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<https://ejournal.upi.edu/index.php/penjas/article/view/46047>DOI: <https://doi.org/10.17509/jpjo.v7i2.46047>**The Role and Mechanism of Cinnamon for Athlete Metabolism and Recovery Process: A Systematic Literature Review****Muhamad Fahmi Hasan^{1*}, I Ketut Adanyana², Samsul Bahri¹, Hamidie Ronald Daniel Ray³**¹Department Sport Science, School of Pharmacy, Institut Teknologi Bandung, Indonesia²Department Pharmacology Clinic and Community, School of Pharmacy, Institut Teknologi Bandung, Indonesia³Universitas Pendidikan Indonesia, Indonesia**Article Info***Article History :**Received Mei 2022**Revised June 2022**Accepted July 2022**Available online September 2022**Keywords :**Athletes, Cinnamon, Sports Nutrition***Abstract**

Athletes have a high need to maintain their performance to stay fit while performing a high training intensity and frequent exercise. It makes athletes have a high need for supplements. However, athletes are prohibited from taking supplements included in the doping category. The lowest risk of doping is herbal-based supplements. This study used a systematic review method. The screening employed the PRISMA method as the preferred reporting item for systematic review and meta-analyses. The articles were obtained from Scopus and Dimensions databases using "cinnamon" as the keyword. Furthermore, the words "cinnamon" and "athlete" were added so that the data were obtained more specific. The exclusion criteria of this study involved original article documents, while the inclusion criteria included not more than 5-year publications. In the article selecting process, there were four articles that fulfilled the inclusion and exclusion criteria stating that cinnamon was effective for preventing inflammation that had an impact on accelerating recovery in athletes. *Cinnamomum zylanicum* is the most effective type of cinnamon for athlete recovery. It is because *Cinnamomum zylanicum* contains the most Cinnamaldehyde to help speed up recovery, which is most suitable for athletes. Thus, cinnamon is expected to be an alternative supplement for athletes to improve their performance.

INTRODUCTION

For elite athletes, injury is the most feared enemy because injuries often make them fail to compete and make them have to end their careers as athletes. Athletes not only experience injuries during matches, but injuries often occur during training caused by the athlete's level of fatigue (Pirruccio & Kelly, 2019; Rajaratnam & Adiartha, 2020). Injuries caused by fatigue are often experienced by junior athletes, which makes them often dim when entering seniors because of their injury history (Steffen & Engebretsen, 2010). Therefore, all efforts to improve performance must be carried out for elite athletes, including ways to speed up recovery. This makes many coaches and researchers look for various ways to make athletes recover quickly. Various ways to speed up the recovery process have been developed, including the cold water immersion method, then the use of rolling forms, to supplementation (Junaidi et al., 2020; Kuswahyudi et al., 2020; Pelana et al., 2019). From these various methods, many methods have developed in the form of non-oral treatment, and all treatments are given after experiencing fatigue. Of the various methods of accelerating recovery, the supplement method has the most risk, namely the risk of being included in the doping category. As is well known, many athletes take supplements but are in the doping category (Faiss et al., 2019).

Historically, there has been no doping caused by herbal supplements; in the list issued by the World Anti-Doping Agency (WADA), there is little chance that herbal supplements are included in doping. Therefore, research on supplements for athletes must continue to be developed to answer the needs of athletes who require more nutritional intake to help them get the best performance without violating fair play in the context of doping. (Faiss et al., 2019). Natural ingredients are starting to be researched for athletes, such as curcumin, pomegranate, and cinnamon (Ammar et al., 2016; Junaidi et al., 2020; Mashhadi et al., 2013; Suhett et al., 2021). Various benefits emerged from this research, such as its impact on improving performance and helping to accelerate mass muscle gain and recovery. Although not all studies have shown a significant effect of these natural ingredients (Mashhadi et al., 2013), but the difference in results and the increasing interest in research in the scope of natural ingredients is a sign that the urgency of research around natural materials to be

used as supplements for athletes is very much needed in the sports environment.

Cinnamon is a spice that humans have used for years; in the context of research, cinnamon has been widely reported on its efficacy for those who have diabetes because the content of cinnamon can increase insulin sensitivity which is needed by people with diabetes (Rao & Gan, 2014). However, another benefit of cinnamon is that it contains antioxidants and anti-inflammatory properties. The polyphenol content in cinnamon provides a variety of effects that can not only be used for people with diabetes but athletes, in this case, to overcome fatigue because of its antioxidant and anti-inflammatory properties (Anderson, 2008; Junaidi et al., 2020; Mashhadi et al., 2013; Rao & Gan, 2014; Shishehbor et al., 2018). Cinnamon has been tested on athletes to determine the improvement in muscle damage and inflammation experienced after training or competition (Junaidi et al., 2020; Mashhadi et al., 2013). In badminton, which has aerobic characteristics, cinnamon consumed for four weeks effectively overcoming muscle damage, as indicated by the improvement in creatine kinase (CK) numbers before and after consuming cinnamon (Junaidi et al., 2020). Another study showed similar things, which showed an accelerated recovery after consuming cinnamon extract for six weeks, but recovery was shown by C-Reactive Protein (CRP) as a biomarker (Rao & Gan, 2014).

The need for finding ways to accelerate the recovery process applies to almost all sports, not only sports games such as football, basketball and badminton, but sports such as weightlifting also require ingredients to speed up the recovery process. Although weightlifting is a short competition, during training, athletes often undergo very strenuous training, which makes them need fast recovery. Some studies say weightlifters experience injuries caused by fatigue (Alabbad & Muaidi, 2016; Fred, 2014; Golshani et al., 2018; Pirruccio & Kelly, 2019). Weightlifters have a very high history of injury during training; this is caused by a high level of fatigue from one exercise to the next (Pirruccio & Kelly, 2019; Rajaratnam & Adiartha, 2020). In preparation for the Olympics, elite weightlifters train at least three times a week (Ane, 2004). Whereas the regeneration of the damage of a person who had severe muscle damage required at least one week (Giechaskiel, 2020). This damage can be caused by overtraining that is not

followed up by adjustments to a lighter exercise program. Fatigue experienced by weightlifters is very normal, especially when the applied exercise program is intense and is likely to overtrain (Bell et al., 2021; Robinson, 2010; Siahkoughian & Kordi, 2010). Therefore, recovery is very important to help weightlifters achieve their best performance (Ane, 2004; Biotechnology et al., 2011; Liu et al., 2005). The process of accelerating the recovery of athletes and coaching teams has a variety of methods, such as active recovery, cold water immersion, scraping therapy, and providing nutritional menus and supplements (Feiffer & Eyer, 2017; Raeder & Wiewelhoeve, 2017; Taber et al., 2017; Wang et al., 2014).

Based on previous studies on cinnamon, there are still differences in results, so research is needed to explain the impact and differences in these results in a summary that has been synthesized using the literature review method. This research is expected to answer the various benefits and causes of the diversity of research results about cinnamon on athletes. In addition, this research is expected to answer the various benefits and causes of the diversity of research results on cinnamon in athletes to answer the athlete's needs for alternative supplements with natural ingredients.

METHODS

This study's main aim was to summarise cinnamon's impact on athletes' metabolism. This research was conducted using the literature review method by collecting all published articles from 2001 to 2021. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) was the screening method. The collection of articles was obtained from the databases in Scopus and Dimensions. Using the word "cinnamon" from the database of all articles. Furthermore, the word is added to "cinnamon" AND "athlete" so that the data obtained is more specific. To ensure the discussion refers to cinnamon and athlete, the search was devoted to titles, abstracts and keywords. Then the year of the article is also limited to the last five years. So the search rule is obtained as follows: TITLE-ABSTRACT-KEY ("cinnamon" AND "athlete") AND (LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2017)).

The inclusion criteria in this study were all articles using cinnamon as the main test without any other mixed ingredients, then tested for recovery, all samples were not in health problems, and all articles used English and Indonesian. The exclusion criteria in this study were that all treatments were carried out at less than four weeks and no more than twelve weeks, samples were not differentiated by gender, and age was not more than 35 years.

RESULT

There is a screening of existing articles based on predetermined inclusion and exclusion criteria, obtained at the identification stage as many as 1.415 articles; then, after a deeper screening, there are only ten articles related to the discussion sought. From this shrinkage, several main discussion points were obtained that will be discussed, including cinnamon, reduced muscle damage, and anti-inflammatory.

DISCUSSION

Kind of cinnamon

Cinnamon is a ubiquitous spice utilized by various civilizations worldwide for ages. *Cinnamomum zeylanicum* (CZ) and Cinnamon cassia (CC) (also known as *Cinnamomum aromaticum*/Chinese cinnamon) are the two main varieties of the genus *Cinnamomum*, a tropical evergreen plant with two main varieties. Cinnamon is a remedy for respiratory, digestive, and gynaecological ailments in Ayurvedic medicine, in addition to its culinary uses. Every aspect of the cinnamon tree has medicinal or culinary value, including the bark, leaves, flowers, fruits, and roots. The chemical makeup of volatile oils extracted from the bark, leaf, and root bark varies greatly, implying that their pharmacological effects may also differ. (Gruenwald et al., 2010). The primary constituents of the plant are cinnamaldehyde (bark), eugenol (leaf), and camphor, which are found in varying proportions in different parts of the plant (root) (Gruenwald et al., 2010). As a result, cinnamon produces a variety of oils with distinct properties, each of which determines its usefulness in different industries. In contrast to the leaf and bark, the root, which contains camphor as its major constituent, has little commercial value. Cinnamon's wide range of medicinal benefits is

Table 1. Sociodemographic and anthropometric comparisons

Variable	Daneghian et al. (2019)	Junaidi et al. (2020)	Belcher et al. (2019)	Shirvani et al. (2017)
Location	Iran	Indonesia	Iran	Iran
n	n = 18	n = 30	n = 18	n = 16
Study Design	a randomized, double-blind, placebo-controlled trial	A double-blind, randomized, placebo-controlled, parallel group comparison trial	a randomized, double-blind, placebo-controlled trial	16 randomized to one of two equal groups
Type of Cinnamon	<i>Cinnamomum</i>	<i>Cinnamomum</i>	<i>Cinnamomum</i>	<i>Cinnamomum</i>
Doses	2 g	500mg	3 g	5 mg
Duration				
Treatment	4 weeks	6 weeks	7 weeks	4 weeks
Indicator of Recovery	Creatine Kinase	Creatine Kinase	Creatine Kinase and C-Reactive Protein	Creatine Kinase

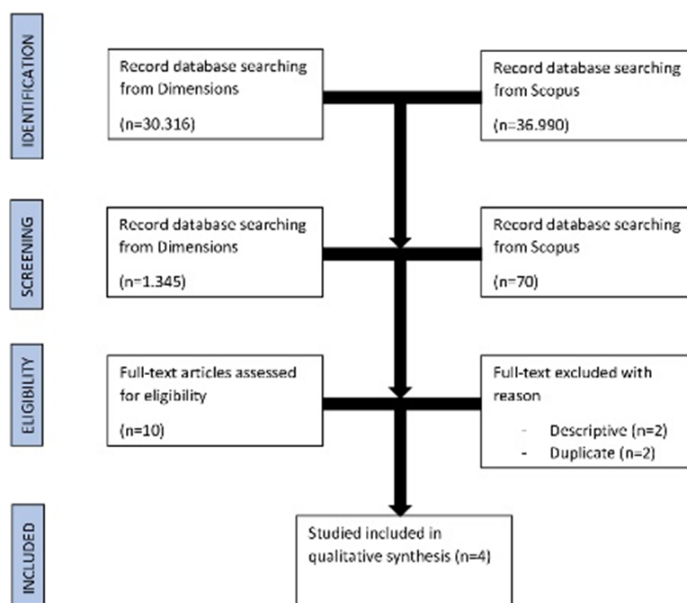


Fig 1. Flowchart Systematic Review

most likely due to its chemical diversity.

CZ, also called Ceylon cinnamon (from the Latin word *zeylanicum*) or 'genuine cinnamon,' is native to Sri Lanka and southern India. (Chericoni et al., 2005). Trans-cinnamaldehyde, eugenol, and linalool are three of the most important components of essential oils ex-

tracted from CZ bark, accounting for 82.5 per cent of the total composition (Chericoni et al., 2005). Trans-cinnamaldehyde makes up about 49.9%–62.8 per cent of the total amount of bark oil (Simić et al., 2004). CZ extracts also include significant amounts of cinnamaldehyde and eugenol (Simić et al., 2004).

The amount of coumarin (1,2-benzopyrone) in CC and CZ differs significantly. Coumarin levels in CC appear extremely high, posing health hazards if ingested in large quantities regularly. According to the German Federal Institute for Risk Assessment (BfR), 1 kg of CC (CC) powder contains around 2.1-4.4 g of coumarin or 5.8-12.1 mg of coumarin in 1 teaspoon of CC powder. This is higher than the European Food Safety Authority's recommended Tolerable Daily Intake (TDI) of 0.1mg/kg body weight/day for coumarin (EFSA) (Abraham et al., 2010). The BfR clearly stated in its study that CZ has "hardly any" coumarin. Coumarins are phytochemicals having anticoagulant, cancer-causing, and hepatotoxic effects (Abraham et al., 2010). The underlying mechanisms of coumarin-related toxicity have yet to be fully understood (Abraham et al., 2010). Despite the comparatively low amounts of spices consumed, research has revealed that coumarin exposure from food consumption is mostly attributable to CC due to its high concentrations (compared to other meals). (Abraham et al., 2010). Because of its coumarin content, the EFSA advises against using CC as a supplement on a regular, long-term basis. (Iffland et al., 2016). Furthermore, coumarin does not appear to play a direct role in the recognized biological effects of CC, according to the currently available information. CC's coumarin content, unlike CZ's, is likely to be a barrier to regular use as a pharmaceutical agent, even though it has many beneficial medicinal properties.

Safety

The tolerance of different cinnamon powder doses, as well as any side effects, were not routinely recorded. The US Food and Drug Administration considers cinnamon use as a spice or flavouring agent to be generally safe (21CFR182.10, 21CFR182.20). The hepatotoxic chemical coumarin is present in varying amounts in cinnamon species, ranging from less than 0.01 g/kg in *C zeylanicum* to 3.6 g/kg in *C cassia*. (Abraham et al., 2010; Ballin & Sørensen, 2014; Hajimonfarednejad et al., 2018). The European Union regulates the amount of coumarin in specified foods, 86 and practical guidelines for maintaining appropriate levels in food products have been presented. (Ballin & Sørensen, 2014). Cinnamon is generally safe for use in controlled clinical trials, according to a recent review of adverse events associated with its use (Hajimonfarednejad et al., 2019). Although adverse effects were not consistently report-

ed, the authors of this analysis found that those identified in clinical trials and case reports were largely allergic reactions and gastrointestinal distress, and were generally small and self-limiting. However, large doses of cinnamon (93 g/d) used over long periods of time should be well watched for potential side effects, including as interactions with prescription medicines. 1,17,68,88 A recent case report of an adult man with diabetes who consumed 1 g of cinnamon per day was linked to fluid retention symptoms similar to those seen with thiazolidinedione medications.

Cinnamon on recovery

Cinnamon and its active ingredients such as cinnamaldehyde, cinnamate, cinnamic acid, and eugenol in the form of aqueous and alcoholic extracts have a variety of therapeutic effects, according to traditional medicine and recent scientific evidence. Cinnamon extracts help with a variety of MetS symptoms, including high blood glucose, dyslipidemia, obesity, and high blood pressure. Cinnamon has been found to be a cardiovascular protective agent with the potential to reduce MetS consequences due to its anti-diabetic, anti-oxidant, anti-inflammatory, and lipid profile-beneficial properties (Couturier et al., 2010; Shen et al., 2012; Ziegenfuss et al., 2006). CZ has been shown to have 65.3 per cent anti-oxidant activity and a very strong free radical scavenging activity in a variety of extracts, including alcoholic, aqueous, and etheric, from various plant parts (Halliwell, 2011). Cinnamon, spinach, chard, Jerusalem artichoke, and red cabbage were all tested for their anti-oxidant capabilities in a recent study. Boga et colleagues discovered that cinnamon extracts provided the strongest anti-oxidant benefits (Boğa et al., 2011). Cinnamon has anti-oxidant action and is a potent scavenger of hydrogen peroxide, nitric oxide, and lipid peroxide free radicals. Phenolic chemicals may be found in practically all portions of the plant (Chericoni et al., 2005). Cinnamon's essential oil and its component eugenol both show anti-oxidant activity (Chericoni et al., 2005). The use of 75 mg/kg of C is recommended. As an anti-oxidant in diet, zeylanicum boosted SOD, GPX, and CAT in rats for four weeks, resulting in the removal of ROS as well as a decrease in lipoperoxidation (LPO) and the apoptotic index (Khaki, 2015). In addition, at 500, 1000, and 2000 ppm concentrations of cinnamon, anti-LPO in vegetable oil prevented malondialdehyde (MDA, a marker of LPO) generation (Khaki, 2015).

The effects of essential oils and some of the major compounds found in cinnamon, such as (E)-cinnamaldehyde, eugenol, and linalool, on peroxynitrite-induced nitration and LPO were studied. Cinnamon flavonoids have both free-radical scavenging and anti-oxidant effects (Okawam M, Kinjo J, Nohara T, 2001). Cinnamon's anti-oxidant properties Between 1995 and 2015, 178 articles were discovered. Cinnamon demonstrated anti-oxidant action in all of them, including in vitro, in vivo, and food industry investigations, with increases in anti-oxidant enzyme activity such as SOD, CAT, and GOX and decreases in MDA, LPO, ROS generation, and overall oxidant index value. These systems can help reduce oxidative stress and its subsequent side effects on all body regions.

The MetS are characterized by inflammation and an increase in proinflammatory cytokines. Local inflammation within adipose tissue may be the sentinel event that causes systemic insulin resistance and systemic inflammation, two of the cardinal features of the MetS, and adipocytes and macrophages within fat secrete numerous hormones and cytokines that may contribute to the pathophysiological changes seen in the MetS (Ziegenfuss et al., 2006). The metabolic effects of circulating cytokines on muscle, liver, and endothelium are comparable. Interleukin 6 (IL-6) and leptin, which are generated from adipose tissue, trigger endothelial cell activation and inflammation, which leads to atherosclerosis and death in the vascular beds (Rega et al., 2007).

The anti-inflammatory activities of cinnamon and its essential oils are indicated in many studies (Mashhadi et al., 2013; Muhammad et al., 2015; Rega et al., 2007). Lee et colleagues observed the suppression of nuclear factor kappa B (NF-B) by 2'-hydroxycinnamaldehyde extracted from *C. cassia* bark was found to reduce nitric oxide generation (S. H. Lee et al., 2005). Muhammad et al. discovered that cinnamaldehyde suppressed NF-B. Cinnamaldehyde suppressed IL-8 secretion/expression from *Helicobacter pylori*-infected cells in an in vitro investigation using AGS/MKN-45 cells, and cinnamaldehyde reduced I-B degradation (Muhammad et al., 2015). Another anti-inflammatory function of cinnamon's ethanolic extract is to reduce the activation of Src/spleen-tyrosine kinase (Src/Syk-) as an inflammatory signalling cascade (Yu et al., 2012). In an in vivo and in vitro model of lipopoly-

saccharide-induced TNF increase, levels of tumour necrosis factor (TNF) were reduced by an aqueous extract of cinnamon. In Lee's work, cinnamon water extract inhibited TNF- gene expression in vitro through modulating JNK, p38, and ERK1/2 activation, as well as IB degradation (B. J. Lee et al., 2011). According to Hong et al., cinnamon water extract (CWE) suppressed TNF expression in an in vitro and in vivo model. In this investigation, the polyphenol-rich CWE fraction effectively prevented the degradation of IB and MAP kinase phosphorylation generated by lipopolysaccharide in macrophages.

The results of this approach inclined to suppression of TNF- α and IL-6 production. The high polyphenolic content of CWE was linked to its potent anti-inflammatory properties. CE's primary anti-inflammatory components are procyanidins, catechins, epicatechins, and ellagic acid (Hong et al., 2012). Also, CWE prevented anti-CD3-stimulated T cells from secreting IFN- γ (B. J. Lee et al., 2011). In OGD-treated cells, cinnamon polyphenols increased the expression of the pro-apoptotic protein Bax while suppressing the expression of the anti-apoptotic protein Bcl-xl. Cinnamon polyphenols inhibited OGD-induced inflammatory factors such as TNF- and phospho-NF-B p65 and promoted sirtuin1 expression as a negative regulator of NF-B activity by deacetylating the p65 lysine 310, which inhibits NF-B activity. Chao et al. demonstrated that interleukin-1 beta (IL-1) suppresses production. The key component in cinnamon used in this investigation was eugenol (Chao et al., 2008). Eugenol has also been shown to block the 5-lipoxygenase enzyme in polymorphonuclear leukocytes, as well as inducible nitric oxide synthesis (iNOS), cyclooxygenase-2 (COX-2) and nitric oxide (NO) production (Hwang et al., 2009). Cinnamon extract was given to rats at doses of 50, 100, and 200 mg/kg to see if it had any anti-inflammatory benefits. All elements of inflammation models, such as paw volume, weight loss, paw oedema, and cotton pellet-induced granuloma, were improved, and high blood TNF- concentrations were significantly reduced. Cinnamon also suppressed the release of cytokines (IL-2, IL-4, and IFN) from concanavalin-stimulated cells in vitro (Lu et al., 2010). Cinnamon extract inhibits angiogenesis by blocking vascular endothelial growth factor 2 (VEGF2) signalling, as well as decreasing endothelial cell proliferation, migration, and tube formation, as observed in an in vitro investigation (Rathi et al., 2013).

CONCLUSION

Cinnamon is effective for preventing inflammation which impacts accelerating recovery in athletes. The type of cinnamon that is effective for the recovery of athletes is *Cinnamomum zylanicum*; this is because *Cinnamomum zylanicum* has the most content to help accelerate recovery, which is most suitable for athletes. Thus, cinnamon is expected to be an alternative supplement for athletes to improve their performance.

CONFLICT OF INTEREST

The authors declared no conflict of interest.

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