Sea cucumber phytochemical compounds have the potential to reduce TNF-a levels after exercise

Los compuestos fitoquímicos del pepino de mar tienen el potencial de reducir los niveles de TNF-a después del ejercicio

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Abstract

Introduction: Increased levels of TNF-a in the blood after exercise can cause muscle pain.
Objective: This study aims to analyze the potential of sea cucumber phytochemical compounds in reducing TNF-a levels after exercise.
Methodology: This type of research is experimental research. Subject selection was carried out using the purposive sampling method. Next, the subjects were divided into two groups, namely the treatment group (K1) received sea cucumbers, and the control group (K2) received placebo. Sea cucumber is given in supplementation form at a dose of 500 mg. This study involved 16 healthy guys. The study's participants were between the ages of 20 and 25. Three days were dedicated to data collection, starting with the collection of information on the subjects' characteristics. Subjects were then instructed to warm up. Practice is done afterwards. The exercises carried out include weight training with maximum intensity. 24 hours after exercise, blood was taken for pre-test data to measure TNF-a levels. Then the samples were given placebo intervention and sea cucumber supplements based on their respective groups. 48 hours after exercise, blood was taken for post test data to measure TNF-a levels.
Results: The results showed that sea cucumber supplementation after exercise was shown to significantly reduce TNF-α levels in healthy men $p<0.05$*.
Discussion: The anti-inflammatory properties of sea cucumber can have a positive impact in reducing TNF-α levels after exercise.
Conclusions: Sea cucumber supplementation at a dose of 500 mg was able to reduce TNF-α levels significantly. We recommend investigating the effect of sea cucumber supplementation on IL-6 levels in the future.

Keywords

Sea cucumber, inflammation, exercise, healthy lifestyle.

Resumen

Introducción: Los niveles elevados de TNF-a en sangre después del ejercicio pueden provocar dolor muscular.
Objetivo: Este estudio tiene como objetivo analizar el potencial de los compuestos fitoquímicos del pepino de mar para reducir los niveles de TNF-a después del ejercicio.
Metodología: Este tipo de investigación es investigación experimental. La selección de sujetos se realizó mediante el método de muestreo intencional. A continuación, los sujetos se dividieron en dos grupos: el grupo de tratamiento (K1) recibió pepinos de mar y el grupo de control (K2) recibió placebo. El pepino de mar se administra como suplemento en una dosis de 500 mg. En este estudio participaron 16 chicos sanos. Los participantes del estudio tenían entre 20 y 25 años. Se dedicaron tres días a la recolección de datos, comenzando con la recopilación de información sobre las características de los sujetos. Luego se indicó a los sujetos que calentaran. La práctica se hace después. Los ejercicios realizados incluyen entrenamiento con pesas con máxima intensidad. 24 horas después del ejercicio, se extrajo sangre para obtener datos previos a la prueba para medir los niveles de TNF-a. Luego, las muestras recibieron una intervención de placebo y suplementos de pepino de mar según sus respectivos grupos. 48 horas después del ejercicio, se extrajo sangre para obtener datos posteriores a la prueba para medir los niveles de TNF-a.
Resultados: Los resultados mostraron que la suplementación con pepino de mar después del ejercicio redujo significativamente los niveles de TNF-α en hombres sanos $p<0,05$*.
Discusión: Las propiedades antiinflamatorias del pepino de mar pueden tener un impacto positivo en la reducción de los niveles de TNF-α después del ejercicio.
Conclusiones: La suplementación con pepino de mar a una dosis de 500 mg fue capaz de reducir significativamente los niveles de TNF-α. Recomendamos investigar el efecto de la suplementación con pepino de mar sobre los niveles de IL-6 en el futuro.

Palabras clave

Pepino de mar, inflamación, ejercicio, estilo de vida saludable.

Introduction

High-intensity physical exercise can enhance physiological reactions, including muscular damage and postponed discomfort (Hung et al., 2021). Pain that occurs post-exercise is usually caused by an uncontrolled and excessive increase in inflammation (Amalraj et al., 2020). Pain that occurs after exercise is commonly called Increased muscle pain and discomfort that often starts 24 hours after exercise and peaks 24 to 48 hours after intense activity is known as delayed onset muscle soreness (DOMS) (Lee et al., 2015). DOMS is seen as a sign of muscle injury as well that triggers a decrease in the work function of the muscles (Chalchat et al., 2022). The heavy use of healthcare resources is a result of the fact that over 20% of people worldwide suffer from unpleasant illnesses (Silva et al., 2013). Other indirect indicators of muscle damage, which have historically been used to measure the extent of exercise-induced muscle damage (EIMD), which impairs physical performance and can happen anywhere from a few of days to a few weeks after exercise, frequently accompany decreased muscle function (Chalchat et al., 2022).

Increased cytokines, ROS, or reactive oxygen species and inflammation are closely associated with muscle damage during physical exercise (de Morais et al., 2024). Exercise-damaged muscles can increase the sensitivity of nociceptor terminals, leading to greater pain sensation (Mizumura & Taguchi, 2016). With physical activity, it will increase both aerobic and anaerobic metabolism, and muscles' increased need for energy (Taherkhani et al., 2020). However, the occurrence of significant skeletal muscle tissue damage is closely triggered by intense physical exercise which results in decreased muscle work and function both muscle force and range of motion (Xu et al., 2022). Because it affects life stability and quality of life, musculoskeletal pain is a significant public health issue (Cuenca-Martínez et al., 2022). Increasing blood flow, enhancing proprioception to lessen muscular soreness, and removing edema linked to muscle fatigue are often the recovery strategies for DOMS (Heiss et al., 2019). However, sometimes that is insufficient to get over the agony.

Adipocytes and macrophages produce the pluripotent cytokine tumor necrosis factor alpha (TNF-α) (Jiménez-Maldonado et al., 2019). Diabetes mellitus and cardiovascular disease can be triggered by inflammation such as increased TNF-α (X. Wang et al., 2024). IL-6 and TNF-α were found to be higher immediately after exercise as markers of inflammation (Żebrowska et al., 2019) even 48 hours post-exercise also still experienced an increase over its resting value (Brown et al., 2018). The increase in TNF-α after high-intensity exercise correlates with the pain experienced. Short and long-term molecular and cytokine changes triggered by HIIT exercise disrupt the redox balance that will trigger ROS to continuously increase which results in lipid peroxidation (Jamurtas et al., 2018). The "good" inflammatory TNF-α-p75 receptor pathway, which promotes cell growth and proliferation, may be activated by exercise (Shobeiri et al., 2022). Delayed onset muscular soreness (DOMS) is a hallmark of high-intensity weight training-induced muscle damage (Yoon et al., 2020). Tumor necrosis factor-alpha (TNF-α) levels in the blood rise in reaction to muscle injury trigger an inflammatory process that results in muscle pain (Jürgenson et al., 2021). Tumor necrosis factor alpha (TNF-α) activates transcriptional pathways that cause oxidative stress, then the induced oxidative stress and inflammation interact with each other to destroy the cells (Bakhtiari et al., 2020).

To stop the rise in inflammation brought on by an increase in TNF-α, a different approach is therefore required. Numerous bioproperties, including antihypertensive, antioxidant, anticoagulant, antibacterial, antifungal, hemolytic, cytotoxic, and immunomodulatory effects, are well-known for sea cucumbers (Pangestuti & Arifin, 2018). Antioxidants are used to combat free radicals and lessen oxidative stress. Flavonoids and other plant-derived polyphenols are examples of natural antioxidants with a variety of biological activity and possible medical uses (Grgić et al., 2020). Numerous secondary metabolites, including alkaloids, steroids, triterpenoids, glycosaminoglycans, lectins, phenols, flavonoids, and saponins, are abundant in sea cucumbers (Phyllophorus sp.) (Zhao et al., 2018). A member of the phylum Echinodermata, sea cucumbers are invertebrates. Bioactive substances with a numerous pharmacological and biological effects, including as anti-inflammatory, anti-cancer, antitumor, wound-healing, anticoagulant, antioxidant, correcting hyperlipidemia, and blood sugar regulation, are abundant in this species (Hossain, Dave, et al., 2022).

The greatest producer of dried sea cucumbers worldwide is Indonesia, which are a lucrative fishery product (Yusuf et al., 2017). The primary sea cucumber-producing region in Indonesia is South Sulawesi

Province (Aprianto et al., 2019). Sea cucumbers' high nutritional value is one of the factors contributing to their high value as a commodity. Sea cucumbers are a low-fat, high-protein shellfish that is also high in iodine, gluten, and nitrogen, among other nutrients (Tuwo & Tresnati, 2015). Sea cucumbers are a type of echinoderm whose meat includes a variety of healthful substances. They can be used medicinally and as a source of protein, such as as anti-inflammatory and wound-healing agents (Elfidasari et al., 2012). Due to these advantages, dried sea cucumbers are a highly valuable commodity that Indonesia exports all over the world (Purcell et al., 2009).

Sea cucumbers contain phenolics, proteins (peptides), carotenoids, lipids, and saponins, among other bioactive substances (Hossain et al., 2020). According to Pranweerapaiboon et al., 2020 Inducible nitric oxide synthase (iNOS), nitric oxide (NO), tumor necrosis factor-α (TNF-α), interleukin-1β (IL-1β), and prostaglandin E2 (PGE2) were among the pro-inflammatory cytokines that were inhibited by the phenolic-rich ethyl acetate fraction of sea cucumber extracts. Extract sea cucumber extract is proven to have a rich content of antioxidants such as phenolic compounds, flavonoids, and anti-cancer (Gustini et al., 2023). Production of proinflammatory cytokines, specifically those of prostaglandin E2 (PGE2), interleukin-1β (IL-1β), TNF-α, nitric oxide (NO), and inducible nitric oxide synthase (iNOS), can be inhibited by phenols (Hossain, Dave, et al., 2022). It is still not understood exactly how sea cucumber consumed after exercise affects TNF-α levels. Whether sea cucumbers are able to suppress inflammation through lowering TNF-α levels or not is still not fully understood. The underlying mechanism is still unclear. Therefore, this research aims to analyze in depth the underlying mechanism.

Method

Study Design

This type of research is experimental research. Subject selection was carried out using the purposive sampling method. Next, the subjects were divided into two groups, namely the treatment group (K1) received sea cucumbers, and the control group (K2) received placebo. Sea cucumber is given in supplementation form at a dose of 500 mg.

Subject

Sixteen healthy men participated throughout the research (Table 1 displays the attributes of the subjects). To determine whether the volunteers could possibly meet the needs of the study, inclusion and exclusion criteria were developed. College students with normal Body Mass Index (BMI) aged between 18 and 25 years met the inclusion criteria. Furthermore, regular exercise was not mandatory for college students. In addition, the study excluded people under the age of eighteen who, prior to exercising, had abnormal blood pressure. Finally, if the subjects were taking nonsteroidal anti-inflammatory drugs (NSAIDs), they were excluded. The 18 study volunteers were divided into two groups, a physical exercise + sea cucumber treatment group (n = 8), and a control group with physical exercise + placebo (n = 8). The study was conducted at the Fitness Center of Surabaya State University.

Research Instruments

Measurements of blood pressure, height, and weight, data collecting sheets, stationery, blood collection gear, sea cucumber supplements, and placebo capsules were among the materials utilized in this study.

Procedure

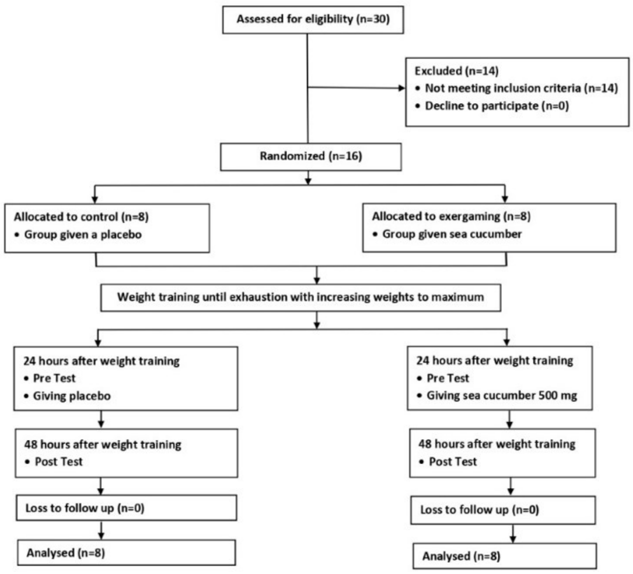
The data collection procedure of this study consisted of several steps. The research subjects underwent a screening procedure before starting the study. Certain parameters that allowed information to be included or excluded in the analysis formed the basis of this approach. Prior to the study, the samples were instructed not to engage in much physical activity and to rest sufficiently and not to overeat or take other supplements that could interfere with the results of the study. In addition, they gave informed consent, agreeing to take part in the study. Two groups were randomly selected from among the trial participants: the treatment group, which was given sea cucumber, and the placebo group. The treatment group received 500 mg of sea cucumber, while the placebo group received empty capsules. The sea cucumber was administered in capsule form.

Three days were dedicated to data collection, beginning with the gathering of information on subject characteristics. Research subjects were prohibited from consuming anything before the implementation of the study. One day before the study, the research subjects were given directions to maintain a regular diet and rest. On the first day, the characteristics of the research subjects were collected. The subjects then warmed up and performed squat and leg press exercises with an intensity of 80-90% of their maximum capacity. The intensity for each subject was determined using the one-repetition maximum (1RM) test. 1RM is the maximum load that can be lifted in one repetition of a movement. Exercises were performed in four sets of 10 repetitions with approximately 60 seconds of recovery time between sets.

There are two tools used, the first is the Leg Machine which is used and given a maximum load. The second exercise was squad training using the Smith Machine which was also given a maximum load. All samples performed both types of exercise alternately. 24 hours after the weight training, the samples were directed to a room to have their blood drawn as pretest data. After that, the samples were given supplements according to their respective groups. Subjects were given 500 mg sea cucumber intervention and placebo according to their respective groups. 24 hours after consumption of sea cucumber supplements and placebo, blood was taken for posttest data. After pretest and posttest blood sampling, laboratory analysis was carried out to check TNF-α levels. This laboratory analysis was carried out at the Airlangga University Hospital Research Laboratory Installation Surabaya. The method of examining TNF-α levels using the ELISA method (Enzyme-linked immunosorbent assay) with the human TNF-α ELISA kit. Finally, as a form of accountability, after reviewing the data, the researcher made a written report.

CONSORT flowchart

Figure 1. The CONSORT flowchart



Statistical analysis

SPSS software was used to do statistical analysis after the data was collected. To determine the mean and standard error, a descriptive analysis was performed on the data. The Shapiro-Wilk test was also used in this investigation as a normality test. Using the paired t-test approach, a difference test was created to ascertain whether the data were normally distributed. The Wilcoxon signed-rank test was used to examine the data, however if the findings indicated otherwise.

Ethics

Prior to data collection, we obtained ethical approval from the Ethics Committee of Malang Health Polytechnic with registration number DP.04.03/F.XXI.31/0492/2024.

Results

The statistics and details regarding the general attributes of the participants in Table 1 are presented in this section. We can gain a better understanding of each group's characteristics thanks to these statistics. The mean ± standard error is used to display the data. The t-test findings from the initial study indicated that there was no significant difference between K1 and K2 (p≥0.05).

Table 1. Characteristics of research subjects

Data	Group	N	x ± Standard Error	p-value
Age (y)	K1	8	21.62±0.84	0.700
	K2	8	22.25±0.97	
Height (cm)	K1	8	168.00±1.01	0.628
	K2	8	167.50±2.29	
Weight (kg)	K1	8	63.75±2.85	0.968
	K2	8	63.50±4.14	
BMI (kg/m²)	K1	8	22.44±1.04	0.918
	K2	8	22.64±1.41	
Systolic (mmHg)	K1	8	126.50±3.15	0.248
	K2	8	119.62±3.80	
Diastolic (mmHg)	K1	8	84.12±3.61	0.147
	K2	8	76.37±2.94	

Table 2. Normality test results

Data	Group	Shapiro-Wilk	
		N	P-value
TNF-α	K1 (Pre-test)	8	0.022
	K1 (Post-test)	8	0.118
TNF-α	K2 (Pre-test)	8	0.584
	K2 (Post-test)	8	0.002

Based on the normality test in Table 2, TNF-α data in the pre-test sea cucumber group were not normally distributed (p<0.05). In the placebo group, the post-test was also distributed abnormally (p<0.05). So that both the sea cucumber and placebo groups can be concluded that the data is not normally distributed (p<0.05). Therefore, the next test carried out is the nonparametric wilcoxon test.

The results of TNF-α analysis between pre-test and post-test in each group are presented in Figure 2.

Figure 2. Group K1 supplemented with sea cucumber after exercise could significantly reduce TNF-α levels.

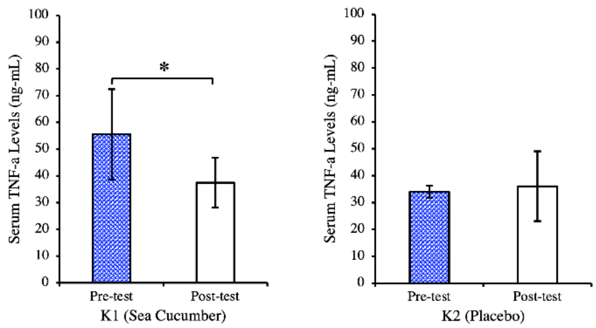


Table 3 shows the results of the wilcoxon test. Data are presented as mean ± standard error.

Table 3. Results of TNF-α levels (ng/L)

Difference Test Method	Data	Pre-test	Post-test	P-value
Wilcoxon Signed Ranks Test	K1	55.50±16.88	37.20±9.35	0.036*
	K2	34.00±2.21	36.09±12.94	0.484

*There is a significant difference in the experimental group (p<0.05) and there is no significant difference in the control group (p>0.05).

Discussion

This study sought to ascertain how supplementing with sea cucumbers affected TNF-α levels, a marker of inflammation, following high-intensity physical activity. According to research findings, taking sea cucumber supplements after exercise has been shown to significantly lower TNF-α levels in healthy individuals. This is consistent with earlier studies that demonstrate that giving rats sea cucumbers lowers their TNF-α levels (Anggraini et al., 2016). Other studies' findings support the notion that supplementing rats with sea cucumbers dramatically lowers their TNF-α levels (Yudo et al., 2022). Other research' findings support the idea that supplementing with sea cucumbers can significantly lower TNF-α levels in diabetic patients. It has been shown that sea cucumbers have anti-inflammatory and antioxidant properties (Haryanto et al., 2022).

The Acute Effect of Exercise Increase TNF-α Levels and DOMS

Muscle damage, metabolic stress, and lack of energy triggered by high-intensity weight training results in Muscle soreness that develops slowly and eventually results in necrosis (cell death) (de Freitas et al., 2017) which peaks between 24 - 48 hours after physical exercise (Sari, 2021). Loss of muscle strength and the occurrence of DOMS during exercise induced muscle damage (EIMD) were initially attributed to subcellular disruptions in skeletal muscle fibers (Givli, 2015). Inflammatory responses may play a major role in bridging the initial response to muscle injury and timely repair of muscle injury or trigger a vicious cycle to exaggerate tissue damage (Tu & Li, 2023). Maximal weight training will provide an inflammatory response and damage to muscle morphology which results in increased pain (Tachtsis et al., 2018). Weight exercise will boost proinflammatory cytokines like TNF-α and IL-6 by stimulating macrophages (Lulińska-Kuklik et al., 2019). TNF-α is a major cytokine involved in the regulation of other pro-inflammatory cytokines. It is released by macrophages, neutrophils, natural killer cells, endothelial cells, and activated lymphocytes. TNF-α mediates leukocyte activation, immune cell adhesion and migration, angiogenesis, chemokine expression, and contributes to osteoclastogenesis. IL-1β has many of the same activities as TNF-α, although it does not cause TNF-α production. It is produced mainly by monocytes and macrophages in the inflamed synovium (Brzustewicz & Bryl, 2015).
An increase in TNF-α will cause macrophages to produce more anti-inflammatory cytokines, such IL-10, which help to regulate inflammation (Mittal & Roche, 2015). TNF-α is important for mammalian immunity and cell homeostasis. The role of TNF-α as a master regulator in balancing cell survival and death has been extensively studied in various cell types and tissues. TNF-α induces inflammatory responses and two programmed cell death mechanisms, namely apoptosis and necroptosis, based on different pathological conditions (Chen et al., 2019). An inflammatory response will result from morphological damage brought on by eccentric contraction. When inflammatory cells like neutrophils and macrophages are more active in injured muscle, cytokines are released. Proinflammatory cytokines like TNF-α and IL-6, as well as anti-inflammatory cytokines like IL-10, are generated as inflammatory mediators. When muscle damage occurs, a rise in TNF-α in the blood will set off an inflammatory process that results in muscle discomfort (Ayubi et al., 2022).

The Acute Effect of Sea Cucumber Supplementation on TNF-α Levels

TNF-α levels significantly decreased following high-intensity exercise, according to the study's findings in group K1 with the sea cucumber intervention. Following a high-intensity physical exercise intervention, TNF-α levels did not drop in the K2 group that received a placebo. It is clear that sea cucumbers' antioxidant content can lower TNF-α inflammatory levels during intense exercise. Sea cucumbers can be used to make a wide range of beneficial natural ingredients for the food, cosmetic, and agricultural industries. They can also be used to cure a number of illnesses, including rheumatism, asthma, discomfort, high blood pressure, wounds, burns, and kidney issues (Hossain, Yeo, et al., 2022).

Antioxidant play an important role in regulating ROS levels through direct free radical scavenging mechanisms, through regulation of ROS/RNS-producing enzymes, and/or through adaptive mechanisms such as electrophilicity. Acute and chronic resistance training tends to increase the expression and activity of endogenous antioxidant enzymes in skeletal muscle, which in turn allows for an increased capacity to moderate the adverse effects of ROS (Mason et al., 2020). To improve the capacity of skeletal muscle to neutralize ROS produced during exercise, athletes regularly take exogenous antioxidant supplements. The benefits of antioxidant supplements may be related to improved cellular redox state and decreased oxidative modifications to DNA, lipids and proteins. Some evidence suggests an ameliorative effect of antioxidants on muscle recovery after intense, muscle-damaging exercise (Jäger et al., 2019). ROS are also involved in premature muscle fatigue during muscle contraction and sustained exercise (Lamb & Westerblad, 2011). Therefore, the use of exogenous antioxidants may help delay muscle fatigue and improve resistance training performance.

Sea cucumbers are well known for their potential health advantages since they are low in fat (calcium, zinc, iron, and magnesium) and high in protein (40–60%), along with vitamins and minerals. Sea cucumbers have also been shown to contain a wide range of bioactive compounds, such as polysaccharides, collagen and peptides, sphingoids, phenolics, triterpene glycosides (sapo-nin), sterols, carotenoids, and chondroitin. Numerous biological and pharmacological characteristics of these compounds include antibacterial, antioxidant, antihypertensive, immunoregulatory, and anti-inflammatory effects, anticoagulant, anticancer, antidiabetic, antifatigue, anti-aging, and antithrombotic properties (Senadheera et al., 2023). During exercise, sea cucumber phytochemical components may help lower inflammation and oxidative stress.

Sea cucumbers are one of the most important marine organisms found in almost every marine environment belonging to the class Holothuroidea. Sea cucumbers are long worm-like organisms with gelatinous bodies that are usually soft-bodied echinoderms (Janakiram et al., 2015). In the past two decades, sea cucumber extracts have been widely studied in the medical and pharmaceutical fields as wound healing promoters, exhibiting anticancer, antimicrobial, and immunomodulatory properties (Santhanam et al., 2022). Sea cucumbers may have potential compounds to fight cancer as they contain protein, vitamin A, thiamine, riboflavin, niacin, calcium, iron, magnesium, zinc, and other unique molecules (Janakiram et al., 2015).

Triterpene glycosides, fucoidan, fucosylated chondroitin sulfate, fucan sulfate, and phenols are among the several bioactive substances found in sea cucumbers. These substances are known to have a number of physiological effects, including anti-inflammatory, anti-thrombotic, anti-cancer, anti-microbial, anti-diabetic, and anti-obesity properties (Maskur et al., 2024). It is the antioxidants that combat free radicals. Therefore, it's crucial to eat this, particularly after vigorous exercise. Furthermore, because they are frequently utilized as delicacies and contain pharmacologically active substances, sea cucumbers have economic significance (Khotimchenko, 2018). For instance, Indonesia produces the most dried sea cucumbers in the world, but because of their poor quality, their export value is minimal (Aprianto et al., 2019). So if this research has been proven to have a protective effect in anti-inflammatory protection, then in the future it must be able to provide recommendations to stakeholders in Indonesia to carry out the process and stages of practical products of sea cucumber supplements for sportsmen and athletes in maintaining their performance. This is important because the potential of Indonesia is extraordinary, which is rich in natural products.

Sea cucumbers' phenolic content is one of the key antioxidants that scavenges free radicals (Hossain, Dave, et al., 2022). Both single oxygen and other oxidizing species, such as superoxide anions, hydroxyl radicals, or peroxide radicals, are captured by phenolic compounds (Ajiboye et al., 2020). Gallic acid, P-cumaric acid, ferulic acid, cinnamic acid, catechins, rutin, quercetin, and pyrogallol are phenolic chemicals that are frequently present in sea cucumbers. The anti-inflammatory and immune-modulating actions of polyphenolic compounds reported by many epidemiological and experimental studies have shown that these natural compounds can affect immune cell populations and modulate the tissue balance between proinflammatory cytokines (e.g., IL-1β, IL-2, IL-6, IL-8, TNF-α) and anti-inflammatory cytokines (e.g., IL-4, IL-10, TGF-β) (Yahfoufi et al., 2018). Animal and epidemiological studies have reported that polyphenolic compounds inhibit tumor activity by reducing cell proliferation and survival, mutagenesis, angiogenesis, apoptosis, and leukocyte immobilization (Kruk et al., 2022). Furthermore, sea cucumbers boost the body's antioxidant levels and activate enzymatic antioxidants like SOD, GSH, CAT, and others (Pangestuti & Arifin, 2018). Additionally, sea cucumbers have protective properties for substances like proteins, lipids, and DNA (Pangestuti & Arifin, 2018).

According to additional lab research, sea cucumber extracts may have anti-inflammatory and antioxidant properties (Carletti et al., 2022). Sea cucumbers' high polyphenol content offers a potent antioxidant action to combat free radicals. Polyphenolic substances have the ability to shield cells from oxidative stress and lessen the negative consequences of proinflammatory cytokine activation (Carletti et al., 2022). Additional evidence supports the claim that sea cucumber extract has a high phenolic content, which enables it to have antioxidant and protective properties (Aatab et al., 2023). By stabilizing free radicals, this sea cucumber extract acts as a hydrogen donor to halt the oxidation process.

Free radicals can be repelled by bioactive substances such phenolic acids (vanillic acid, pyrrolic acid, caffeic acid, and gallic acid) (Aatab et al., 2023). Consequently, this polyphenolic acid makes a substantial contribution to antioxidant activity. Sea cucumbers' anti-cancer properties as an anti-inflammatory and antioxidant to protect against free radicals are further supported by the findings of additional studies (Wargasetia et al., 2023). Sea cucumbers have active chemicals that can suppress free radicals like nitric oxide, hence reducing oxidative stress (Wargasetia et al., 2023). By preventing the KEAP1 and iNOS proteins from interacting with the DLG NRF2 motif, sea cucumber extract helps to prevent oxidative stress in cells (Wargasetia et al., 2023).

Numerous additional myokines, including TNF-α and interleukin-10, are released as a physiological reaction during inflammation (Porto et al., 2023). One of the proinflammatory cytokines that causes muscular soreness is TNF-α (Nanavati et al., 2022). In connection with this, sea cucumbers can also lower pro-inflammatory cytokines like TNF-α, IL-1β, IL-6, and IL-6 (Q. Wang et al., 2021). Sea cucumber can decrease the release of proinflammatory cytokines by blocking TLR4 expression and NF-κB activation (Q. Wang et al., 2021). Alkaloids, steroids, sapogenins, saponins, triterpenoids, glycosaminoglycans, lectins, phenols, and flavonoids are secondary metabolites found in sea cucumber extracts (Dewi et al., 2025). Flavonoids, as active compounds in sea cucumber, exhibit antioxidant and anti-inflammatory properties. As antioxidants, flavonoids can reduce oxidative stress, prevent endothelial dysfunction, and decrease the release of TNF-α, a proinflammatory cytokine (Shukla et al., 2019). Additionally, the anti-inflammatory qualities of sea cucumbers might lessen the uncontrollably elevated inflammation brought on by exercise. In this instance, sea cucumber reduces inflammation by inhibiting the release of cytokines that promote inflammation.

Exogenous antioxidant levels are very important in supporting exercise performance. Other research data shows that supplementing with curcumin during physical exercise can reduce TNF-α levels (Bańkowski et al., 2025). This makes it important that the role of exogenous antioxidants is vital, especially their impact on inflammation. The results of another study in people who performed physical exercise and were given quercetin supplements, which is a polyphenolic flavonoid with high antioxidant and anti-inflammatory properties, also showed that oral quercetin supplementation for 7 days can improve antioxidant and anti-inflammatory responses and can also reduce oxidative stress and inflammation by reducing TNF-α levels caused by high-intensity exercise (Tsao et al., 2022). In addition, antioxidant supplementation will also delay fatigue caused by high-intensity physical exercise (Tsao et al., 2022). So it can be concluded that the effect of anti-inflammatory compounds can have a positive impact on reducing inflammation through a decrease in TNF-α levels after exercise. So it can be a recommendation for supplementation, especially sea cucumbers which are high in antioxidants as an additional supplement in reducing inflammation levels after physical exercise.

Conclusions

Sea cucumber supplementation at a dose of 500 mg after maximal exercise was shown to significantly reduce TNF-α levels as an inflammatory biomarker. For future research recommendations, the effect of sea cucumber supplementation on other inflammatory biomarkers such as IL-6 can be studied. The limitations of this study are the small number of samples and short intervention time so that future studies can increase the number of samples and types of interventions to determine the chronic effects caused during exercise and antioxidants from sea cucumber.

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