



## Research Article

### The Effect of Turmeric and Ginger Herbal Plants on Endurance Performance in Athletes: A Systematic Review

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#### Abstract

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**Introduction:** Intense endurance exercises, while improving cardiovascular performance and positive metabolic adaptations, often lead to increased oxidative stress, systemic inflammation, and muscle damage. This can delay recovery and negatively affect optimal athletic performance. In this context, the use of natural nutritional interventions with antioxidant and anti-inflammatory properties—especially herbal supplements such as turmeric (*Curcuma longa*) and ginger (*Zingiber officinale*)—is expanding as a natural intervention. The main bioactive compounds in these plants, such as curcumin in turmeric and gingerol in ginger, effectively reduce inflammation, control muscle pain, and improve recovery. This is done by inhibiting inflammatory pathways including NF- $\kappa$ B and COX-2 and decreasing inflammation markers like CRP and IL-6.

**Methods:** This study employed a systematic review method based on the PRISMA protocol. It examined published studies between 1992 and 2024 from reputable scientific databases including PubMed, Scopus, the Web of Science, Google Scholar, and SID. From the 200 initially identified articles, 72 studies met preliminary eligibility criteria. After applying the inclusion and exclusion criteria, 46 articles were selected for the final analysis. Inclusion criteria comprise human or animal studies focusing on the effects of turmeric and ginger on endurance performance, inflammation, muscle pain, and recovery.

**Results:** The results showed that supplementation with turmeric and ginger significantly reduces delayed-onset muscle soreness (DOMS), lowers inflammatory marker levels, improves aerobic capacity, and facilitates muscle glycogen resynthesis. Moreover, some studies confirmed a synergistic effect of the combined consumption of these two herbs on enhancing anti-inflammatory responses and accelerating recovery.

**Conclusion:** Based on this systematic review, turmeric and ginger supplementation appears to be a safe, natural, and effective nutritional strategy for improving endurance performance and recovery in athletes. However, there remains a need for more rigorously designed clinical trials to determine the optimal dosage, pharmaceutical form, and duration of use.

#### **Keywords:**

turmeric, ginger, endurance performance, muscle pain, inflammation, athletes

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## 1. Introduction

Maintaining physical capacity for an extended period of time requires effective energy management and inflammation control. Higgins et al. (2020) state that improving endurance performance and accelerating post-exercise recovery are major challenges for athletes because energy production, fuel consumption, and muscle damage directly impact performance. In Asia and the Middle East, herbal plants have a long history. In recent years, extensive research has focused on developing drugs and, more recently, dietary supplements (31). Traditionally used in diet therapy, herbs and medicinal plants hold a prominent position in the medical and pharmaceutical sciences. Plants and spices have been considered natural pharmaceutical sources and dietary additives for centuries (17). Among athletes, herbal supplements are popular dietary aids. NHANES reports that about 7% of the U.S. population uses these supplements, and Herbold et al. Herbal supplements are used by 17% of female collegiate athletes. Physiological or metabolic responses can be improved by taking these supplements to increase energy, lose weight, enhance muscle strength, and enhance muscle power. A product called SportPharm combines turmeric, ma huang, guarana, caffeine, purple willow bark, cayenne pepper, and ginger root to enhance alertness, stimulate fat metabolism, and improve physical performance. The active compound in turmeric, curcumin, reduces inflammation and muscle pain, and accelerates the recovery of muscle function (1) A dose of 90 to 5000 mg of curcumin per day can reduce perceived muscle pain, increase antioxidant capacity, and decrease creatine kinase activity, reducing muscle damage. As well as improving muscle function, curcumin also reduces the production of inflammatory cytokines such as TNF- $\alpha$ , IL-6, and IL-8 (28). Turmeric's active ingredient, curcumin, has anti-inflammatory, antioxidant, healing, and antimicrobial properties. Further clinical research is needed to determine its effectiveness in treating cancer, metabolic, cardiovascular, kidney, respiratory, and neurological disorders (16).

The medicinal plant ginger contains antioxidants and vitamin E. Gingerol, shogaol, paradol, and zingerone contribute to its anti-inflammatory properties (6). After exercise-induced muscle damage, raw or heated ginger has been shown to reduce mild to moderate muscle pain (9). Known for its anti-inflammatory and analgesic properties, ginger is a well-known medicinal plant in Iran and around the world. Inflammatory responses are modulated by active compounds such as gingerol, which inhibits the production of nitric oxide, prostaglandins, and inflammatory interleukins. A number of studies have shown that ginger reduces pain and inflammation by inhibiting cyclooxygenase and arachidonic acid metabolism (34, 26). The bioactive compounds in ginger and turmeric, including gingerol, shogaol, and curcuminoids, have significant anti-inflammatory and therapeutic properties. Al-Suhaimi et al. (2011) report that these herbal supplements can improve endurance performance and reduce muscle damage in athletes while accelerating recovery with minimal side effects. A study examines the effects of turmeric and ginger, both individually and in combination, on endurance performance in athletes. Muscle inflammation is reduced, pain is alleviated, recovery time is improved, and endurance capacity is increased. The goal is to provide evidence-based strategies for enhancing athletic performance with herbal plants.

## 2. Materials and Methods

The purpose of this systematic review was to investigate the effects of turmeric (*Curcuma longa*) and ginger (*Zingiber officinale*) on endurance performance and recovery in athletes. In order to conduct this review, a comprehensive search was conducted in scientific databases such as PubMed, Scopus, Web of Science, Google Scholar, and SID. We searched in English using keywords such as "ginger supplementation," "curcumin supplementation," "athletic performance," "endurance," "muscle recovery," and "exercise-induced inflammation."

### Criteria for selecting studies

The inclusion criteria for selecting studies were as follows:

**Study Type:** Studies examining the effects of turmeric and ginger on endurance performance and recovery after physical activity.

**Dosage and Duration:** Research on the effects of turmeric and ginger supplementation on athletic performance and recovery.

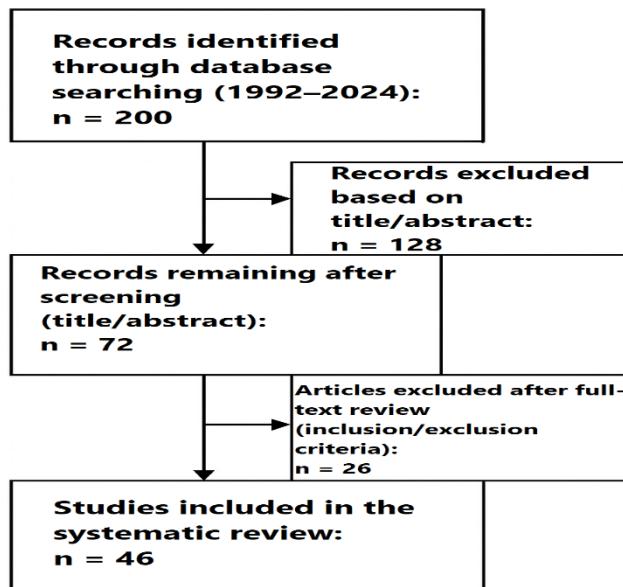
**Investigated Parameters:** Research examines endurance capacity ( $VO_2$  max), muscle recovery time, pain and inflammation levels, and biochemical markers of inflammation and damage to muscles.

### Search and Study Selection Process

Database searches identified 200 articles published between 1992 and 2024. Based on the inclusion criteria, 72 studies were selected focusing on the effects of turmeric and ginger on endurance performance. The final analysis of this review included 46 studies that met all entry criteria. Inclusion criteria required studies with human or animal subjects examining the effects of these two herbal plants on functional, inflammatory, and recovery-related parameters following exercise.

**Table 1.** A systematic review search strategy was used in this study.

Stage	Description
Search	200 articles were identified from databases.
Screening	128 articles were excluded based on title and abstract.
Full Assessment	72 articles were reviewed in full.
Exclusion by Criteria	26 articles were deemed ineligible.
Final	46 studies were included in the final analysis.

**Fig. 1.** Strategy for searching scientific databases such as PubMed, Scopus, Web of Science, Google Scholar, and SID.

### 3. Results

#### The results of the search and selected sources

After removing duplicates and screening by title and abstract, 72 articles from the 200 articles retrieved in the initial search phase were reviewed in full. In the final analysis, 46 studies met the inclusion criteria (human or animal studies focused on endurance performance, inflammation, muscle pain, or post-exercise recovery). Of these 46 studies, 20 examined ginger's effects, another 20 examined turmeric's or curcumin's effects, and 6 investigated their combined effects. Clinical trials, reviews, animal experiments, and laboratory studies were included in the studies. Researchers found that ginger reduced delayed-onset muscle soreness (DOMS), improved inflammation markers, and accelerated recovery (6, 9, 21, 41), as well as improved endurance performance after turmeric (curcumin) supplementation (1, 28, 15). There have also been studies exploring the synergistic effects of combining these two herbs, showing enhanced anti-inflammatory and performance benefits (5, 45). As a result, this review provides evidence that ginger- and turmeric-based herbal supplements may enhance endurance athletes' performance and recovery.

#### Quality and Limitations of the Studies

It was found that many studies had high-quality research designs, but there were also weaknesses. Studies have been limited by small sample sizes or lack of precise information on dosage and duration, for instance. The final results could be affected by this. In addition, many studies used different supplementation protocols, making it difficult to compare results.

#### Conclusion by Methodology

This systematic review examined 46 studies on turmeric and ginger's effects on endurance performance and post-exercise recovery. There is evidence that these herbal plants reduce inflammation and speed up muscle recovery. The results of these studies have generally been favorable, but further research is necessary to determine the optimal dosage, duration, and long-term effects of these supplements.

Table 2. Characteristics of Participants and Interventions in the Studies Included in This Systematic Review

Author/Year	Study Design	Population	Intervention	Analyzed Outcomes	Main Conclusion
Garjiani et al., 2019	Clinical Trial	Knee Osteoarthritis Patients	Supplement of turmeric extract, black pepper, and ginger	Pain, knee function	Pain reduction and improved function
Nouri & Nikoufar, 2018	Cross-Sectional Study	Athletes	Herbal supplements	Aerobic capacity	Improved aerobic capacity in interval training
Abbott et al., 2023	Clinical Trial	Male Professional Football Players	Curcumin supplementation	Muscle soreness after matches	Reduced muscle pain and improved performance
Afshan & Dabidi Roshan, 2016	Two-Group Comparison	Resistance Training Individuals	Resistance training with and without ginger	Inflammatory markers	Decreased inflammation with ginger use
Ahmad et al., 2020	Narrative Review	Various	Biochemical, immune, and pharmacologic review of turmeric	Metabolism, immunity	Therapeutic potential of turmeric in diseases

Author/Year	Study Design	Population	Intervention	Analyzed Outcomes	Main Conclusion
Akbari et al., 2019	Meta-Analysis	Metabolic Syndrome Patients	Curcumin supplementation	Weight loss	Curcumin helps weight loss
Al-Suhaimi et al., 2011	Review	Various	Physiological effects of ginger and turmeric	Endocrine function	Beneficial role in hormonal regulation
Anugrah et al., 2024	Systematic Review	Athletes	Herbal supplements	Muscle recovery	Accelerated recovery of injured muscles

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Anugrah et al., 2024	Systematic Review	Athletes	Herbal supplements	Muscle recovery	Accelerated recovery of injured muscles
Bhagavathula et al., 2009	Animal Experiment	Hairless mice	Combination of curcumin and ginger	Wound healing	Improved wound healing process

Author/Year	Study Design	Population	Intervention	Analyzed Outcomes	Main Conclusion
Bischoff-Kont & Fürst, 2021	Review	Various	Effects of 6-shogaol from ginger	Inflammation	Inhibition of inflammatory processes
Black et al., 2010	Clinical Trial	Athletes	Ginger consumption	Muscle pain	Reduced pain after eccentric exercise
Boroumand et al., 2018	Review	Various	Immunomodulatory effects of curcumin	Inflammation & antioxidants	Immune enhancement and inflammation reduction
Bradford, 2013	Review	Various	Relationship of curcumin with obesity	Fat metabolism	Curcumin plays a role in obesity control
Chanda & Ramachandra, 2019	Review	Various	Pharmacology of turmeric	Anti-inflammatory effects	Review of medicinal uses of turmeric
Clayton et al., 2023	Pilot Study	Professional footballers	Turmeric supplementation	Recovery markers	Improved inflammatory and performance markers
Daniel et al., 2024	Systematic Review	Athletes	Curcumin supplementation	Muscle damage	Reduced muscle damage and inflammation

Author/Year	Study Design	Population	Intervention	Analyzed Outcomes	Main Conclusion
Fernández-Lázaro et al., 2020	Systematic Review	Active individuals	Curcumin supplementation	Inflammation and oxidative stress	Reduced sports injuries and inflammation
Hattori et al., 2021	Animal Study	Male mice	Ginger extract	Muscle glycogen storage	Increased glycogen storage and endurance
Higgins et al., 2020	Review	Athletes	Antioxidants (Vitamin C and E)	Athletic performance	Review of antioxidant supplementation effects
Hong et al., 2020	Cellular Study	Liver model	6-Gingerol	Nrf2 pathway	Reduced liver damage
Hoseinzadeh et al., 2015	Clinical Trial	Healthy individuals	Ginger extract	Delayed onset muscle soreness	Reduced muscle soreness symptoms
Kawanishi et al., 2013	Animal Study	Mice	Curcumin	Muscle oxidative stress	Reduced exercise-induced muscle damage
Madkor et al., 2011	Animal Study	Diabetic mice	Combination of garlic, ginger, turmeric	Glucose and lipid metabolism	Improved metabolic parameters

Author/Year	Study Design	Population	Intervention	Analyzed Outcomes	Main Conclusion
Mashhadi et al., 2013	Clinical Trial	Iranian female athletes	Ginger and cinnamon	Inflammation and muscle pain	Reduced inflammation and pain post-exercise
Mason et al., 2020	Review	Endurance athletes	Antioxidant supplements	Athletic performance	Review of supplementation effects on performance
Montserrat-de la Paz et al., 2018	Animal Study	Mouse model	Ginger rhizome extract	Anti-inflammatory and analgesic effects	Enhanced paracetamol effect
Morvaridzadeh et al., 2020	Meta-Analysis	Clinical studies	Ginger supplementation	Inflammatory markers	Significant inflammation reduction
Nanavati et al., 2022	Narrative Review	Athletes	Curcumin supplementation	Muscle damage	Reduced muscle injury and pain
Nicol et al., 2015	Clinical Trial	Athletes	Curcumin supplementation	Delayed onset muscle soreness	Reduced DOMS symptoms
Nosrati-Oskouie et al., 2022	Review	Athletes	Curcumin supplementation	Athletic performance	Enhanced recovery and performance

Author/Year	Study Design	Population	Intervention	Analyzed Outcomes	Main Conclusion
Saher et al., 2022	Laboratory Study	Laboratory model	Herbal hydrogel formulation	Analgesic and anti-inflammatory	Efficacy of herbal compounds
Sciberras et al., 2015	Clinical Trial	Endurance athletes	Curcumin supplementation	Inflammatory markers	Reduced post-exercise inflammation
Shirpoor et al., 2017	Animal Study	Mouse model	Ginger extract	Pulmonary changes and oxidative stress	Lung protection
Srirod & Tewtrakul, 2019	Laboratory Study	Topical cream model	Curcuma mangga extract	Anti-inflammatory and wound healing	Enhanced wound healing
Srivastava & Mustafa, 1992	Review	Rheumatic patients	Ginger	Joint pain	Effective in musculoskeletal disease pain
Sorani et al., 2016	Clinical Trial	Obese men	Aerobic exercise with ginger	Inflammatory markers IL-18, CRP	Inflammation reduction
Suryawati & Jawi, 2020	Laboratory Study	Nanoparticle model	Turmeric extract	Topical anti-inflammatory	Improved anti-inflammatory effects

Author/Year	Study Design	Population	Intervention	Analyzed Outcomes	Main Conclusion
Tripathi et al., 2008	Cellular Study	Macrophage model	Ginger extract	Macrophage activity	Inhibition of inflammation
Williams, 2006	Review	Athletes	Herbal supplements	Athletic performance	Review of herbal supplement effects
Wilson, 2020	Clinical Trial	Recreational runners	Ginger root	Muscle pain and recovery	Reduced pain and improved recovery
Wilson et al., 2015	Pilot Study	Athletes	Ginger root	Running-induced muscle pain	Pain reduction and performance improvement
Zamani & Rezagholizadeh, 2021	Pilot Study	Diabetic women	Curcumin	Glycemic markers	Improved blood sugar control
Zhang et al., 2024	Review	Athletes	Curcumin	Fatigue and recovery	Review
Zhou et al., 2022a	Laboratory Study	RAW 264.7 cells	Ginger and turmeric extracts	Inflammatory pathways	Synergistic anti-inflammatory activity of the combination

<b>Author/Year</b>	<b>Study Design</b>	<b>Population</b>	<b>Intervention</b>	<b>Analyzed Outcomes</b>	<b>Main Conclusion</b>
Zhou et al., 2022b	Laboratory Study	Stimulated immune cells	Ginger and turmeric extracts	Inflammatory cytokines	Inhibition of inflammatory mediators by combination

## Turmeric and endurance performance

The anti-inflammatory and antioxidant properties of turmeric (*Curcuma longa*) have attracted researchers and athletes in recent years. Turmeric contains curcumin, a polyphenolic compound with therapeutic effects. As a result, inflammation is reduced, pain is relieved, and athletic performance is enhanced. The effects of turmeric and curcumin on endurance performance by athletes are discussed below.

### Turmeric's anti-inflammatory effects on endurance performance

Muscle inflammation caused by intense training is a major factor in endurance performance decline. As a result, strength, endurance, and recovery can be reduced. Turmeric's active compound, curcumin, has anti-inflammatory properties that reduce inflammation markers such as CRP and IL-6 and increase athletic performance (33). After strenuous exercise, less inflammation can lead to less muscle soreness and accelerated muscle recovery, which improves endurance performance in athletes (14). Turmeric's natural polyphenolic compound curcumin has antioxidant and anti-inflammatory properties that can improve athletic performance and recovery by reducing exercise-induced muscle damage and pain, improving muscle function, and reducing inflammatory cytokines (15).

### Reducing muscle damage with curcumin

In one of the few human studies investigating the effect of curcumin treatment on recovery from exercise-induced injury, Nicol and colleagues conducted a double-blind, placebo-controlled trial in which 17 men were supplemented with curcumin for 2.5 days before and 2.5 days after completing an eccentric exercise protocol. The study assessed jump performance, creatine kinase levels, pain indices, and changes in circulating cytokines. Curcumin reduces injury-related pain and may improve jumping performance following muscle damage (29). Curcumin's properties were examined by Nanavati et al. (2022).

Curcumin reduces exercise-induced muscle damage (EIMD) and improves muscle performance due to its antioxidant and anti-inflammatory properties. Reduced muscle pain, inhibition of inflammatory cytokines, and decreased activity of creatine kinase (CK) are the mechanisms responsible for these effects. In addition, curcumin effects depend on dosage, concentration, and bioavailability.

### Fatigue reduction with curcumin

By regulating signaling pathways, reducing oxidative stress, inhibiting inflammation, and interacting with the intestinal microbiota, Zhang et al. (2024) demonstrated that curcumin reduced fatigue caused by intense exercise. Anti-fatigue supplements now have an exciting horizon.

### Enhance metabolic efficiency with curcumin

Bradford (2013) found that curcumin could reduce obesity and improve its metabolic complications. Adipose tissue inflammation is inhibited, inflammatory cytokines are reduced, adiponectin is increased, fat cell differentiation is inhibited, and antioxidant activity is enhanced. Researchers found that curcumin consumption significantly reduced body mass index (BMI), weight, waist circumference, and fasting blood sugar levels in patients with metabolic syndromes (4). In women with polycystic ovary syndrome, curcumin supplementation combined with endurance training improved glucose indices (43).

### The benefits of turmeric for recovery

In human studies, curcumin supplementation reduces muscle recovery after endurance exercise, although more research is needed to confirm these findings. There is a need to further investigate curcumin supplementation in human athletes after some promising findings in animals regarding performance outcomes and mitochondrial biogenesis (25).

## Antioxidant properties of turmeric

In human exercise studies, there is little research on curcumin's skeletal muscle-related or systemic antioxidant effects. Acute and chronic curcumin supplementation reduces oxidative stress markers in skeletal muscles in rodents (22).

## Reducing muscle pain with curcumin

In a study conducted by Nosrati Oskoui et al. (2022), curcumin was shown to reduce muscle pain and inflammation after intense exercise. A turmeric-containing beverage consumed twice daily by professional football players reduced muscle soreness and CRP levels after matches (13). Curcumin, in particular, has significant effects on endurance performance. The anti-inflammatory, antioxidant, and recovery-accelerating properties of this natural compound make it an effective supplement for enhancing endurance performance, reducing inflammation, muscle damage, and obesity. In spite of positive findings from various studies, further research is needed to determine the optimal dosage and duration of curcumin supplementation. The long-term effects of this supplement on athletes need to be investigated further. Turmeric can enhance athletic performance when combined with other sports supplements.

## Performance of endurance athletes after consuming ginger

There are a number of therapeutic properties associated with ginger (*Zingiber officinale*). Because of its active compounds, such as zingerone and shogaol, it is especially recognized as an anti-inflammatory and antioxidant. There has been considerable interest in ginger's ability to enhance endurance performance in athletes. Ginger has been shown to improve endurance performance in a variety of ways, including reducing muscle pain, lowering inflammation, improving recovery time, and enhancing stamina.

## The Effect of Ginger on Delayed Onset Muscle Soreness (DOMS)

Inflammation and microscopic muscle damage cause delayed onset muscle soreness (DOMS) after intense endurance exercise. The anti-inflammatory properties of ginger can help reduce this pain. According to Wilson et al. (2015), ginger root supplementation can moderately reduce muscle soreness caused by prolonged running. Muscle performance was not affected by it, however. Analgesic and anti-inflammatory properties of ginger (*Zingiber officinale*) were explored by Srivastava and Mustafa (1992), noting its traditional use in treating pain, particularly muscle pain. Prostaglandin E2 (PGE2) and leukotriene B4 (LTB4) are inflammatory mediators produced when cyclooxygenase (COX) and 5-lipoxygenase enzymes are inhibited by ginger. Inflammation and pain are reduced by ginger's dual inhibition of eicosanoid biosynthesis. Blake et al. (2010) demonstrated that consuming 2 grams of ginger for 11 days significantly decreased exercise-induced muscle pain in 74 participants. Researchers found that taking 2 grams of ginger before exercise reduced DOMS and interleukin-6 (IL-6) levels (21).

## Muscle inflammation and ginger

In a study on obese men, Sorani et al. (2016) found that aerobic exercise combined with ginger supplementation reduced CRP levels. It may prevent inflammation, cardiovascular disease, and metabolic diseases in obese men. According to Afshan and Dabidi Roshan (2016), resistance training coupled with ginger supplementation reduces TNF- $\alpha$  levels in male athletes. Ginger supplementation is reported to possess anti-inflammatory and antioxidant properties, inhibiting prostaglandin synthesis and reducing pro-inflammatory cytokines by Tripathi et al. (2008). Its anti-inflammatory effects are caused by blocking leukotriene and prostaglandin synthesis, inhibiting cyclooxygenase and lipoxygenase pathways, preventing arachidonic acid metabolism, reducing platelet aggregation, and suppressing free radical production. In turn, this modulates immune responses that exacerbate inflammation.

### The effects of ginger on recovery

A study by Wilson et al. (2020) found ginger root had modest positive effects on running-induced pain, but improved physical performance (recovery), as well as providing temporary pain relief for runners.

### An Enhanced Endurance Capacity with Ginger

In an experimental study, Hattori et al. (2021) found that ginger extract (GE) improved endurance performance and reduced exercise-induced fatigue in trained mice by increasing fat oxidation and preserving skeletal muscle glycogen stores. As a natural supplement with anti-inflammatory, antioxidant, and muscle-relaxing properties, ginger can positively influence endurance performance in athletes. These effects were accompanied by a significant increase in muscle glycogen content and blood free fatty acid (FFA) levels following exercise. Ginger may improve endurance performance by reducing delayed-onset muscle soreness, reducing inflammation, accelerating recovery, and improving endurance capacity. While existing studies generally support ginger consumption's benefits, further research is needed to determine the optimal dosage and its long-term effects on athletes.

### The combination of turmeric and ginger in endurance performance

Studies have examined turmeric and ginger as medicinal plants with strong anti-inflammatory and antioxidant properties. These two plants have not only positive effects on athletes' endurance performance individually, but also synergistic effects when combined. We will examine the effects of turmeric and ginger on endurance performance in this section. Turmeric and ginger have been studied for their anti-inflammatory effects in endurance sports. Ginger and cinnamon reduced muscle pain in Iranian female athletes, but did not significantly affect IL-6 levels (24). Known for their anti-inflammatory properties, ginger (*Zingiber officinale* Roscoe, G) and turmeric (*Curcuma longa* L., T) are two popular functional foods from the Zingiberaceae family (12).

Ginger's anti-inflammatory effect is attributed to its phenolic compounds like 6-gingerol and 6-shogaol, which reduce IL-6 and TNF, key mediators of inflammation (27). Turmeric's polyphenols, called curcuminoids, include curcumin (C), demethoxycurcumin (D), and bisdemethoxycurcumin (B), which are the main bioactive compounds. Turmeric's anti-inflammatory properties are attributed primarily to curcumin (3). Ginger and turmeric have many similar signaling pathways and molecular targets, including the Nrf2 pathway (38). According to scientific evidence, ginger and turmeric reduce inflammation in a synergistic manner (46). Ginger (*Zingiber officinale*) contains gingerol, shogaol, and zerumbone, while turmeric (*Curcuma longa*) contains curcumin, demethoxycurcumin, and bisdemethoxycurcumin. In addition to belonging to the same scientific classification, they have numerous anti-inflammatory and therapeutic effects (5). Using ginger and turmeric extracts at a ratio of 5:2 synergistically reduced the production of inflammatory markers, including TNF- $\alpha$ , IL-6, and nitric oxide in immune cells (45). Furthermore, a study by Saher et al. (2022) confirmed that a methanolic extract of a multi-herbal formulation, including bell pepper fruit, cinnamon bark, turmeric rhizome, and ginger rhizome, demonstrated significant anti-inflammatory and analgesic properties.

### Turmeric and Ginger Reduce Muscle Damage and Improve Tissue Repair (Improved Recovery Time)

It is common for athletes to suffer muscle damage due to endurance exercise, which results in decreased performance and prolonged recovery times. With their soothing and anti-inflammatory effects, turmeric and ginger can prevent muscle damage and shorten recovery time. According to a study on mice, topical application of a mixture of curcumin and ginger extract improved wound healing, indicating a synergistic effect of these two substances (7).

## Metabolic effects of turmeric and ginger

Studies on diabetic mice showed that turmeric, ginger, and garlic reduced blood glucose levels, improved lipid profiles, and decreased oxidative stress (23). Turmeric and ginger are effective natural supplements for reducing inflammation and muscle pain and accelerating recovery after exercise. As they have synergistic properties, consuming them together may enhance performance and reduce muscle damage more than taking them separately. For improving metabolic function, turmeric and ginger can serve as natural, effective supplements. It is recommended to consult a physician or nutrition specialist to determine the appropriate dosage and evaluate potential interactions with medications.

### Turmeric's positive effects on endurance

The active compound curcumin in turmeric reduces muscle damage and improves endurance. Its antioxidant and anti-inflammatory properties contribute to this. Several studies have shown that curcumin helps alleviate delayed-onset muscle soreness (DOMS) and accelerate the recovery process by inhibiting NF- $\kappa$ B and reducing markers like IL-6 and TNF- $\alpha$ . According to Abbott et al. (2023), curcumin supplementation after matches led to a significant reduction in muscle pain and improved performance in football players. Additionally, Fernández et al. (2020) demonstrated that curcumin reduces exercise-induced oxidative stress and enhances aerobic capacity. For endurance athletes who frequently experience muscle damage, these effects are particularly important.

### Endurance and performance benefits of ginger

The active compounds in ginger, such as gingerol and shogaol, are anti-inflammatory and anti-analgesic. By inhibiting inflammation-causing enzymes like COX-2 and LOX and reducing inflammatory cytokines, these compounds improve athletic performance. In a study by Blake et al. (2010), ginger consumption significantly reduced muscle soreness caused by eccentric exercise. In addition, Wilson et al. (2020) reported that ginger root reduced muscle pain and enhanced recovery in long-distance runners.

Ginger also enhances metabolic responses and improves endurance during aerobic exercise by increasing muscle glycogen storage.

### Turmeric and ginger combined and their synergistic effects

Studies have shown that ginger and turmeric supplementation can enhance athletic performance, reduce inflammation, and accelerate recovery. By inhibiting multiple inflammatory pathways and boosting antioxidant mechanisms, this combination improves athletes' muscle health. In two laboratory studies, Zhou et al. (2022a, 2022b) have demonstrated that ginger and turmeric extracts suppress inflammatory mediators in immune cells. Bhagavathula et al. (2009) found that curcumin and ginger accelerate tissue repair and modulate inflammatory responses in animals. These two plants can therefore be considered complementary strategies for endurance athletes when used concurrently.

## 3. Conclusion

Studies examining ginger and turmeric's effect on endurance performance indicate that each of these medicinal plants, either individually or in combination, has beneficial effects on reducing inflammation, reducing muscle pain, accelerating recovery, and improving endurance. With its anti-inflammatory properties and active compounds like gingerols and shogaols, and turmeric's impact on molecular pathways, ginger and turmeric are promising tools for optimizing athletic performance. Supplements such as these can be an important part of endurance athletes' nutritional strategies. To provide more precise and practical recommendations, high-quality clinical trials are needed to determine the optimal dosage, duration, and form of supplementation.

The findings of the study indicate that the targeted rehabilitation exercise program significantly influenced the enhancement of emotional skills among participants, encompassing both male and female subjects. Individuals with autism spectrum disorder (ASD) present considerable challenges to social-emotional development. Consequently, they may struggle with communication and exhibit difficulties in engaging in social behaviors, including friendship and recognizing others' emotions through facial expressions or body language. Such individuals often face challenges in forming interpersonal relationships and may find it challenging to communicate effectively with others (22).

The findings of the present study align closely with those observed in previous studies, including those conducted by Uness et al. (2020), Hire and Sava et al. (2020), Namedet and Kobenn (2020), Baharani et al. (2019), and Moradi et al. (2013). The results of the study by Roohpaver (2015) showed that the application provided by the researcher had a positive effect on the social-emotional development of preschool children and improved the emotional skills of these children. Another characteristic of people with autism is inappropriate emotional reactions in certain social situations. They may show almost constant emotional behaviors in different emotional situations. Some of them may show shifted emotional behaviors from giggling and hysterical laughter to sobbing and crying loudly, which is independent of environmental events. These people can quickly go from one pole to another, without having a reason. (16)

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## Compliance with ethical standards

**Conflict of interest** None declared.

**Ethical approval** the research was conducted with regard to the ethical principles.

**Informed consent** Informed consent was obtained from all participants.

## Author contributions

Conceptualization: Z.M, E.F, Z.S ; Methodology: Z.M, E.F, Z.S ; Software: Z.M, E.F, Z.S ; Validation: Z.M, E.F, Z.S . ; Formal analysis: Z.M, E.F, Z.S ; Investigation: Z.M, E.F, Z.S ; Resources: Z.M, E.F, Z.S ; Data curation: Z.M, E.F, Z.S ; Writing - original draft: Z.M, E.F, Z.S ; Writing - review & editing: Z.M, E.F, Z.S ; Visualization: S.M.B, K.M, E.A, A.K ; Supervision: Z.M, E.F, Z.S ; Project administration: Z.M, E.F, Z.S ; Funding acquisition: Z.M, E.F, Z.S .

## References

1. Abbott W, Hansell EJ, Brett A, Škarabot J, James LJ, Clifford T. Curcumin Attenuates Delayed-Onset Muscle Soreness and Muscle Function Deficits Following a Soccer Match in Male Professional Soccer Players. *Int J Sports Physiol Perform.* 2023 Feb 13;18(4):347-353. doi: 10.1123/ijspp.2022-0283. PMID: 36780901.
2. Afshan S, Dabidi Roshan V. Comparing the effect of two resistance training with and without supplement ginger on inflammatory markers. *Research in Medicine* 2016;40(3):118-24 [Persian].
3. Ahmad, R.S.; Hussain, M.B.; Sultan, M.T.; Arshad, M.S.; Waheed, M.; Shariati, M.A.; Plygun, S.; Hashempur, M.H. Biochemistry, safety, pharmacological activities, and clinical applications of turmeric: A mechanistic review. *Evid. Based Complementary Altern.Med.* 2020, 2020, 7656919. [CrossRef] [PubMed]
4. Akbari, M., Lankarani, K. B., Tabrizi, R., Ghayour-Mobarhan, M., Peymani, P., Ferns, G., Ghaderi, A., & Asemi, Z. (2019). The Effects of Curcumin on Weight Loss Among Patients with Metabolic Syndrome and Related Disorders: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Frontiers in pharmacology*, 10, 649. <https://doi.org/10.3389/fphar.2019.00649>
5. Al-Suhaimi, E. A., Al-Riziza, N. A., & Al-Essa, R. A. (2011). Physiological and therapeutical roles of ginger and turmeric on endocrine functions. *The American journal of Chinese medicine*, 39(2), 215-231. <https://doi.org/10.1142/S0192415X11008762>
6. Anugrah, S. M., Kusnanik, N. W., Wahjuni, E. S., Muhammad, H. N., Sulistyarto, S., Purwanto, B., Resmana, D., Juniarisyah, A. D., Ayubi, N., & Sari, E. (2024). Herbal Supplements That Have the Potential to Accelerate Recovery of Exercise-Induced Muscle Damage: Systematic Review. *Retos*, 51, 840-848. <https://doi.org/10.47197/RETOS.V51.100616>
7. Bhagavathula, N., Warner, R. L., DaSilva, M., McClintock, S. D., Barron, A., Aslam, M. N., Johnson, K. J., & Varani, J. (2009). A combination of curcumin and ginger extract improves abrasion wound healing in corticosteroid-impaired hairless rat skin. *Wound repair and regeneration: official publication of the Wound Healing Society [and] the European Tissue Repair Society*, 17(3), 360-366. <https://doi.org/10.1111/j.1524-475X.2009.00483.x>
8. Bischoff-Kont, I.; Fürst, R. Benefits of Ginger and Its Constituent 6-Shogaol in Inhibiting Inflammatory Processes. *Pharmaceuticals* (2021), 14, 571. [CrossRef]
9. Black, C. D., Herring, M. P., Hurley, D. J., & O'Connor, P. J. (2010). Ginger (*Zingiber officinale*) reduces muscle pain caused by eccentric exercise. *The journal of pain*, 11(9), 894-903. <https://doi.org/10.1016/j.jpain.2009.12.013>
10. Boroumand, N.; Samarghandian, S.; Hashemy, S.I. Immunomodulatory, anti-inflammatory, and antioxidant effects of curcumin. *J. HerbMed Pharmacol.* 2018, 7, 211-219. [CrossRef]
11. Bradford P. G. (2013). Curcumin and obesity. *BioFactors* (Oxford, England), 39(1), 78-87. <https://doi.org/10.1002/biof.1074>
12. Chanda, S.; Ramachandra, T. Phytochemical and pharmacological importance of turmeric (*Curcuma longa*): A review. *RRJoP* 2019, 9, 16-23.
13. Clayton, D. J., Burbeary, R., Hennis, P. J., James, R. M., Saward, C., Colledge, A., Scott, R., Gilpin, S., McMahon, R., & Varley, I. (2023). Turmeric supplementation improves markers of recovery in elite male footballers: a pilot study. *Frontiers in nutrition*, 10, 1175622. <https://doi.org/10.3389/fnut.2023.1175622>
14. Daniel Vasile, P. R., Patricia, M. L., Marta, M. S., & Laura, E. (2024). Evaluation of curcumin intake in reducing exercise-induced muscle damage in athletes: a systematic review. *Journal of the International Society of Sports Nutrition*, 21(1), 2434217. <https://doi.org/10.1080/15502783.2024.2434217>
15. Fernández-Lázaro, D., Mielgo-Ayuso, J., Seco Calvo, J., Córdova Martínez, A., Caballero García, A., & Fernandez-Lazaro, C. I. (2020). Modulation of Exercise-Induced Muscle Damage, Inflammation, and Oxidative Markers by Curcumin Supplementation in a Physically Active Population: A Systematic Review. *Nutrients*, 12(2), 501. <https://doi.org/10.3390/nu12020501>
16. Gorgian P, Askari G, Heidari -Beni M, Tarrahi M J, Bahreini N. The effect of curcuma, black peper, ginger on pain and performance of the patient with chronic knee osteoarthritis in comparison with Naproxen drug. *J Health Syst Res* 2020; 15 (4) :246-254.URL: <http://hsr.mui.ac.ir/article-1-1095-fa.html>

17. Hakim Al Masoody, I., Alarkwazi, R. K., Al Yasssiry, A. Sh. (2023). Pharmaceutical and Biological Properties of Dill: A Review. *IOP Conf. Series: Earth and Environmental Science* 1158 (2023) 062005. IOP Publishing. doi:10.1088/1755-1315/1158/6/062005.

18. Hattori, S., Omi, N., Yang, Z., Nakamura, M., & Ikemoto, M. (2021). Effect of ginger extract ingestion on skeletal muscle glycogen contents and endurance exercise in male rats. *Physical activity and nutrition*, 25(2), 15-19. <https://doi.org/10.20463/pan.2021.0010>

19. Higgins, M. R., Izadi, A., & Kaviani, M. (2020). Antioxidants and Exercise Performance: With a Focus on Vitamin E and C Supplementation. *International Journal of Environmental Research and Public Health*, 17(22), 8452. <https://doi.org/10.3390/ijerph17228452>

20. Hong, M.-K.; Hu, L.-L.; Zhang, Y.-X.; Xu, Y.-L.; Liu, X.-Y.; He, P.-K.; Jia, Y.-H. 6-Gingerol ameliorates sepsis-induced liver injury through the Nrf2 pathway. *Int. Immunopharmacol.* 2020, 80, 106196. [CrossRef]

21. Hoseinzadeh, K., Daryanoosh, F., Baghdasar, P. J., & Alizadeh, H. (2015). Acute effects of ginger extract on biochemical and functional symptoms of delayed onset muscle soreness. *Medical journal of the Islamic Republic of Iran*, 29, 261.

22. Kawanishi, N., Kato, K., Takahashi, M., Mizokami, T., Otsuka, Y., Imaizumi, A., Shiva, D., Yano, H., & Suzuki, K. (2013). Curcumin attenuates oxidative stress following downhill running-induced muscle damage. *Biochemical and biophysical research communications*, 441(3), 573-578. <https://doi.org/10.1016/j.bbrc.2013.10.119>

23. Madkor HR, Mansour SW, Ramadan G. Modulatory effects of garlic, ginger, turmeric and their mixture on hyperglycaemia, dyslipidaemia and oxidative stress in streptozotocin-nicotinamide diabetic rats. *British Journal of Nutrition*. 2011;105(8):1210-1217. doi:10.1017/S0007114510004927

24. Mashhadi, N. S., Ghiasvand, R., Askari, G., Feizi, A., Hariri, M., Darvishi, L., Barani, A., Taghiyar, M., Shiranian, A., & Hajishafiee, M. (2013). Influence of ginger and cinnamon intake on inflammation and muscle soreness endured by exercise in Iranian female athletes. *International journal of preventive medicine*, 4(Suppl 1), S11-S15.

25. Mason, S. A., Trewin, A. J., Parker, L., & Wadley, G. D. (2020). Antioxidant supplements and endurance exercise: Current evidence and mechanistic insights. *Redox biology*, 35, 101471. <https://doi.org/10.1016/j.redox.2020.101471>

26. Montserrat-de la Paz, S., Garcia-Gimenez, M. D., Quilez, A. M., De la Puerta, R., & Fernandez-Arche, A. (2018). Ginger rhizome enhances the anti-inflammatory and anti-nociceptive effects of paracetamol in an experimental mouse model of fibromyalgia. *Inflammopharmacology*, 26(4), 1093-1101. <https://doi.org/10.1007/s10787-018-0450-8>

27. Morvaridzadeh, M.; Fazelian, S.; Agah, S.; Khazdouz, M.; Rahimlou, M.; Agh, F.; Potter, E.; Heshmati, S.; Heshmati, J. Effect of ginger (*Zingiber officinale*) on inflammatory markers: A systematic review and meta-analysis of randomized controlled trials. *Cytokine* 2020, 135, 155224. [CrossRef]

28. Nanavati, K., Rutherford-Markwick, K., Lee, S. J., Bishop, N. C., & Ali, A. (2022). Effect of curcumin supplementation on exercise-induced muscle damage: a narrative review. *European journal of nutrition*, 61(8), 3835-3855. <https://doi.org/10.1007/s00394-022-02943-7>

29. Nicol, L. M., Rowlands, D. S., Fazakerly, R., & Kellett, J. (2015). Curcumin supplementation likely attenuates delayed onset muscle soreness (DOMS). *European journal of applied physiology*, 115(8), 1769-1777. <https://doi.org/10.1007/s00421-015-3152-6>

30. Nosrati-Oskouie, M., Aghili-Moghaddam, N. S., Tavakoli-Rouzbehani, O. M., Jamialahmadi, T., Johnston, T. P., & Sahebkar, A. (2022). Curcumin: A dietary phytochemical for boosting exercise performance and recovery. *Food science & nutrition*, 10(11), 3531-3543. <https://doi.org/10.1002/fsn3.2983>

31. Nouri, Ramazan; Nikoofar, Morteza. (2018). The effect of herbal supplements on aerobic capacity in athletes with intermittent endurance training. The 4th National Conference on Sport Sciences and Physical Education of Iran, Tehran. <https://civilica.com/doc/774758>.

32. Saher, T., Manzoor, R., Abbas, K., Mudassir, J., Wazir, M. A., Ali, E., Ahmad Siddique, F., Rasul, A., Qadir, M. I., Aleem, A., Qaiser, N., Usman, A., Romman, M., & Ali, M. S. (2022). Analgesic and Anti-Inflammatory Properties of Two Hydrogel Formulations Comprising Polyherbal Extract. *Journal of pain research*, 15, 1203-1219. <https://doi.org/10.2147/JPR.S351921>. <https://doi.org/10.1186/s12970-014-0066-3>

33. Sciberras, J. N., Galloway, S. D., Fenech, A., Grech, G., Farrugia, C., Duca, D., & Mifsud, J. (2015). The effect of turmeric (Curcumin) supplementation on cytokine and inflammatory marker responses following 2 hours of endurance cycling. *Journal of the International Society of Sports Nutrition*, 12(1), 5.

34. Shirpour, A., Gharalari, F. H., Rasmi, Y., & Heshmati, E. (2017). Ginger extract attenuates ethanol-induced pulmonary histological changes and oxidative stress in rats. *Journal of biomedical research*, 31(6), 521-527. Advance online publication. <https://doi.org/10.7555/JBR.31.20160151>

35. Sorani M, Jalali K, Jalali Dehkordi A. Effect of 12 Weeks Aerobic Training with Ginger Consumption on IL-18 and CRP in Obese Men. *Report of Health Care*. 2016;2(4):1-9 [Persian].

36. Srirod, S.; Tewtrakul, S. Anti-inflammatory and wound healing effects of cream containing Curcuma mangga extract. *J. Ethnopharmacol.* **2019**, 238, 111828. [CrossRef] [PubMed]

37. Srivastava, K. C., & Mustafa, T. (1992). Ginger (*Zingiber officinale*) in rheumatism and musculoskeletal disorders. *Medical hypotheses*, 39(4), 342-348. [https://doi.org/10.1016/0306-9877\(92\)90059-1](https://doi.org/10.1016/0306-9877(92)90059-1)

38. Suryawati, N.; Jawi, I.M. Potential development of turmeric extract nanoparticles as a topical anti-inflammatory agent. *BaliMed. J.* **2020**, 9, 573-578. [CrossRef]

39. Tripathi S, Bruch D, Kittur D. Ginger extract inhibits LPS induced macrophage activation and function. *BMC complementary and Alternative Medicine*. 2008;8(1):1-8

40. Williams M. (2006). Dietary supplements and sports performance: herbals. *Journal of the International Society of Sports Nutrition*, 3(1), 1-6. <https://doi.org/10.1186/1550-2783-3-1-1>

41. Wilson P. B. (2020). A Randomized Double-Blind Trial of Ginger Root for Reducing Muscle Soreness and Improving Physical Performance Recovery Among Experienced Recreational Distance Runners. *Journal of dietary supplements*, 17(2), 121-132. <https://doi.org/10.1080/19390211.2018.1492484>

42. Wilson, P.B., Fitzgerald, J.S., Rhodes, G.S., Lundstrom, C.J., & Ingraham, S.J. (2015). Effectiveness of Ginger Root (*Zingiber officinale*) on Running-Induced Muscle Soreness and Function: A Pilot Study. *International Journal of Athletic Therapy and training*, 20, 44-50.

43. Zamani, S. K., & Rezagholizadeh, D. M. (2021). Effect of eight-week curcumin supplementation with endurance training on glycemic indexes in middle age women with type 2 diabetes in Iran, A preliminary study. *Diabetes & metabolic syndrome*, 15(3), 963-967. <https://doi.org/10.1016/j.dsx.2021.04.002>

44. Zhang, H., Kang, R., Song, T., Ren, F., Liu, J., & Wang, J. (2024). Advances in relieving exercise fatigue for curcumin: Molecular targets, bioavailability, and potential mechanism. *Journal of food science*, 89(8), 4604-4619. <https://doi.org/10.1111/1750-3841.17162>

45. Zhou, X., Afzal, S., Wohlmuth, H., Münch, G., Leach, D., Low, M., & Li, C. G. (2022). Synergistic Anti-Inflammatory Activity of Ginger and Turmeric Extracts in Inhibiting Lipopolysaccharide and Interferon- $\gamma$ -Induced Proinflammatory Mediators. *Molecules* (Basel, Switzerland), 27(12), 3877. <https://doi.org/10.3390/molecules27123877>

46. Zhou, X., Münch, G., Wohlmuth, H., Afzal, S., Kao, M. T., Al-Khazaleh, A., Low, M., Leach, D., & Li, C. G. (2022). Synergistic Inhibition of Pro-Inflammatory Pathways by Ginger and Turmeric Extracts in RAW 264.7 Cells. *Frontiers in pharmacology*, 13, 818166. <https://doi.org/10.3389/fphar.2022.818166>