Expert Statement on the Use of Supplements for Crossfit

By Lynn Starke

1 Introduction

1.1 What is Crossfit?

Crossfit has developed into a popular sport during the last decade and there are currently more than 11500 gyms worldwide (Schlegel, 2020). Crossfit is a constantly varied, high intensity functional movement training based on the three modalities weightlifting, gymnastics and metabolic conditioning (Glassman, 2013). These three domains are used either separately or are combined into high intensity workouts, called "workout of the Day" (WOD). The WOD is usually the main or only part of the training session (Schlegel, 2020). Normally the WODs are performed quickly, repeatedly, and with limited time to recover between sets. The nature of each WOD can be very different (Gogojewicz et al., 2020). High levels of lactate (10-18mmol/L) and high heart rates, exceeding 170bmp are found during WODs, which underline the high intensity of these training sessions (Schlegel, 2020). Overall, Crossfit combines many types of exercise, mostly strength and endurance based (e.g. running, cycling, rowing, olympic weightlifting, powerlifting and gymnastics) (dos Santos Quaresma et al., 2021) with the general goal to improve ten physical skills: cardiovascular, respiratory endurance, stamina, strength, flexibility, power, speed, coordination, agility, balance and accuracy (Schlegel, 2020). Strength in the squat, Overhead-press, deadlift, and Olympic Weightlifting performance is of high importance for overall Crossfit performance, and elite athletes have shown to have excellent strength parameters. Depending on the nature of the WOD, VO2max and anaerobic power are also important (Schlegel, 2020). Up to date there is no study that investigated typical body composition of elite Crossfit athletes, but Mangine et al., (2020) have shown that low body fat and high body density are the best predictors for a good Crossfit performance during competition.

1.2 Training Structure – Training and Competition Demands

According to Glassman (2013), elite Crossfit athletes are advised to train on a three day on, one day off basis, because this allows for the highest volume. WODs need considerable variance and each three-day cycle should never be repeated in the life of a Crossfit athlete (Glassman, 2013). Several Crossfit competitions occur throughout the year at local, regional, national, and international level. The ultimate, annual competition is known as the CrossFit Games and its winners are awarded the title "Fittest on Earth" (Mangine et al., 2020). The nature of each competition is always unpredictable and differs a lot between events. Mostly athletes do not know the workout of the event until shortly before. Competitions are often held over multiple days with multiple workouts during each day (Mangine et al., 2020). Thus, recovering after and fueling before and after each workout is of great importance (De Souza et al., 2021). Concerning the metabolic pathways required in Crossfit, one can say, that the phosphagen, glycolytic and oxidative pathway are all necessary, depending on the demands of the event (Glassman, 2003). In the past, the time of events during the Crossfit Games ranged between seconds for a One-Repetition-Maximum (1RM) in the Snatch, Clean and Jerk or Deadlift to several hours during a marathon row (Pritchard et al., 2020).

1.3 Nutritional Requirements

Up to date there is limited data available evaluating nutrition in Crossfit athletes (De Souza et al., 2021). Overall, athletes should aim to meet their daily energy demands by considering the details of their training schedule to avoid chronic energy deficiency, which might have performance consequences associated with the Relative Energy Deficiency in Sport model (Areta et al., 2020). Due to the high intensity in workouts, carbohydrates are essential to maintain high glycogen stores (dos Santos Quaresma et al., 2021). According to Gogojewicz et al., (2020), Crossfit athletes should consume around 5-8g/kg of carbohydrates per day. Additionally, Burke (2007), recommends 6-10g/kg/day for moderate to high intensity for 1-3 hours of training per day, which is in line with current volume reported by elite Crossfit athletes (Gogojewicz et al., 2020). Furthermore, Escobar et al., (2016) reported an improved number of repetitions during Crossfit workouts when athletes consumed 6-8g/kg/day of carbohydrates compared to when they consumed less than 6g/kg/day. All of this summarizes the importance of a high carbohydrate diet (>6g/kg/day) for Crossfit athletes. Concerning Protein recommendations of the International Society of Sport Nutrition (ISSN) Crossfit athletes should consume around 1.4-2g/kg/day of proteins (dos Santos Quaresma et al., 2021). Special emphasis should be placed on protein after training and before bed, as well as on the whole distribution during the day. Increases in muscle mass and strength are shown to be greater with immediate post-exercise protein. A combination of carbohydrates and protein at this time point results in improvement in recovery, including restoration of muscle glycogen and elevates muscle protein synthesis (MPS) (Slater & Phillips, 2011). Moreover, Crossfit athletes should consume around 0.5-1g/kg/day of fats, to make sure all fat-soluble vitamins are absorbed (ACSM, 2016; Gogojewicz et al., 2020). Furthermore, Crossfit can lead to high sweat rates, thus athletes should start every workout well hydrated and fluid should be available during and between training sessions (Cronin et al., 2016), because dehydration could negatively impact the athletes performance (Shirreffs & Sawka, 2011). When possible, nutrient provision should come from whole foods and drinks, but this is not always optimal. Thus, athletes might consider the additional use of specific supplements, to improve their performance or recovery (Close et al., 2022).

2 Supplement Requirements

The following should focus on supplements that might improve Crossfit performance, including caffeine, creatine, and beta-alanine *(Figure.1).*

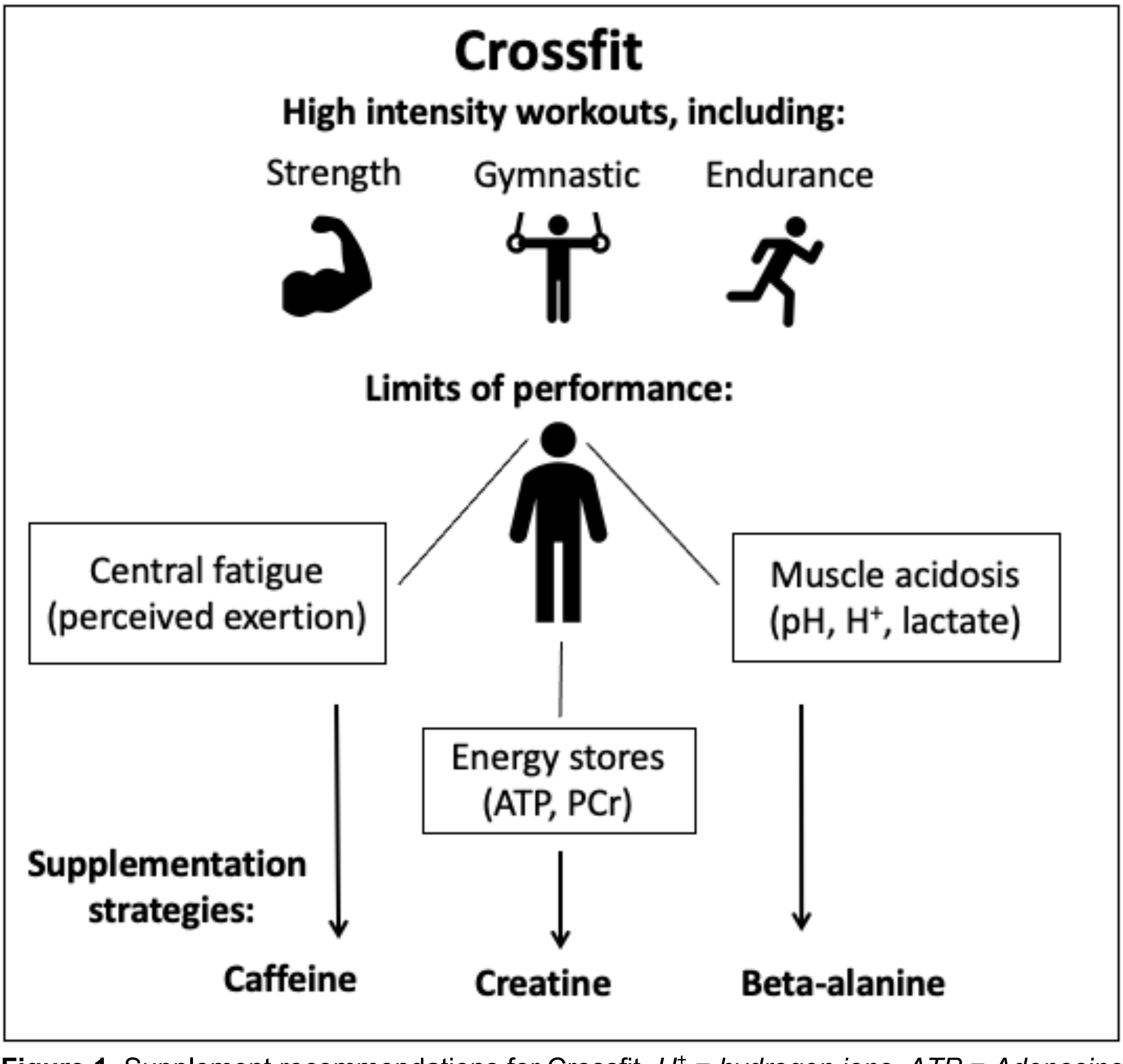

Figure 1. Supplement recommendations for Crossfit. *H^+ = hydrogen ions, ATP = Adenosine triphosphate, PCr = Phosphocreatine*

2.1 Caffeine

2.1.1 Mechanisms of Action of Caffeine

Caffeine is the world´s most consumed psychoactive substance and naturally occurs in many plant species, including coffee, tea and cocoa (Guest et al., 2021). It was removed from the prohibited list by the World Anti-Doping Agency (WADA) in 2004 and many studies have focused on its widespread effects (Mottram & Chester, 2011). Caffeine can be classified as an A-list supplement. Supplements in this category have high research and can support sports performance (Australian Institute Of Sport, 2021). Following oral ingestion, caffeine is rapidly absorbed via the gastrointestinal tract. This happens mainly through the small intestine, but also in the stomach (Guest et al., 2021). Over 95% of caffeine is metabolized in the liver by the Enzyme Cytochrome P450 1A2 (CYP1A2). This enzyme catalyzes caffeine into its primary metabolites: paraxanthine, theobromine and theophylline. These three metabolites then undergo further oxidation and demethylations (Goldstein et al., 2000; Guest et al., 2021). The main mechanism of caffeine is being an adenosine receptor antagonist. In contrast to adenosine (which has mainly inhibitory effects), caffeine, as a receptor antagonist, has mainly stimulatory effects (Mottram & Chester, 2011). Furthermore, caffeine can decrease fatigue by decreasing plasma potassium levels through stimulating sodium/potassium ATPase (Mottram & Chester, 2011).

2.1.2 Performance Benefits of Caffeine

Currently there are not many studies directly evaluating the effect of caffeine supplementation on Crossfit performance, but many studies underline that caffeine can improve performance in various endurance sports (dos Santos Quaresma et al., 2021). Concerning endurance performance, cycling, running, swimming and rowing are important elements of Crossfit (Glassman, 2013). Caffeine has shown to significantly improve cycling time-trial performance, with a workload equal to one hour at 70% of the maximal wattage (Ivy et al., 2009) and 5-km running performance (Prins et al., 2016). Additionally, caffeine reduced the time to complete a 50m swim (Lara et al., 2015) and a 2000m row (Carr et al., 2011). All of these elements are found in the same intensity and duration during various Crossfit WODs (Glassman, 2020).
Related to strength and resistance exercise, performance in the 1RM of squat, deadlift, Snatch and Clean and Jerk, as well as muscular endurance in several exercises are important for Crossfit performance (dos Santos Quaresma et al., 2021). Most reviews that focused on these elements also support caffeine as an ergogenic aid for enhancing velocity and power in resistance exercise (Guest et al., 2021).
Furthermore, Caffeine can reduce pain and ratings of perceived exertion (RPE) during exercise (Goldstein et al., 2000; Guest et al., 2021). The reduction in RPE may lead to an improvement in CrossFit performance. Athletes could work harder, but do not perceive the effort as such. This can be explained through the increased secretion of ß-endorphins with caffeine, which can lead to a decrease in pain perception (Goldstein et al., 2000).

2.1.3 Practical Recommendations for Caffeine

The optimal performance enhancing dose of caffeine is between 3-6mg/kg (Goldstein et al., 2000; Guest et al., 2021; Mottram & Chester, 2011). Higher doses (9mg/kg) have not shown further performance improvement and are associated with higher risk of side effects (Goldstein et al., 2000; Guest et al., 2021). For mostly short duration exercise like Crossfit WODs, caffeine has shown to have the best performance benefit when ingested one hour before training or competition, due to its peak plasma concentrations 30-120 minutes after oral ingestion (Guest et al., 2021). Furthermore, it has shown to have a greater ergogenic effect when consumed in anhydrous state (e.g., caffeine tablets) as compared to coffee or energy drinks (Goldstein et al., 2000). Besides, caffeine content in coffee can be highly variable, and for ingesting the necessary amount, athletes might consider using caffeine tablets, from which they know the specific amount of caffeine (Close et al., 2022). All benefits of caffeine are not influenced by sex, age and habitual caffeine consumption (Guest et al., 2021).

2.1.4 Possible Side-Effects of Caffeine

Concerning side-effects, caffeine concentrations above 15ug/ml can result in toxic symptoms like tachycardia, arrhythmia and tremor (Mottram & Chester, 2011). Moreover, hindered sleep quality and increased anxiety were observed after caffeine ingestion (Guest et al., 2021).

2.2 Creatine

2.2.1 Mechanisms of Creatine

Creatine is a naturally occurring non-protein amino acid compound, which is found primarily in red meat and seafood. Although it is found in food, it is difficult to achieve the recommended amount within a normal diet: achieving a performance enhancing effect would require eating at least 1 kg of raw meat per day (Close et al., 2022). Creatine is synthesized in the liver and pancreas from the amino acids arginine, glycine and methionine and 95% of all creatine in the body is found in skeletal muscle. Two third of the intramuscular creatine can be found as Phosphocreatine (PCr) and the rest as free creatine (Buford et al., 2007). A normal diet contains around 1-2g of creatine, and with this muscle creatine stores are around 60-80% saturated (Kreider et al., 2017). Already in 1992, investigators found that several days of creatine supplementation significantly increases these stores of free creatine and PCr in skeletal muscle (Kraemer & Volek, 1999). The energy supplied to resphosphorylate Adenosine diphosphate (ADP) to Adenosine triphosphate (ATP) during intense exercise is largely dependent on the amount of PCr stored in the muscle (Kreider et al., 2017). When PCr becomes depleted the body cannot resynthesize ATP at the rate required during high-intensity exercise like Crossfit (De Souza et al., 2021; Kreider et al., 2017).

During high-intensity-exercise: *PCr + ADP → Creatine + ATP*

Therefore, increasing muscle PCr content via creatine supplementation can allow for an accelerated rate of resynthesize of ATP during high-intensity, short-duration exercise (Kraemer & Volek, 1999; Kreider et al., 2017).

2.2.2 Performance Benefits of Creatine

Up to date there is no study that directly investigated the effects of creatine supplementation on Crossfit performance, but many studies underline the supporting effects of creatine supplementation for short-duration exercise (Kreider et al., 2017). Just like caffeine, creatine can be considered an A-List supplement, and thus, can enhance sports performance (Australian Institute Of Sport, 2021; Swisssportsnutritionsociety, 2017). Due to the accelerated rate of ATP resynthesize creatine supplementation can enhance anaerobic exercise (Jäger et al., 2011), and thus might enhance Crossfit performance during short-duration WODs.

Furthermore, strength in the lower-body, as well as in the upper-body has been shown to have a strong correlation to overall Crossfit performance (Mangine et al., 2020). Due to the greater ATP resynthesis creatine supplementation can allow an athlete to do more work over a series of sets and thus can lead to greater gains in strength and muscle mass due to an improvement in the quality of training (Buford et al., 2007). By combining oral creatine supplementation with resistance training, Dempsey et al., (2002) found significant increases in the 1RM of the squat, which is one of the most important strength elements for Crossfit performance (Mangine et al., 2020). Additionally, Lanhers et al., (2015), found that creatine supplementation is effective in lower limb strength performance for exercises with a duration of less than 3 minutes. Moreover, Lanhers et al., (2017) stated that supplementation can also improve upper limb strength performance. Thus, according to the International Society of Sport Nutrition (Kreider et al., 2017), creatine is the most effective ergogenic supplement currently available to increase strength performance and anaerobic exercise capacity.

2.2.3 Practical Recommendations for Creatine

Supplement manufactures are continually producing new forms of creatine, but up to now, creatine monohydrate is the most effective and safest form of creatine (Jäger et al., 2011). The fastest and most common method of supplementation is to start with a loading phase and consume 0.3g/kg/day for 5-7 days, divided in 3-4 portions a day. This is followed by 3-5g/day thereafter (consumed in one portion) to maintain the elevated stores. Larger athletes may need to ingest around 5-10g/day as a maintenance dose (Antonio et al., 2021; Kreider et al., 2017). Instead of the loading phase, athletes can also directly start with the amount of the maintenance dose, but doing so it might take longer to reach elevated creatine levels (Antonio et al., 2021). Overall, there exist a greater creatine retention when ingested together with carbohydrates or carbohydrates and proteins. Thus, its recommended to consume creatine together with a snack or meal (Steenge et al., 2000).

2.2.4 Possible Side-Effects of Creatine

Concerning potential side-effects, creatine supplementation of up to 30g/day for 5 years is well-tolerated in healthy individuals. The only reported side effect that might occur is weight gain, due to water retention in the muscles (Antonio et al., 2021). The legal and regulatory status of creatine monohydrate all over the world is clearly defined, but controversy, the safety and regulatory status of most of the newer forms have not been well established (Jäger et al., 2011).

2.3 Beta-alanine

2.3.1 Mechanisms of Beta-alanine

Beta-alanine is a non-essential amino acid, which is produced in the liver and additionally obtained through the diet from sources such as meat and poultry (Forbes et al., 2020). While found in small quantities in some meat, it is practically not possible to get enough beta-alanine through food: getting a performance enhancing effect would require eating around 1kg of meat each day (Close et al., 2022). The research on beta-alanine is relatively new, with the first human study published in 2006 (Trexler et al., 2015). Just like caffeine and creatine, beta-alanine can be classified as an A-List supplement (Australian Institute Of Sport, 2021). Beta-alanine has been identified as the rate-limiting precursor to Carnosine synthesis and thus, increases the levels of carnosine in human skeletal muscle. Carnosine is produced when beta-alanine bonds with L-histidine and protects against pH changes in skeletal muscle during exercise (Ojeda et al., 2020). Carnosine can limit the reduction in pH, because nitrogen atoms on its imidazole ring can accept a proton (Trexler et al., 2015). After 2-4 weeks of supplementation, the typical increase in muscle carnosine following beta-alanine supplementation is 60-80%, which results in around 3-5% increase in muscle buffering capacity (Trexler & Smith-Ryan, 2015). The enzyme carnosinase, which breaks down carnosine, is present in the serum and various tissues, but not in skeletal muscle. Thus, humans cannot directly ingest carnosine because it would be broken down before reaching skeletal muscle (Forbes et al., 2020).

2.3.2 Performance Benefits of Beta-alanine

Beta-alanine has shown to improve high-intensity exercise performance by increasing muscle carnosine content and therefore enhancing intracellular buffering of hydrogen ions (H^+) (Trexler et al., 2015). Crossfit workouts are often performed with limited time to recover between each set. Moreover, high levels of lactate are found during Crossfit WODs, which underline the intensity of the training sessions (Schlegel, 2020). The accumulation of lactate is associated with the release of H^+ and can cause a reduction of skeletal muscle pH, resulting in acidosis and fatigue (Ojeda et al., 2020). Beta-alanine supplementation has shown to limit the reduction in pH, and thus reduce the subjective feeling of fatigue at the same exercise intensity. Therefore the subjects were able to exercise for longer at the same intensity (Forbes et al., 2020). Moreover, beta-alanine supplementation has shown to significantly improve 2000m rowing performance (Baguet et al., 2010) and enhance running and cycling time trial performance (Forbes et al., 2020). 2000m rowing as well as running and cycling time trials can be found during various Crossfit WODs (Glassman, 2013).

2.3.3 Practical Recommendations for Beta-alanine

Beta-alanine supplementation should be started with a loading phase of around 2 to 4 weeks, to increase muscle carnosine levels. The dose of the loading phase is the same as afterwards: 3.2 to 6.4g should be ingested per day (or 65mg/kg/day). This dose should be divided in equal doses of 2g or less to reduce possible side effects (Trexler et al., 2015). For best tolerance, beta-alanine should be combined with a carbohydrate rich meal. Furthermore, to optimal support performance, the duration of the supplementation period should last between 2 and 24 weeks (Forbes et al., 2020). In addition to beta-alanine, sodium-bicarbonate has shown to enhance intracellular buffering in similar ways. Athletes might consider using sodium-bicarbonate instead of beta-alanine, but supplementation was often accompanied by gastrointestinal syndromes (Durkalec-Michalski et al., 2018), and thus might negatively impact the athletes performance.

2.3.4 Possible Side Effects of Beta-alanine

The most widely known side effect of beta-alanine supplementation is paresthesia. The tingling typically occurs in the face, neck and back of hands, with higher doses resulting in greater side effects. Up to date there is no evidence to support that this tingling is harmful (Trexler et al., 2015).

3 Risk of Supplementation

The sport supplement market presents a growing industry, but unlike the pharmaceutical market, supplement manufactures are not required to test their products to prove their safety or efficiency. Thus, around 10-25% of supplements have been found to be contaminated, either due to poor manufacturing or undeclared addition of ingredients (Mottram & Chester, 2011). Therefore, the ergogenic effects from the use of a supplement must be carefully balanced against potential side-effects, mostly concerning health risks or inadvertent doping (ACSM, 2016). Health concerns can include the presence of ingredients due to contamination, that are toxic, or poor practices of athletes consuming very large doses of products (ACSM, 2016). Additionally, contamination with banned substances could lead to inadvertent doping. Athletes should be aware, that laboratories from the world anti-doping agency (WADA) can detect those substances at much lower concentration than supplement manufactures can (Mottram & Chester, 2011).

To minimize those health and doping risks athletes who compete under anti-doping code should only use batch-tested products like informed sport, to provide a greater assurance of purity (Close et al., 2022). Moreover, athletes should ask accredited practitioners for advice, and not rely on marketing claims from the internet or advice from friends (ACSM, 2016). Besides, athletes could use the classification system of the Australian Institute of Sport (Australian Institute Of Sport, 2021), to detect whether a product is safe and might improve sports performance. All supplements should just be taken in addition to a well-chosen nutrition (ACSM, 2016). When considering a supplement athletes might use the additional decision flow chart (*Figure.2*), to figure out whether to use a product or not.

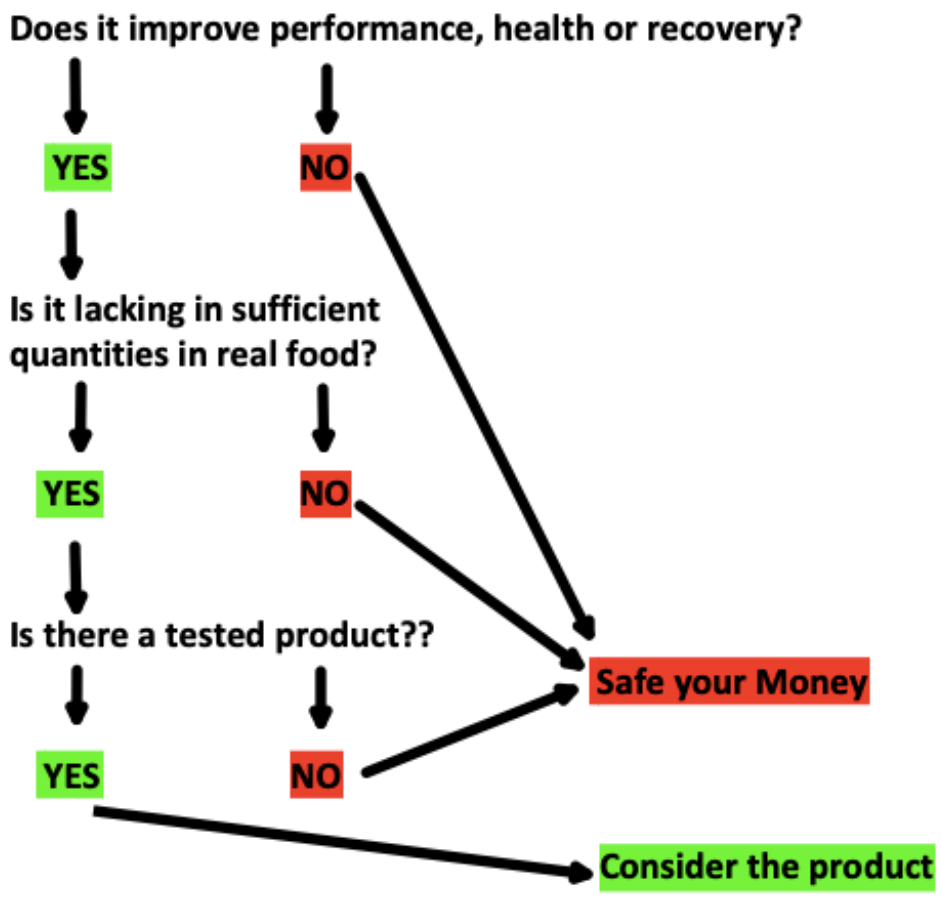

Figure.2: Supplement use decision flow chart adapted from Close et al., (2016)

4 Summary

Crossfit can be classified as a constantly varied, high-intensity training. Even though nutrient provision should to a high ratio come from whole foods and drinks, there are situations where this is not always optimal, and where supplements can help athletes improve performance or recovery. Caffeine can be found in coffee or tea, but the amount of caffeine is highly variable. Therefore, caffeine capsules might help athletes to consume the recommended amount. Furthermore, creatine and beta-alanine are found in food, but are difficult to obtain in sufficient quantities in the diet. Thus, supplementation of these can help athletes to achieve performance enhancing doses. Due to the large variety in Crossfit training, competition and WODs, there might also be other supplements that could potentially benefit performance. In addition, many supplements might also improve recovery, which could also enhance overall Crossfit performance. *Table.1* summarizes the practical applications for the use of the supplements mentioned above:

Table 1. Practical recommendations for Crossfit athletes

Supplement	Practical recommendations
Caffeine	3-6mg/kg, around 60min pre-exercise
Creatine	Loading phase: 0.3g/kg/day for 5-7 days (3-4 portions/day) Maintenance phase: 3-5g/day
Beta-Alanine	3.2 – 6.4g/day or 65mg/kg/day (divided in doses of 2g or less)

Mg = milligrams, kg = kilograms

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