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THE EFFECT OF TURMERIC AND ITS COMPOUND CURCUMIN ON MUSCLE RECOVERY IN ATHLETES: MINI REVIEW

VPLIV KURKUME IN NJENE SESTAVINE KURKUMINA NA OBNOVO MIŠIC PRI ŠPORTNIKIH: MINI PREGLEDNI ČLANEK

ABSTRACT

Dietary supplements are used to enrich the diet of athletes, and contribute to better adaptation on the part of athletes to their training, as well as quicker recovery from physical exercises. One such substance is turmeric, which has received wide-spread interest from medical, scientific and sports specialists due to its numerous benefits to human health and recovery. Curcumin is the most widely researched bioactive component of turmeric, but even curcumin-free turmeric is believed to be as effective as curcumin, and, therefore, this review concentrates on the effect of turmeric as a whole. Turmeric, also known as the 'golden spice', may help in the treatment of exercise-induced inflammation and muscle soreness, and, therefore, turmeric can enhance recovery in athletes. This current review focuses on the benefits of turmeric for athletes, including anti-inflammatory, antioxidant and muscle recovery activities exhibited by turmeric.

Keywords: turmeric, curcumin, benefits, recovery, sport

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IZVLEČEK

Prehranska dopolnila se uporabljajo za obogatitev prehrane in prispevajo k boljši aklimatizaciji športnikov na trening ter hitrejšemu okrevanju po športni dejavnosti. Ena takih snovi je kurkuma, ki je zaradi številnih koristi za zdravje in okrevanje ljudi deležna velikega zanimanja medicinskih, znanstvenih in športnih strokovnjakov. Raziskovalci vedno bolj verjamejo, da je kurkuma brez kurkumine enako učinkovita kot kurkuma kot celota, zato se ta pregled osredotoča na učinek kurkume kot celote. Kurkuma, znana tudi kot "zlata začimba", lahko pomaga pri zdravljenju vnetja in bolečin v mišicah, ki ga povzroča vadba, zato lahko kurkuma izboljša okrevanje pri športnikih. Pričujoči pregled se osredotoča na prednosti kurkume za športnike, vključujoč njene protivnetne, antioksidativne in obnavljajoče prednosti.

Ključne besede: kurkumin, kurkuma, koristi, šport, okrevanje

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INTRODUCTION

Dietary supplements can play a substantial role in athletes' health, as well as their adaptation to, and recovery from, physical exercises. Turmeric has been shown to reduce markers of muscle damage and inflammation (Rawson, Miles, & Larson-Meyer, 2018), stimulate muscle regeneration after trauma (Thaloor, Miller, Gephart, Mitchell, & Pavlath, 1999), offset the muscle damaging effects of downhill running on inflammation and whole-body exercise performance (Davis et al., 2007), and it has received worldwide attention for its multiple health benefits (Hewlings & Kalman, 2017). Although turmeric has been known and used for hundreds of years for the treatment of various conditions, studies are now providing further evidence of how it can be of assistance to athletes in order to cope better with exercise-induced inflammation and muscle soreness, and thereby enhance performance recovery in active people (Hewlings & Kalman, 2017). Moreover, turmeric has been listed in a recent review as one of several dietary supplements (including creatine monohydrate, vitamin D, omega 3-fatty acids, probiotics, and collagen) which can potentially influence cellular and tissue health, resilience, and repair, in order to help athletes adapt to physical exercises, increase the quality and quantity of their training, and maintain their health (Rawson et al., 2018). Based on the potential positive effects, numerous commercial medical preparations containing turmeric are offered on the market in the form of capsules containing powder, extracts, or in combination with other nutritional supplements (Ravindran, Babu, & Sivaraman, 2007).

Turmeric – the golden spice

Turmeric is the dried root of the Curcuma longa plant (part of the ginger family Zingiberaceae) and has a strong connection with the Indian subcontinent. Turmeric is known as the 'golden spice,' due to thousands of years of documented history of its application as a medicine and in many socio-religious practices (Ravindran et al., 2007). The name turmeric originally comes from the Latin word 'terra merita,' which means 'beneficial earth', and in French is known as 'terre merite.' Throughout the world, this spice has many different names in different cultures and countries, such as 'yellow root', 'curcuma', 'Indian saffron', etc (Prasad & Aggarwal, 2011).

Turmeric is grown most extensively in India, but is also cultivated in Bangladesh, China, Thailand, Cambodia, Malaysia, Indonesia, and the Philippines. It can also be found on a small scale in some tropical regions in Africa, America, and Pacific Ocean islands. However, India is by far the largest producer, consumer, and exporter of turmeric (Ravindran et al., 2007).

Turmeric is known for its yellow colour, which comes from the presence of compounds called curcuminoids. The curcuminoids (1-6% of the weight of turmeric) are a group of compounds, such as curcumin (the most researched compound in turmeric), demethoxycurcumin, bis-demethoxycurcumin and cyclic curcumin. The IUPAC (International Union of Pure and Applied Chemistry) name of curcumin is (1E,6E)-1,7-bis(4-hydroxy-3-methoxyphenyl)-1,6-heptadiene-3,5-dione, also called diferuloylmethane, and it is the major component which makes up 60-70% of the weight of the curcuminoids, with the chemical formula $C_{21}H_{20}O_6$, and molecular weight of 368.38 (Priyadarsini, 2014). Vogel and Pelletier were the first to discover curcumin in 1815, when they reported the isolation of a yellow substance from turmeric, and named it curcumin (Gupta, Patchva, Koh, & Aggarwal, 2012). In fact, turmeric consists of more than 200 different compounds, and although curcumin is believed to account for most of the benefits accruing from turmeric, a recent review on curcumin-free turmeric (CFT) showed that CFT is as effective as, or even more effective than, curcumin containing turmeric (Aggarwal, Yuan, Li, & Gupta, 2013).

Nutritional analysis of turmeric has shown that the biggest fraction of the spice consists of carbohydrates (60-70% carbohydrates, 6-8% protein, 5-10% fat, 2-7% fibre, 3-7% mineral matter, 1-6% curcuminoids, 6-13% moisture, 3-7% Volatile oils), and a typical 100 g sample of turmeric contains 390 kcal, 69.9 g carbohydrates, 8 g protein, 8.9 g fat, 200 mg calcium, 260 mg phosphorous, 10 mg sodium, 2500 mg potassium, 47.5 mg iron, 0.09 mg thiamine, 0.19 mg riboflavin, 4.8 mg niacin, and 50 mg ascorbic acid (Ravindran et al., 2007).

Application of turmeric in traditional medicine

Turmeric has been used as a medicine and flavouring agent since 600 B.C., and it has been a traditional remedy in Asian folk medicines for the last 2000 years (Ravindran et al., 2007). In Ayurvedic medicine and in traditional Chinese medicine, turmeric is well documented for the treatment of various conditions: asthma, bronchial hyperactivity, allergies, gastric problems, inflammatory conditions, infectious diseases, hepatic disorders, colds, and others (Prasad & Aggarwal, 2011). Throughout Asia, turmeric has been used internally to treat stomach problems, different allergies, fevers, diarrhoea, chronic cough, bronchial asthma, flatulence, jaundice and other diseases. In India and Bangladesh, the spice is mixed with calcium oxide (CaO), then it is warmed and used to treat inflammation and the swelling of limbs caused by different external injuries (Ravindran et al., 2007).

Application of turmeric in modern medicine

In vitro and in vivo studies with turmeric

Turmeric has been applied for both the prevention and treatment of diseases. Prasad and Aggarwal summarised numerous modern in vitro studies, which showed that turmeric is a powerful antioxidant, anti-inflammatory, antimutagenic, antimicrobial, and anticancer agent, as well as in vivo studies, in which turmeric exhibited anticancer, hepatoprotective, cardioprotective, hypoglycaemic and antiarthritic properties (Prasad & Aggarwal, 2011).

Turmeric, or its compound curcumin, was reported to be active in the fight against the development of different types of cancer, such as skin cancer (Villasenor, Simon, & Villanueva, 2002), breast cancer (Deshpande, Ingle, & Maru, 1998; Talib, Al-Hadid, Ali, Al-Yasari, & Ali, 2018; Wen et al., 2019), metastatic colorectal cancer (Hosseini, Zand, & Cheraghpour, 2019), gastric cancer (Gu, Zhang, Zhang, & Zhu, 2019) and stomach cancer (Azuine & Bhide, 1992) in different models. Although curcumin was shown to have chemotherapeutic effects in different types of cancer cells, its efficacy has been limited in clinical studies. This could be due to its low level of solubility in water, rapid metabolism and inefficient absorption (Wang et al., 2019). Improving the bioavailability of curcumin will be the main problem before using it as a standard therapeutic agent to treat cancer (Talib et al., 2018; Wang et al., 2019). One such possibility might be to add piperine (the active compound of black pepper) to curcumin. This was shown to increase the bioavailability of curcumin by 154% in rats (Shoba et al., 1998).

Clinical studies with turmeric

Shoba et al. found that serum levels of curcumin, unlike in rats, were very low or even undetectable in humans. Similar to their experiments with rats, the serum concentrations of curcumin in humans increased significantly when piperine (a compound found in black pepper) was added. However, the increase was much higher, and the relative bioavailability of curcumin, when given with piperine, was reported to be 2000% in humans (Shoba et al., 1998). These results suggest that a combination of piperine and turmeric can provide more benefits.

Most of the trials were conducted with curcumin itself (a compound of turmeric), but some studies applied specific compounds of turmeric (curcuminoids), and others combined turmeric and piperine. For instance, a combination of curcuminoids and piperine was shown to improve the treatment of non-alcoholic fatty liver disease in a study with 70 subjects, who were given

either 500 mg curcuminoids with 5 mg piperine daily, or a placebo for 12 weeks (Panahi et al., 2019).

In studies on humans, turmeric has been applied in the fight against different diseases (Prasad & Aggarwal, 2011). For instance, turmeric was shown to significantly decrease the abdominal pain/discomfort score in patients with irritable bowel syndrome, after taking between 72-144 mg/day of a standardised turmeric extract for 8 weeks (Bundy, Walker, Middleton, & Booth, 2004). In another study, turmeric was given in doses of 1.5 g/day for 1 month, after which the participants (16 chronic smokers) experienced a significant reduction in the urinary excretion of mutagens (Polasa, Raghuram, Krishna, & Krishnaswamy, 1992). These results suggested an anti-mutagen effect of turmeric, which can be useful in chemoprevention.

Some of the most promising effects observed with curcumin were on pain, inflammatory conditions, and diabetic nephropathy (Gupta et al., 2012). However, curcumin was also used in healthy people. For instance, a low dose of curcumin (80mg/day for four weeks) was shown to lower triglyceride levels, increase nitrous oxide, and decrease markers of brain aging and liver injury in healthy middle-aged people (DiSilvestro, Joseph, Zhao, & Bomser, 2012). A similar dose of 80mg/day of curcumin was also found to improve important cognitive functions, resilience to the detrimental effects of psychological stress on mood, and reduce fatigue, as well as lowering total and LDL cholesterol in healthy elderly people (60-85 years of age), after taking it for four weeks (Cox, Pipingas, & Scholey, 2015).

DISCUSSION

Benefits of turmeric for athletes

Turmeric is a powerful antioxidant with health benefits for the cardiorespiratory, skeletal, and digestive systems. Turmeric was reported to be used by yoga practitioners, due to its beneficial effect on the ligaments (Ravindran et al., 2007). Strenuous exercise can cause muscle damage and athletes can experience muscle soreness and reduced range of movement (Howatson & van Someren, 2008). Strategies to attenuate inflammation after intense exercise regimens are becoming gradually popular. Dietary supplements with anti-inflammatory properties, such as turmeric, a derivative of curcuminoids, have been consumed for this purpose (Howatson et al., 2010).

In vitro studies, previously mentioned, concluded that muscle injuries could be treated with curcumin, which can be beneficial in reconstructive surgery and sports-related injuries (Thaloor et al., 1999). Similar findings were reported in trails with humans. In a study on 20 healthy men, with a moderately-active lifestyle, it was concluded that curcumin may be beneficial to reduce exercise-induced muscle soreness. The participants were given either 1 g of curcuminoids two times a day (corresponding to 200 mg of curcumin twice daily) or a placebo, 48 hours prior to and 24 hours after performing a downhill running test to induce eccentric muscle injury. The men from the group using curcumin reported less pain, and they had significantly less injury in their thighs 48 hours after the exercise test (Drobnic et al., 2014). A double-blind randomized-controlled study on 17 healthy men, who were given 2.5 g curcumin or placebo (two times a day for 2.5 days prior to sets of eccentric exercises, and 2.5 days after the exercises), showed that curcumin lowered subsequent pain associated with delayed onset muscle soreness, and lowered a blood marker for muscle damage (Nicol, Rowlands, Fazakerly, & Kellett, 2015).

In another study, curcumin was reported to reduce biological inflammation after physical exercises designed to induce muscle soreness. The participants were divided into curcumin (n=16, given 400 mg/day curcumin for 2 days before and 4 days after exercise test) and placebo (n=12) group. The authors concluded that using curcumin may help to decrease recovery time, and, therefore, improve performance during subsequent training sessions (McFarlin et al., 2016). Delecroix et al. provided further evidence for the application of curcumin to reduce muscle soreness. The authors were one of the first to examine the effects of a mix of curcumin and piperine on the muscle function recovery after exercise-induced muscle damage. The study included 16 elite level rugby players in a randomized, balanced cross-over design. The exercise test included 25 repetitions of one leg jumps (over 25m) on an 8% downhill slope. It was concluded that 2 g of curcumin and 20 mg of piperine (3 times a day) can reduce some, but not all, aspects of muscle damage (Delecroix, Abaidia, Leduc, Dawson, & Dupont, 2017). All of these results indicated that curcumin may be beneficial to reduce muscle soreness after physical exercises.

Faria et al. (Faria et al., 2020) conducted a randomized, double-blind, placebo-controlled study to evaluate the effects of CLE (*Curcuma longa L.* Extract) on inflammation and muscle damage with male amateur runners aged 25 to 50 years post half-marathon race. Of the 28 participants, 14 were administered 500mg of CLE (33.0mg of curcumin, 16.5mg of demethoxycurcumin, 15.0mg of bisdemethoxycurcumin) and 14 were the control group receiving placebo. Each participant ingested two capsules with lunch and one with dinner for a period of 29 days prior

to the competition. Participants' adherence to protocol was monitored by weekly phone calls and counting empty packs returned to the research team. Training volume before the competition, was relegated to running no more than 16km in one session, maintain exercise intensity between 70-85% of heart rate and rest 2 days prior to the competition. After the 29 days intervention period, all participants competed in the half-marathon. Thirty minutes before the competition, the runners were fed a standardized breakfast (one banana, one slice of white toast, two slices of cheese, and 200ml of maltodextrin (Kerksick et al., 2018) and consumed three capsules of CLE. Blood samples were drawn at three time points for analysis, before and after 29 days and 2 hours after the half marathon race. There were no differences in the blood samples between the two groups at baseline. Results of the study indicated that the CLE participants experienced a lower myoglobin concentration or lower muscle damage and soreness than that of the placebo group as a result of participating in a high intensity competition (Faria et al., 2020). In accordance with the findings from this study, curcumin supplementation was found to be beneficial in reducing myoglobin concentration after exposure to physical stress in studies with mice (Boz, Belviranli, & Okudan, 2014; Davis et al., 2007).

Sciberras et al. sought to observe the effects of curcumin supplementation on inflammatory marker responses after two hours of cycling. Eleven male cyclists participated in three trials in which they exercised for 2 hours at a power output equivalent to 95% of their lactate threshold. Five were assigned the placebo and six received the intervention dosage of 500 mg of curcumin. While the results of this study were not statistically significant between the placebo and curcumin groups, the interpretation of the finding lends the possibility of an attenuating effect on IL-6 by curcumin. An additional promising observation suggests that acute curcumin supplementation may reduce inflammation for participants when engaged in higher intensity training loads (Sciberras et al., 2015).

The potential effect that turmeric has in reducing muscle pain and soreness is due to the effect it has on activating nerve endings. Turmeric supplementation acts as a mediator in the suppressing the induction of isoform COX-2, which limits the production of mediating substances that cause muscle soreness post intense exercise regimens. Long lasting hyperalgesia is reduced due to the action of curcumin decreasing the mediators to attenuate the pain (Hatcher, Planalp, Cho, Torti, & Torti, 2008).

Previous research has indicated that turmeric may have anti-inflammatory effects on delayed onset muscle soreness (Nakhostin-Roohi., Moradlou, Hamidabad, & Ghanivand, 2016).

According to Tanabe et al. ingesting curcumin prior to exercise and sporting events could facilitate faster recovery and attenuate muscle damage through the decrease in creatine kinase (Tanabe, Chino, Ohnishi, et al., 2019). The ingestion of 2.5 g of curcumin supplementation capsules taken 48 hours before and 72 hours after eccentric exercise yield significant reduction in muscle pain according to Nicol et al. (Nicol et al., 2015). Tanabe et al. conducted two studies (Tanabe, Chino, Ohnishi, et al., 2019; Tanabe, Chino, Sagayama, et al., 2019) wherein a significant reduction in muscle soreness and pain were noted by the effect of a 180 mg curcumin supplementation protocol, administered in 90 mg twice daily. The capsules were administered four and seven days after eccentric muscle contraction exercise. Supplementation conditions are varied in terms of dose, frequency, and time. Curcumin supplementation administered consecutively for four days after exercise attenuated increase in muscle soreness thus having a positive effect on delayed-onset muscle soreness. Conversely, a single dose of 150 mg of curcumin immediately after exercise significantly reduced muscle pain (Nakhostin-Roohi. et al., 2016). Therefore, it can be concluded that turmeric doses demonstrate benefits in effectively attenuating muscle pain and soreness range from 150 mg – 2.5 g administered immediately following exercise. Best practices indicated that doses should be consecutively ingested through a duration of 72 hours respectfully.

Mechanical stress during eccentric exercise cause muscle damage which leads to a deterioration of muscle performance. Changes in range of motion (ROM), maximum voluntary contraction (MVC), and isokinetic dynamometry are indicative of exercise induced muscle damage. These parameters serve as indicators of athletic performance (Delecroix et al., 2017). Curcumin acts as a therapeutic mediator that blocks the signalling of NF-$_K$B, reducing the leucocyte adhesion and migration, resulting in pain relief and swelling and improves joint stiffness and mobility (Daily, Yang, & Park, 2016). Tanabe and colleagues conducted three studies to evaluate ROM and MVC. One of the studies demonstrated that 150 mg of curcumin before and 12 hours after exercise (50 eccentric contractions of elbow flexion) presented a significant decreasing magnitude on MVC. ROM decreased significantly at time intervals between 24- and 72-hours post exercise in the curcumin group with no significant interaction effects for changes between curcumin and placebo (Tanabe et al., 2015). The authors conducted another study wherein 180 mg of curcumin was ingested after exercise creating a significantly faster recovery of torque MVC and significant improvements in ROM (Tanabe, Chino, Sagayama, et al., 2019). A third study by Tanabe et al. concluded that 180 mg of curcumin ingested three to four days post

exercise significantly improved ROM with no relevant changes in MVC (Tanabe, Chino, Ohnishi, et al., 2019).

Concerns and possible side effects

Curcumin has been traditionally used as a spice in food products, household remedies and used in both Ayurvedic and Chinese medicine as an anti-inflammatory agent (Maroon, Bost, & Maroon, 2010). Curcumin has benefits associated with its anti-inflammatory effects and has a well-established safety record. The safety and efficacy of curcumin have been documented in several trials on healthy human subjects. The U. S. Food and Drug Administration (USFDA) published a 300-page monograph on its trials with turmeric and determined that the safety and efficacy of turmeric and its active component curcumin as generally regarded as safe (Prasad & Aggarwal, 2011). Despite the long-established safety of curcumin use, there are concerns and possible side effects reported.

Side effects of turmeric are few. A study conducted by Lao et al. in 2006 indicated that seven subjects receiving 500 mg – 12.000 mg in a dose response study, experienced symptoms such as diarrhoea, headache, rash and yellow stool when monitored for 72 hours (Lao et al., 2006). Curcumin was found to be safe at a dosage of 6 g per day orally for 4 –7 weeks and some adverse effects, such as gastrointestinal upsets, may occur. Prolonged use can cause gastrointestinal concerns and in extreme cases, gastric ulcers may occur with prolonged high doses. Caution is warranted for those taking anticoagulant medications and nonsteroidal drugs (Maroon, Bost, Borden, Lorenz, & Ross, 2006). Studies on humans have not revealed any toxic effects associated with the use of turmeric (Lao et al., 2006). It is evident that high doses of curcumin and turmeric are well tolerated by humans without significant side-effects (Fernandez-Lazaro et al., 2020).

A potential side effect of turmeric use is the impact it could have on male fertility, which was shown in mice. Research suggested that treatment of curcumin in laboratory mice noted adverse effects on motility, viability and number of sperms (Ashok & Meenakshi, 2004; Mishra & Singh, 2009). It should be noted however, that after 2 months of treatment withdrawal, all parameters returned to normal levels. Conversely, another study noted that dietary supplementation with turmeric, a derivative of curcumin, and ginger prevented changes in biomarkers of reproductive function in hypertensive rats. The authors suggested that ginger and turmeric could be applied as functional foods to prevent hypertension-mediated male reproductive dysfunction (Akinyemi et al., 2015).

Limitations of the study

This review has potential limitations. Only journal articles and clinical reports published in English were selected. Therefore, findings reported in other languages are not included in this review. Although, the authors of this review searched through multiple databases, including PubMed (MEDLINE database maintained by the United States National Library of Medicine of the National Institutes of Health), Web of Science, EMBASE (database maintained by Elsevier), and Google Scholar, articles might have been missed during the literature search. The titles and abstracts were screened, and full manuscripts were obtained to ensure that the methods involved turmeric. This review follows narrative style by synthesising primary studies and exploring this through description rather than statistics.

CONCLUSION

Curcumin has received worldwide attention for its multiple health benefits and is known as a generally recognized as safe substance. Long term studies support curcumin doses and have revealed no toxic or adverse effects. We postulate that turmeric, most specifically its active component curcumin, can be safely ingested to modulate the markers of inflammation and exercise induced muscle damage and soreness.

Curcumin is able to decrease muscle damage by attenuating muscle CK activity to increase muscle performance and provides post exercise anti-inflammatory effect in addition to a slight antioxidant effect. Curcumin, derived from turmeric, is recommended to athletes who are comfortable using ergogenic aids to enhance performance and to modulate the effects of muscle soreness, damage and inflammation caused by exercise bouts. Recommended dosage of turmeric for athletes is 400mg taken 3 times daily, administered before and immediately after exercise and for 72 hours after.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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