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The Consumption of Fruits as a Potential Alternative to Accelerate the Recovery Process After High Intensity Exercise

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ABSTRACT

A prevalent desire in the sports world is the acceleration of post-exercise recovery; therefore, many studies have examined the use of dietary supplements before, during, and after exercise to determine the positive effects on athletes as a catalyst for recovery. Overall, studies have found that adaptations to regular exercise promotes advantageous reactions in the body to boost the immune system, prevent dyslipidemia and muscle loss, and increase bone density. However, exercise at an increased intensity or duration usually performed under competitive settings can deplete glycogen stores, increase lactic acid, form an excess amount of reactive oxygen species (ROS), increase tissue damage, and decrease immunologic function. This review incorporated studies that tested the use of fruits as a strategy to attenuate the period by which the body buffers the increase in acidity and inflammation, scavenge ROS and to regenerate muscle damage after high intensity exercise. Therefore, the effect of fruit intake rich in vitamins and those containing polyphenolic ring-based flavonoids and carbohydrates was discussed. Nutrient supplementation can enhance recovery after high intensity exercise, particularly fruits of red-blue color such as cherries and blueberries seem to decrease oxidative stress, inflammation, and muscle damage. In summary, each fruit has specific targets to offset body regeneration, avoid over training, and improve overall performance.

Keywords: Body regeneration. Muscle damage. Cherry. Blueberry.

O CONSUMO DE FRUTAS COMO POTENCIAL ALTERNATIVA PARA ACELERAR O PROCESSO DE RECUPERAÇÃO APÓS EXERCÍCIO DE ALTA INTENSIDADE

RESUMO

A aceleração da recuperação pós-exercício é importante no mundo dos esportes; portanto, muitos estudos examinaram o uso de suplementos dietéticos antes, durante e após o exercício para determinar os efeitos como um catalisador para a recuperação. No geral, estudos demonstraram que as adaptações aos exercícios regulares promovem reações vantajosas no corpo para estimular o sistema imunológico, prevenir dislipidemia e perda de músculo e aumentar a densidade óssea. No entanto, o exercício em uma intensidade ou duração aumentada realizado em ambientes competitivos pode esgotar os estoques de glicogênio, aumentar o lactato, formar uma quantidade excessiva de espécies reativas de oxigênio (ROS), aumentar o dano ao tecido e diminuir a função imunológica. Esta revisão incorporou estudos que testaram o uso de frutas como estratégia para atenuar o período em que o corpo recupera do aumento da acidez e inflamação, diminui ROS e regenera os músculos após exercícios de alta intensidade. Foi discutido, portanto, que o efeito da ingestão de frutas contendo flavonóides polifenólicos baseados em anéis e ricos em vitaminas e carboidratos, bem como bebidas e alimentos ricos em carboidratos e proteínas. A suplementação de nutrientes pode melhorar a recuperação após exercícios de alta intensidade, especialmente frutas de cor vermelho-azulada, como cerejas e mirtilos, parecem diminuir o ROS, a inflamação e o dano muscular. Em resumo, cada fruta tem metas específicas para compensar a regeneração do corpo, evitar o excesso de treinamento e melhorar o desempenho geral.

Palavras chave: Regeneração corporal. Dano muscular. Cereja. Mirtilo.

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INTRODUCTION

Proper nutrition is important for various reasons regarding human health, including maintaining a healthy body weight, decreasing risk of chronic diseases, and increasing exercise performance. Sports nutrition has shown the importance of dietary behavior on athletic performance to improve strength, power, and endurance (BECK *et al*., 2015; RATTRAY *et al*., 2015). Exercise induces different responses on the body depending on the intensity, duration, type and frequency.

Overall, studies have found that adaptations to regular exercise promotes advantageous reactions in the body to boost the immune system, prevent dyslipidemia and muscle loss and increase bone density (MARCOS; NOVA; MONTERO, 2003; KARP *et al*., 2006). However, exercise at an increased intensity or duration usually performed under competitive settings can promote damage to the body (MARCOS; NOVA; MONTERO, 2003).

Many dietary supplements such as fruits, vegetables and beverages contain antioxidants, carbohydrates, and proteins that can facilitate a quicker recovery for the body, which can decrease recovery time necessary to avoid over training, dehydration, and oxidative damage. Therefore, the aim of this review was to analyze studies that tested the use of fruits as post-exercise recovery strategies. For complete comprehensive discussion on this topic it is necessary to briefly discuss the isolated effect of high intensity and prolonged exercise on the body system.

EFFECT OF HIGH INTENSITY EXERCISE ON GLUCOSE METABOLISM, OXIDATIVE STRESS, MUSCULAR DAMAGE AND IMMUNOLOGICAL SYSTEM

During exercise the human body endures several changes to compensate alterations on body homeostasis. Moreover, there are increases in capillarization in the active muscles, change in blood distribution, and increases in body temperature. Hormones, for instance, adrenaline and noradrenaline, are secreted and energy demands are increased (MORO *et al*., 2019; WADE *et al*., 2020; BOGDANICH; KIGER; SANTOS, 2019). Several pathways are overstimulated generating accumulation of waste products.

Since skeletal muscles produce the force for all voluntary movements, the demand of energy is increased during exercise. Glucose is the first organic compound metabolized to produce ATP during high intensity aerobic exercise. In the contracted muscle, the concentration of skeletal muscle glucose transporter, GLUT4, translocate to the cell membrane to increase glucose uptake (SANTOS *et al*., 2008). To control blood glucose levels during exercise, the liver breaks down the glycogen releasing glucose to the blood stream. In the sarcoplasm, glucose is broken down, and in high intensity exercises, lactate is a byproduct of the anaerobic glycolysis process. The fatigue is characterized by glycogen depletion and an increase in lactate concentration or acidosis, and typically occurs during exercise performed above the blood lactate threshold (KARP *et al*., 2006).

After the first minute/s of exercise (1.5 to 3 minutes) the main source of energy progressively redirects to aerobic; mitochondrial citric cycle and electron transport chain (ETC) play a central role on this process. In the process of energy production, complex I and III of ETC produce reactive oxygen species (ROS) and during exercise, with the increase in energy demand and oxygen uptake ROS generation increase exponentially (YAVARI *et al*., 2015). ROS might activate the pathway for mitochondrial biogenesis, but also change the structure of macromolecules, such as the DNA, fatty acids, amino acids, and proteins (YAVARI *et al*., 2015).

This energy generated with the breakdown of organic components allows the actin cytoskeleton to contract and be transmitted across the plasma membrane to the basement membrane and adjacent myofibers. Stress due to this force transmission and ROS generated might injure the sarcolemma. During high intensity exercise, if a myofiber is damaged beyond repair, it is regenerated in the following weeks through a series of steps (HORN *et al*., 2017). Damage in the sarcolemma allows intramuscular proteins, such as myoglobin, creatine kinase (CK), and lactate dehydrogenase (LDH), to leak into the blood (LAMB *et al*., 2019; AMMAR *et al*., 2016).

Regular exercise promotes an improvement on the immunologic system; however, acutely prolonged, high intensity exercise could induce depression of immunologic function. Oxidative stress, change in body temperature, and damage in skeletal muscle membrane have been associated with leukocytosis after heavy exercise (DAVISON *et al*., 2012). In addition, studies have reported that physical activity can induce an acute inflammation phase response characterized by an increase in multiple circulating cytokines and chemokines, such as Interleukin-1 (IL-1), Interleukin-6 (IL-

6), Tumor Necrosis Factor α (TNFα), Epidermal Growth Factor (EGF), and Monocyte Chemoattractant-1 (MCP-1) (ACCATTATO *et al*., 2017).

In summary, at the end of high intensity exercise the human body faces dehydration, depletion of glycogen reserve, an increase in acidity, ROS, muscle damage and pro-inflammatory cytokines. Fortunately, the human body contains a sophisticated compensatory mechanism to buffer the increase in acidity, scavenge ROS through inflammatory enzymes, and to regenerate muscle damage. After exercise, ROS act as signals in exercise activating signaling pathways that cause useful adaptations in cells. Chronically, this process might result in upregulation of antioxidant enzymes, increase in mitochondrial density, and skeletal muscle growth (DOS SANTOS *et al*., 2015; GOMEZ-CABRERA; DOMENECH; VIÑA, 2008). Yet, the complete recovery could take several hours to days. Different strategies have been used to abbreviate the recovery period, such as fruits consumption as dietary supplements. The overall aim of this review is to analyze the use of fruits to improve post-exercise recovery and determining which type will be the most beneficial based on the published literature.

Fruits as Dietary Supplements for Exercise Recovery

Fruits are present in the majority of diets as a potent source of essential vitamins, minerals, and fiber. Fruits provide a wide range of health-boosting antioxidants and anti-inflammatory agents including flavonoids (SEERAM, 2008). In addition, fruits are a source of carbohydrate that can fulfill the promotion of cellular and systemic damage and the deficit of glycogen faced post high intensity exercise (MCLEAY *et al*., 2012). The fruits may be composed of potassium, vitamin B6, C, E, pro-vitamins A phenolics, carotenoids, lutein, folic acid, magnesium, catecholamines, and antioxidants; all important in reduction of oxidative stress, inflammation, and recovery post high intensity exercise (NIEMAN *et al*., 2018a; LAPUENTE *et al*., 2019). Thus, fruits may assist in decreasing the effects of exercise on the body due to their anti-inflammatory and antioxidant capabilities.

Studies have shown red and blue colored fruits, such as cherries, blueberries, pomegranates, and grapes, contain anthocyanins, which are polyphenolic ring-based flavonoids that decrease the risk of cardiovascular disease, might hinder the growth of many types of cancers, and activate the immunological system (MCANULTY *et al*., 2011). These fruits contain high levels of bioactive compounds and polyphenols antioxidants, carotenoids, flavanoids, phenolic acids, hydroxycinnamates, ellagic acid, quercetin, ellagitannins, and proanthocyanins (AMMAR *et al*., 2018). Bell *et al*. (2015) found such components are capable of decreasing cell damage caused by oxidative stress and have high levels of anti-inflammatory capacities (BELL *et al*., 2015; HOWATSON *et al*., 2010; KELLEY *et al*., 2006; SEERAM *et al*., 2001).

Cherries

Tart and sweet cherries provide to dietary fiber intake and carry high amounts of antioxidants (WANG; CAO; PRIOR, 1997; BELL *et al*., 2015). A study by Howatson *et al*. (2010) was performed to investigate the effect of tart cherry juice blend ingested before and after running a Marathon on muscle damage, inflammation, and oxidative stress. In the study, total antioxidant capacity increased and lipid peroxidation decreased in the group that consumed the cherry juice in comparison to the placebo group (HOWATSON *et al*., 2010).

Moreover, it was shown that Montmorency cherry concentrate consumption twice per day for 8 consecutive days can be an efficacious functional food for accelerating recovery and reducing exercise-induced inflammation such as IL-6 and high-sensitivity C-reactive protein following strenuous cycling exercise (BELL *et al*., 2015). The same study did not find an effect on levels of CK in blood (BELL *et al*., 2015). In agreement, a study performed in 36 resistance trained men found no effect of tart cherry juice intake in blood levels of CK after resistance (LAMB *et al*., 2019).

Analyzing different markers of muscle catabolism and soreness (blood creatinine and total protein), Levers *et al.* (2015) suggest that short-term consumption (10 days pre and 48 h after exercise) of Montmorency powdered tart cherries in a capsule is an effective supplement to recovery after a single bout of resistance exercise in resistance trained individuals (LEVERS *et al*., 2015). Therefore, cherry intake seemed to account for the improvement of the recovery after high intensity exercise; however; it's effect on muscle damage marker remain contradictory.

Blueberries

Blueberries have benefits in attenuating ROS and inflammatory cytokines, which was shown to inhibit neural degeneration (MCANULTY *et al*., 2011; YOUDIM *et al*., 2002). This makes blueberry an attractive fruit to mitigate damages induced after heavy exercise. McAnulty *et al*. (2011) tested on twenty-five trained subjects prior to and after 2.5 h of running. This study found reduction of plasma 8-isoprostanes (a classical ROS marker) and elevated plasma IL-10 post--exercise. Natural killer cell counts are usually reduced after long durations of exercise, but in McAnulty *et al*. (2011) study, the blueberry group had high pre-exercise natural killer cell levels, which assisted in maintaining levels after exercise close to the control group prior to physical activity (MCANULTY *et al*., 2011). Similar effect of blueberry supplementation on immunological system was found after 3 days of intensified running training (AHMED *et al.,* 2014) when blueberry-green tea-polyphenol soy protein complex for 17 days, with a 3-day running period inserted at day 14 (AHMED *et al.,* 2014).

In addition, the intake of blueberry was studied after eccentric exercise and was found to have a faster rate of decrease in oxidative stress when this fruit was consumed 5 and 10 hours prior to 300 strenuous eccentric contractions of the quadriceps and then immediately, 12 and 36 hours (MCLEAY *et al.,* 2012). Increase in antioxidant capacity as well as decrease in IL-6 and CK was found when blueberry have been consumed (MCLEAY *et al.,* 2012). Moreover, despite of no effect in performance, 4 days of blueberry supplementation decreased blood lactate after 8 km running (BRANDENBURG *et al*., 2019). In contrast, supplementation polyphenol soy protein complex containing blueberry over a 17 days period did not alter blood biomarkers for inflammation and oxidative stress after from 3 days of heavy running exertion (NIEMAN *et al.,* 2013). As a result, the ingestion of blueberries seemed to increase recovery rate and muscle repair, and stimulate the reduction of oxidative stress, inflammation, and prevent diseases after exercise.

Pomegranate

Utilization of pomegranate as a supplement has been shown to prevent oxidative stress by increasing antioxidant status and decreasing oxidative stress with the inclusion of lipid peroxidation and low-density lipoprotein oxidation (AMMAR *et al*., 2018). Pomegrante also improved exercise performance of aerobic (TREXLER; SMITH-RYAN; MELVIN, 2014) and strength exercise (ROELOFS *et al*., 2017). Pomegranate juice ingestion seemed to reduce oxidative stress response to intense physical activity through the enhancement of antioxidant responses and accelerate recovery; pomegranate supplementation has implications for performance recovery post-exercise bouts (AMMAR *et al*., 2018).

Healthy subjects performed once exhaustive exercise running on treadmill after one cup of pomegranate juice for two weeks. Antioxidant enzymes activity of superoxide dismutase and glutathione peroxidase was increased in the group who consumed pomegranate juice when compared to the control placebo group (MAZANI; FARD; BAGHI, 2014). Moreover, Ammar *et al*. (2016) tested the consumption of 1.5L of pomegranate juice or placebo on the 48 hours following the performance of two Olympic-Weightlifting-sessions. Pomegranate intake improved the recovery kinetic CK and LDH showing its effect on muscle damage (AMMAR *et al*., 2016).

On the other hand, a study observed no change in inflammatory markers such as IL-6, and CK or myoglobin for 9-days of pomegranate extract consumption 2, 24, 48, 72, and 96 h after two sets of 20 maximal eccentric elbow flexion exercises with one arm when compared to placebo (TROMBOLD; BARNES; CRITCHLEY, 2010). Indeed, pomegranate intake was not effective to attenuate exercise-induced muscle damage from eccentric exercise of the elbow flexors of their non-dominant arm (LAMB *et al*., 2019). Therefore, the effect of pomegranate consumption on exercise recovery still contradict.

Grapes and apple

Oligomeric proanthocyanidins (OPCs) are polyphenols that are polymers of flavanols (MANACH *et al*., 2004), and the main nutrient sources are grapes, cocoa, and apples (SANTOS-BUELGA; SCALBERT, 2000). It is supported that constant consumption of grape juice decreased oxidative stress damage caused by carbon tetrachloride in the brain, liver, and plasma (DANI *et al*., 2008a, 2008b). In Dalla Corte *et al*. (2013) study, organic purple grape juice intake was verified to be sufficient in protecting vital organs from oxidative stress induced by prolonged exercise in laboratory animals (DALLA CORTE *et al*., 2013). Beside healthy humans ingested 300 mg/day of polyphenol-rich grape seed extract or placebo from the time of eccentric exercise to 72 h after exercise (KIM; SO, 2019). CK level was significantly decreased 96 h after exercise in the polyphenol-rich grape seed extract group compared with the placebo group (KIM; SO, 2019). Together these result suggested that grapes might inhibit muscle ROS increase in skeletal muscle damage.

Apples are important in protecting body cells from damage that can be caused from oxidative stress. Another attribute of apples is their abundance of antioxidants used in the inhibition of poor cell proliferation, decrease in lipid oxidation, and lowering cholesterol (LAPUENTE *et al*., 2019). Therefore, apples and grapes are useful supplements in the promotion of a decrease in oxidative stress and inflammation. Few research have been performed analyzing the effect of apple and grape intake and together suggest that both promote effect of recovery blood pressure or time to exhaustion (DELEY *et al*., 2017; NETO *et al*., 2017), outcomes linked to health rather than performance. During the two testing sessions, healthy subjects completed an endurance test at a high percentage of their maximal aerobic power and time to exhaustion was measured. The preceding evening and 1 h before testing, subjects consumed either 500 mg of polyphenols (grapes and apples) or placebo and the intake of polyphenols improve performance and maximal perceived exertion (DELEY *et al*., 2017). Therefore, the effect of grapes and apple combined on recovery by an analysis using ROS and muscle damage waits for further verification.

Tomato

Tomatoes are comprised of numerous phytochemicals and bioactive components, which encompass a wide variety of vitamins, minerals, and antioxidants (LAPUENTE *et al*., 2019). Consumption of tomatoes have been found to reduce levels of inflammatory response, oxidative stress markers, and lipid peroxidation (LAPUENTE *et al*., 2019). The effect of tomato on the recovery process after high intensity exercise has still not been well explored. In one of the few studies in this topic, supplementation of tomatoes with lycopene, phytoene, and phytofluene over a 4-week period attenuated muscle damage biomarker myoglobin, but not CK post-exercise from 2 hours running bout, inflammation or oxidative stress (NIEMAN *et al*., 2018b). Therefore, the effect of tomatoes after exercise waits for further clarifications.

Bananas

Bananas are high in many of the aforementioned components making them an eminent post-exercise supplement. Nieman *et al*. (2018a) found that banana consumption was related to increased post-exercise plasma glucose and fructose, and a reduction in leukocyte counts. The study displayed acute consumption of bananas during prolonged, high intensity exercise reduced inflammation by increasing blood glucose and tissue glucose uptake; the higher plasma sugar levels are efficient in maintaining mitochondrial oxidative metabolism (NIEMAN *et al*., 2018a). The same laboratory found that banana consumption provided benefits to the immunological system and antioxidant defense after athletes cycled 75 Km (NIEMAN *et al*., 2018a). In contrast, banana intake did not affect blood lactate production after high intensity interval exercise (ASTORINO *et al.,* 2019). Due to the sugar and phytochemicals in bananas, the ingestion during exercise can be used to improve metabolic recovery and lower post-exercise inflammation at the cellular level.

CONCLUSION

In summary, fruits contain nutrients with carbohydrates, proteins, and antioxidants to endure the most abundant recovery after exhaustive exercise (Figure 1). Most of studies have shown that cherries and blueberry can control oxidative stress and inflammation; however, its effect on damage in the skeletal muscle membrane remain contradicted. Regarding pomegranate, studies agreed on its effect towards the increase in oxidative stress after exercise. The effect of grapes, apple, banana, tomato as an asset to abbreviate recovery after high intensity exercise awaits future clarifications. Further studies should be carried out associating the fruit effect with parameter related to glucose metabolism. Another limitation on this field is the heterogeneity of the fruit intake, studies have been using fruit extract, fruit juice, or encapsulate fruit components. Indeed, researchers should test the single effect of various fruits using similar exercise protocols and population. Based on the studies reviewed each fruit appeared to have specific targets to attenuate body regeneration, avoid over training, and improve overall performance (Table 1). Together the majority of data demonstrated beneficial effect of fruit on the recovery process after high intensity exercise.

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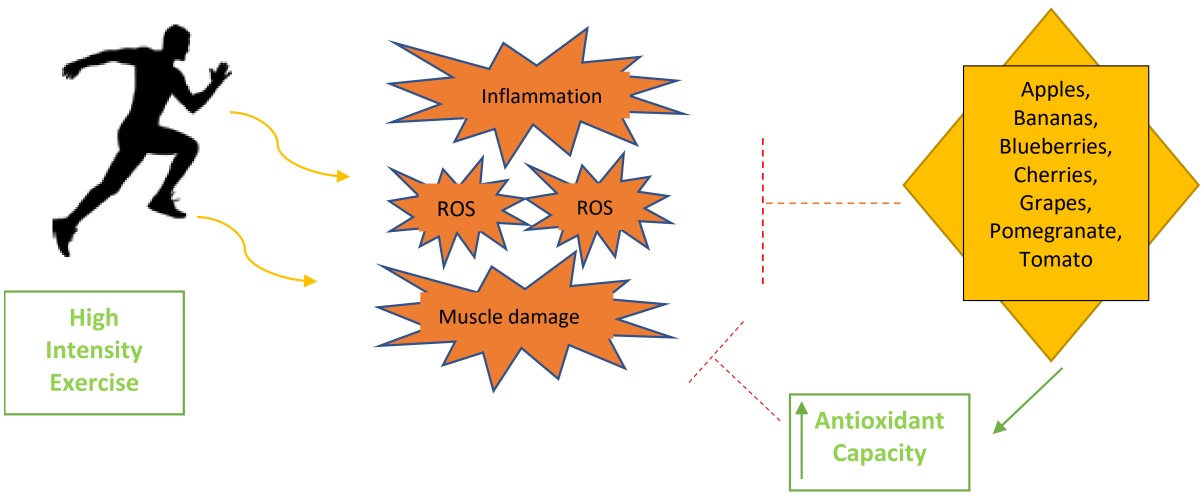
Table 1 – Effect of fruits and its target on the recovery process after high intensity exercise

Fruits	Effect	Reference
Apples	↓ Oxidative Stress ↓ Exercise-Induced Inflammation ↑ Total Antioxidant Capacity	Deley *et al.* (2017) Neto *et al.* (2017)
Bananas	↓ Exercise-Induced Inflammation	Nieman *et al.* (2018a)
Blueberries	↓ Oxidative Stress ↓ Exercise-Induced Inflammation ↑ Total Antioxidant Capacity ↑ Recovery Rate Muscle Membrane Damage (contradict)	McLeay *et al.* (2012) McAnulty *et al.* (2011) Youdim *et al.* (2002)
Cherries	↓ Lipid Peroxidation ↓ Exercise-Induced Inflammation ↑ Total Antioxidant Capacity Muscle Membrane Damage (contradict)	Bell *et al.* (2015) Lamb *et al.* (2019) Howatson *et al.* (2010) Wang; Cao; Prior (1997)
Grapes	↓ Oxidative Stress	Dalla Corte *et al.* (2013) Kim & So (2019)
Pomegranate	↓ Oxidative Stress ↓ Exercise-Induced Inflammation ↑ Total Antioxidant Capacity Muscle Membrane Damage (contradict)	Ammar *et al.* (2018) Trexler; Smith-Ryan; Melvin (2014) Roelofs *et al.* (2017)
Tomatoes	↓ Lipid Peroxidation ↓ Exercise-Induced Inflammation ↑ Total Antioxidant Capacity	Lapuente *et al.* (2019) Nieman *et al.* (2018b)

Font: The authors.

Figure 1 – Schematic representation of the effect of fruits on ROS (reactive oxygen species), inflammation, muscle membrane damage and antioxidant capacity after high intensity exercise. These fruits-effects improve the recovery after exercise



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