aids have been investigated to test their effectiveness to increase handball performance. In addition, no previous study has summarized the scientific literature on this topic to determine the ergogenic aids with good level of evidence regarding their effectiveness to increase handball physical performance. Thus, the aim of this narrative review was to describe the prevalence in the use of ergogenic aids in handball players and to analyse this information to identify which of these substances may increase physical performance in an intermittent sport such as competitive handball.

Keywords: nutritional supplements; team-sports; elite athlete; sport performance

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INTRODUCTION

In the last years, the study of the efficacy of ergogenic aids has become popular in the context of sport sciences, mostly driven by the high number of marketed substances claiming benefits on sport performance and the high prevalence in the use of some of these substances. Briefly, athletes use ergogenic aids with the aim of enhancing their athletic performance to allow more effective training, and to increase the rate of recovery (Bishop, 2010). Although there are other substances that may be used for athletes with the aim of correcting or preventing nutrient deficiencies that may impair health, the ergogenic aids are defined as a dietary supplement with the potential of enhancing energy production and nutrients around an exercise session, better recovery from training sessions, or to achieve a specific and direct performance benefit in competition (Ahrendt, 2001). Although the term ergogenic aid is commonly used in scientific literature referring to substances that enhances physical performance in an exercise or sport context, athletes often confuse dietary/sport supplements and ergogenic aids assuming that these terms are interchangeable (Maughan, Depiesse, Geyer, & International Association of Athletics, 2007). To this regard, it is necessary to clear up that ergogenic aids are un type of dietary supplements with the sole objective of obtaining a direct or indirect enhancement of sports exercise or sport performance while the range of dietary supplements is wider because there are dietary supplements that only offer benefits on health parameters or reduce risks of injury and illness.

The consumption of ergogenic aids has suffered a dramatical increase in the last years as a result of high professionalization of athletes and the potent advertising that companies that sell ergogenic aids produce in national and international competitions. It is worth to mention that 64.0-88.5% of professional athletes of different disciplines (Baltazar-Martins et al., 2019; Braun et al., 2009; Pumpa, Madigan, Wood Martin, Flanagan, & Roche, 2012), 89.0-98.6% of university athletes (Froiland, Koszewski, Hingst, & Kopecky, 2004; Kristiansen, Levy-Milne, Barr, & Flint, 2005), 54.0-94.0% of team-sports athletes (e.g. basketball/soccer) (Schroder et al., 2002; Sekulic et al., 2019) and 81.0%-100% of athletes competing in individual sports such as tennis and squash (Lopez-Samanes et al., 2017; Ventura Comes, Sanchez-Oliver, Martinez-Sanz, & Dominguez, 2018) confirmed taking at least 1 nutritional supplement or ergogenic aid at the moment of questioning/during the last year. However, the scientific information regarding the prevalence in the use of ergogenic aids in handball is scarce in other team sports such as handball, despite the high professionalization of this team sport. Only one previous study has analysed the use of dietary supplements in handball players. In this study, 48.5% of the professional team surveyed reported the consumption of at least one dietary supplement (Sekulic et al., 2019). However, the proportion of handball players who consumed dietary supplements regularly descended to 15.5%. In addition, in that investigation, the consumption of ergogenic aids was not specifically questioned and thus, to date, it is unfeasible to know the real prevalence in the use of ergogenic aids in handball.

Handball is an intermittent sport, characterized by high-intensity bouts of exercise combined with resting periods (Michalsik, Madsen, & Aagaard, 2014). In addition to the physical demands, competitive handball requires a mixture of technical, tactical, and psychological aspects to produce an excellent performance. During the game, players perform a high number of actions such as accelerations and decelerations, fast changes of direction, running sprints, and collisions with opponents. Although handball has similarities with other team sports, such as basketball, football, the unlimited number of substitutions allow players to occupy specific roles for attacking and defending. Despite the specific movement patterns of the different handball playing positions, all of the share the need of high values of strength and power output in upper and lower body, together good values running speed and acceleration in short distances, and excel jumping capacity (Michalsik et al., 2014; Muñoz et al., 2020). The high physical challenges of competitive handball has attracted the attention of sport scientists who are looking for strategies to increase performance with the inclusion of nutritional strategies (Heaton et al., 2017) that maximize the performance benefits obtained during the training process. The use of ergogenic aids may be a potentially valuable strategy to achieve success, especially in professional handball, where players have a congested calendar with national and international competitions that includes continuous trips and low time for recovery.

Although the consumption of ergogenic aids in different sports is extensive, such as previously reported, according to the International Olympic Committee, only a few ergogenic aids (i.e., creatine, caffeine, sodium bicarbonate, beta-alanine and beetroot juice) have demonstrated good evidence of achieving benefits to sport performance (Maughan et al., 2018). However, the scientific literature that related these substances to enhanced handball performance is scarce and to the authors' knowledge only a few studies have been developed to investigate the efficacy of ergogenic aids such as creatine (Aaserud, Gramvik, Olsen, & Jensen, 1998; Izquierdo, Ibanez, Gonzalez-Badillo, & Gorostiaga, 2002), caffeine (Muñoz et al., 2020; Ribeiro et al., 2016), sodium bicarbonate (Sajedi, Ozturk, & Ozturk, 2015) or beetroot juice ingestion (De Rapahel & Furlan, 2016) on handball physical performance. The aim of this narrative review is to analyse this information to identify which of these substances may increase physical performance in an intermittent sport such as competitive handball.

CAFFEINE

Caffeine (1,3,7 trimethylxanthine) is a potent stimulant of the central nervous system with the capacity of reducing fatigue and drowsiness. This stimulant nature of caffeine has produced that this substance is most widely consumed psychoactive drug in the world. In addition, unlike many other psychoactive substances, it is legal and unregulated in nearly all parts of the world. Caffeine is and is rapidly absorbed by the body and appears in the blood within 5-15 minutes, reaching a peak between 45-60 minutes after ingestion (Graham & Spriet, 1995). Caffeine is metabolized by the liver and, through enzymatic actions, results in three metabolites: paraxanthine, theophylline , and theobromine (Heckman, Weil, & Gonzalez de Mejia, 2010). Evidences suggest that caffeine supplementation improves the activity of the Na + -K + pump (Mohr, Nielsen, & Bangsbo, 2011) and promotes the release of calcium from the sarcoplasmic reticulum (Reggiani, 2020). However, the most well-documented action of caffeine associated to its potential benefits is its capacity to block adenosine receptors, blocking then the "fatiguing" action of adenosine. Thus, supplementation with caffeine has been shown to be effective in increasing neuromuscular recruitment (Kalmar & Cafarelli, 2004) improving intra- and intermuscular coordination (Del Coso, Salinero, Gonzalez-Millan, Abian-Vicen, & Perez-Gonzalez, 2012) or time to exhaustion (Graham & Spriet, 1995).

In team sports, acute caffeine intake has demonstrated a clear performance benefit with low to moderate doses (i.e., 3–6 mg/kg/ body mass (bm)) (Salinero, Lara, & Del Coso, 2019). Specifically, the ingestion of an acute dose of caffeine withing this range, about 60 min before exercise, has been deemed effective to increase different physical qualities such as vertical jumping (Del Coso et al., 2014; Muñoz et al., 2020), sprint performance (Glaister et al., 2012; Lara et al., 2014) or match-play demands (running distance, accelerations, decelerations, body impacts; (Lara et al., 2014; Muñoz et al., 2020)).

However, the effects of caffeine on handball performance has been less extensive studied that in other team sports (e.g. soccer). As previously mentioned, handball is an intermittent sport which requires higher levels of strength and muscle power output values (Gorostiaga, Granados, Ibanez, Gonzalez-Badillo, & Izquierdo, 2006) high capacity of velocity in short to medium distances and good capacity of change-of-direction (Michalsik & Aagaard, 2015). Thus, one may consider that the findings of previous investigations in other team sports may be extrapolatable to handball players. However, there is still the doubt about how the higher physical performance with caffeine demonstrated in other investigations impact handball specific actions during the game.

To the author's knowledge, only two studies have been measured the ergogenic effect of acute caffeine ingestion in handball. Ribeiro et al., (2016) studied the effects of caffeine ingestion (6 mg/kg/bm) in 6 handball players who performed 4 × 30 s of continuous vertical jumps. These authors found that acute caffeine intake improved leg power output during jumping by ~5% with no higher levels of exercise-induced muscle damage (Ribeiro et al.,

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2016). More recently, Muñoz et al., (2020) studied the effects of 3 mg/kg/bm in fifteen elite female handball players. This study analysed the effects of this dose of caffeine in a battery neuromuscular test and match-play movements during a simulated handball match. Caffeine ingestion improved ball throwing velocity, isometric handgrip strength, jump capacity and sprint running velocity. In addition, caffeine ingestion improved some aspects during the simulated match (e.g. accelerations, decelerations, body impacts; (Muñoz et al., 2020)). Under this background with investigations carried out in handball and other team sports with similar characteristics, it may be concluded that caffeine is an effective ergogenic aid for handball performance.

Despite its benefits, acute caffeine intake produce several side effects such as increased urine flow, gastrointestinal problems, heart palpitations, etc (Pallares et al., 2013). The prevalence of this side effect is lower when using 3 mg/kg/bm of caffeine (Salinero et al., 2014) instead the use of higher doses (i.e., 9 mg/kg/bm; (Pallares et al., 2013)). Hence, the selection of the minimal dose with ergogenic benefits is recommended to reduce the prevalence and strength of caffeine-induced side effects.

In summary, caffeine ingestion before handball matches/training sessions may be a useful ergogenic aid to increase handball performance, although future studies should determine the optimum dose for handball players. Despite this, the recommendation in the use of caffeine for handball players should only be done after a careful evaluation of the drawbacks typically associated to this stimulant, only to players who are willing to use ergogenic aids to increase performance and on an individual basis under supervision by an exercise practitioner. Lastly, experimenting with caffeine while high-intensity handball training or simulated competition may be recommended to detect any side effect that may interfere with the potential benefits of acute caffeine ingestion.

CREATINE

Creatine supplementation is a common practice among sports athletes (Kreider et al., 2017). Creatine is a combination of non-essential amino acids (arginine, glycine and methionine) which is mainly produced endogenously in the liver and kidney. However, creatine is also ingested with the diet whose daily requirements are 2 g/day in healthy individuals (Cooper, Naclerio, Allgrove, & Jimenez, 2012). Several physiological functions have been attributed to creatine such ATP re-synthesis (Volek et al., 1997), intracellular acid-base balance regulation (Kreider et al., 2017), biological membranes stabilization and muscle protein synthesis stimulation (Persky & Brazeau, 2001). Briefly, the oral administration of high doses of creatine increases the concentration of intramuscular creatine, ultimately producing higher ratings of ATP re-synthesis. In the sport context, creatine is employed under the expectancy of a higher exercise performance in tasks that requires near-to-maximal intensity and/or during high-intensity efforts that are repeated over time.

The most common method of creatine administration starts with a loading phase, consisting of 4 repeated doses of 5 g separated by 6 hours during 3–5 days, followed by a maintenance dose of 3–5 g/d which can be continued over time. This protocol of creatine administration showed a 17–20% increase in intramuscular levels of creatine (Mesa, Ruiz, Gonzalez-Gross, Gutierrez Sainz, & Castillo Garzon, 2002). Other protocols have proven to have the same success or even better results, such as doses of 0.25 g of creatine/kg fat-free mass/day (D. G. Burke et al., 2003), 3 g of creatine per day during 30 days (Kreider et al., 2017), or 20 doses of 1 g of creatine during the day (Sale et al., 2009). Oral administration of low-medium doses of creatine in humans (1–5g) reaches its maximum plasma creatine concentrations in less than 2 hours, whereas doses above 10 g reach maximal plasma concentrations over 3 hours (Schedel, Tanaka, Kiyonaga, Shindo, & Schutz, 1999).

As it happened with caffeine, only two studies have been developed to examine the effect of creatine supplementation on handball performance. Aaserud et al., (1998) investigated the effect of creatine supplementation (15 g/day) on repeated sprint runs in well-trained young male handball players. The handball participants in this study performed 8x40 m maximal sprint runs with a 25-s rest period between each sprint. Afterwards, the participants received creatine supplementation or a placebo (both for five consecutive days) and the capacity to repeat sprints was measured again. The authors stated that creatine supplementation improved the last three sprint runs compared to the placebo condition (Aaserud et al., 1998). The second study that investigated the effects of creatine supplementation in handball players was carried out by Izquierdo et al., (2002). In that study, the effects of creatine supplementation (20 g of creatine for 5 consecutive days) were tested on maximal strength, muscle power production during repetitive high-power-output exercise bouts and repeated running sprints. Nineteen trained male handball players were randomly assigned in a double-blind fashion to either creatine or placebo supplementation. Creatine supplementation significantly increased the number of repetitions performed to fatigue, muscle power output, jump capacity and the capacity to repeat sprints over the placebo condition (Izquierdo et al., 2002).

A few secondary effects have been reported with creatine ingestion. The most common adverse effect is an increase of 1–2% in body weight (Kutz & Gunter, 2003) possibly associated with water retention. Other secondary effects linked to creatine consumption, are gastrointestinal, renal, and liver damage (in a reduced cases; (Kreider et al., 2017)). In addition, a recent investigation suggested the possibility of developing alopecic effects with creatine ingestion (van der Merwe, Brooks, & Myburgh, 2009). However, due to the weak evidence, future investigations should clarify these secondary effects anecdotally reported in the literature.

In summary, creatine supplementation may be considered as an effective ergogenic strategy to develop a higher capacity of performing high-intensity actions in handball players. However, the use of this supplementation protocol should be recommended for those periods of intense training and congested calendar, in order to avoid a chronic use of this substance during the season. Due to the water retention/increase in body mass that accompanies the long-term use of creatine, its consumption in some specific positions should be evaluated in terms of benefits/drawbacks (e.g. wingers). Lastly, the evidence indicates that several protocols of creatine supplementation may be effective to increase in intramuscular levels of creatine although we recommend the use of protocols that uses dosages relatives to athlete's body mass.

SODIUM BICARBONATE

Sodium bicarbonate ($NaHCO_{3-}$) is an extracellular buffer with different physiological roles such as regulating blood pH (Hadzic, Eckstein, & Schugardt, 2019) and enabling acceleration of glycogenolysis (Percival et al., 2015). Thus, this alkalizing agent has shown to have an ergogenic effect in high intensity intermittent efforts in which the decrease in muscle pH constitutes a performance limiting factor (Carr, Slater, Gore, Dawson, & Burke, 2011). Under this background, oral administration of $NaHCO_{3-}$ would produce higher levels of intramuscular and blood ($NaHCO_{3-}$) that indirectly would produce a greater utilization of the glycolytic pathway due to the capacity of $NaHCO_{3-}$.to buffer the hydrogen ions (H^+) produced during the anaerobic metabolism (Siegler, Mudie, & Marshall, 2016). Hence, in the sport context, $NaHCO_{3-}$ supplementation may be effective in those scenarios which produce reductions in muscle and blood pH such as high-intensity actions longer than 6-20 s or repeated over time with low recovery times.

To increase the efficacy of this potential ergogenic aid, sodium bicarbonate is habitually ingested 1-2 hours before exercise, normally in doses between 0.2-0.3 g/kg/bm (Siegler, Marshall, Bishop, Shaw, & Green, 2016). Several studies have studied the optimal dose of $NaHCO_3$- (0.1 to 0.5 g/kg/bm) (McNaughton, 1992) stablishing that acute doses ranging between 0.2 and 0.3 g/kg/bm are beneficial for improving athletic performance. Interestingly, greater doses have not reported any further benefit while they only induced severe side effects (Siegler, Marshall, et al., 2016). Interindividual variations in the ergogenic response to sodium bicarbonate may be attributed to different factors such as training status (i.e., untrained athletes may benefit more from sodium bicarbonate intake when compared with high-level athletes), sex or sodium bicarbonate dosage (L. M. Burke, 2013). In addition, the use of sodium bicarbonate has been particularly proposed in sporting events which anaerobic glycolysis have a role such as handball, that is characterized by high intermittent efforts.

In our knowledge, only one study has been developed in the handball field, while the efficacy of sodium bicarbonate supplementation to enhance handball performance was tested in conjunction with glutamine ingestion (Sajedi et al., 2015). Three

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groups that included six handball male players were selected; the control group did not receive any treatment and the two experimental groups ingested glutamine alone or glutamine plus sodium bicarbonate. Handball players performed a Wingate test (30-s version) and the authors of this investigation concluded that the co-ingestion of both glutamine and sodium bicarbonate increased anaerobic power of players comparing placebo condition. However, the addition to sodium bicarbonate to glutamine had little benefits respect the use of only glutamine.

It is worth to mention that several effects have been reported with sodium bicarbonate ingestion. The major side effect of bicarbonate supplementation is gastrointestinal discomfort, while other side effects such as nausea, stomach pain, diarrhoea and vomiting are relatively frequent, especially with high oral doses (L. M. Burke, 2013).

In summary, the evidence is weak to clearly define sodium bicarbonate supplementation as an ergogenic aid for handball-specific physical performance. Further investigations are required to ascertain the potential benefits of this ergogenic aid in competitive handball.

BEETROOT JUICE

Beetroot juice is a good source of nitrate (NO_{3-}). NO_{3-} is a precursor of nitric oxide (NO) through the nitrate–nitrate–NO pathway (Lundberg, Weitzberg, & Gladwin, 2008). Once NO_{3-} is orally ingested, it is reduced to nitrite (NO_{2-}) by anaerobic bacteria in the oral cavity, thanks to the action of nitrate reductase enzymes. Then, NO_{2-} is reduced to nitric oxide (NO) in the stomach (Ashworth et al., 2019). This pathway of single-electron transfer reactions is interesting for exercise physiology because NO is a potent vasodilator compound with the capacity to increase blood flow and to improve muscle efficiency by reducing the O_2 cost of submaximal exercise. Thereby, the use of beetroot juice has been suggested as an potential beneficial strategy to improve endurance exercise and enhance skeletal muscle contractile function (Jones, Thompson, Wylie, & Vanhatalo, 2018).

Since 2009, where the first studies were developed with beetroot juice ingestion (Bailey et al., 2009), the use of supplements that contain NO_{3-} are very popular among athletes. Several sports nutrition brands have marketed beetroot juice concentrate bottles, commonly in individual serving of 70 ml (Lopez-Samanes et al., 2020). However, the dose-response that maximizes sports performance has not been well explored in the athletic performance context (Wylie et al., 2013). Therefore the majority studies that have obtained benefits with beetroot ingestion have reported ingestions between 70-500 mL (Bailey et al., 2009; Cuenca et al., 2018). In addition, since the International Olympic Committee recognized a good level of evidence to support the supplementation of beetroot juice (Maughan et al., 2018), it has been gaining increasing importance in sport to improving cardiovascular endurance or strength-power output values (Jones et al., 2018). However, in the team-sports context field the literature is scarce and have reported controversial findings (Lopez-Samanes et al., 2020; Nyakayiru et al., 2017; Thompson et al., 2016).

To our knowledge, only one research studied the effect of beetroot juice ingestion in ten female handball players (De Rapahel & Furlan, 2016). The participants ingested 500 mL of beetroot juice or placebo in acute doses administrated three hours before of making a repeated sprint test. Beetroot ingestion improved the mean time employed to complete the test in comparison with the placebo. Moreover, other physiological parameters were measured such as blood pressure, heart rate and perceived exertion while no significant differences between groups (beetroot juice vs placebo condition) were found for these variables.

Interestingly, the prevalence of side effects reported with beetroot juice supplementation are limited, although it is worth to mentioned that excessive consumption of beetroot juice can produce red urine and feces (McMahon, Leveritt, & Pavey, 2017). Other investigations have reported gastrointestinal problems immediately after beetroot juice ingestion (Hoon et al., 2014; Wickham et al., 2019) although they are rare.

In summary, to date, the evidence to determine beetroot juice supplementation as an ergogenic aid for competitive handball is scarce. New studies should be developed to determine the efficacy of beetroot juice ingestion in physical variables directly associated to handball success such as ball throwing velocity or to explore if beetroot juice could improve match play demands during simulated or real situations.

CONCLUSION

As presented in this narrative review, the scientific literature associated to the examination of ergogenic aids efficacy for handball-specific performance is limited. However, the existence of investigations that have reported clear benefits of acute caffeine ingestion and long-term creatine supplementation in high-level handball players, and in analogue team sports, suggest the convenience of recommended these substances as effective ergogenic aids for handball. In contrast, more studies are necessary with to establish the benefits of beetroot juice and sodium bicarbonate supplementation as the current evidence in handball is low and the extrapolation of laboratory-based investigations is difficult to the specific characteristics of handball. In any case, to the authors' opinion, the use of ergogenic aids in handball should only be recommended for those players that have maximized adaptations through appropriate diet and training, while it should be supervised by a certified professional (e.g., nutritionist). Lastly, the use of ergogenic aids should be a preference (not an obligation) even in professional handball and thus, elite handball players may obtain excel levels of physical performance without the need of these ergogenic aids. For those willing to use ergogenic aids, these will present a potential benefit to increase their performance although the purchase of these and other dietary supplements has to be secure to avoid supplements contaminated with banned substances.

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