

# Research on the Immunomodulatory Effects of Krill Oil

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**Abstract:** Krill oil, as an emerging marine lipid, has garnered considerable attention due to its abundant bioactive components, including Omega-3 fatty acids, phospholipids, and astaxanthin. This article provides a comprehensive review of the immunomodulatory effects of krill oil and its underlying mechanisms, as explored through both animal experiments and clinical studies. It delves into the impact of krill oil on immune organs, immune cells, and immune function. The research findings demonstrate that krill oil can enhance the functionality of immune organs, modulate the activity of immune cells, and bolster the immune capacity of the body. These insights not only provide scientific support for the potential value of krill oil in dietary supplements, functional foods, and clinical applications but also open new avenues for research and application in the field of immunoregulation.

**Keywords:** Krill Oil; Omega-3 Fatty Acids; Astaxanthin; Immunomodulatory Effects.

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## 1. Introduction

Krill oil, extracted from Antarctic krill, has garnered extensive research attention due to its unique chemical composition and biological activity. Enriched with Omega-3 fatty acids, phospholipids, and astaxanthin, krill oil demonstrates significant potential in the realms of health supplements and functional foods. The immune system, a critical mechanism for defending against pathogenic microorganisms and maintaining health, directly influences an individual's well-being through its functional integrity. In recent years, an increasing number of studies have focused on the regulatory effects of natural bioactive substances on the immune system, with krill oil emerging as a focal point of this research owing to its multifaceted biological activities. This article aims to provide a comprehensive overview of the role of krill oil in immune regulation, exploring its potential applications and serving as a reference for research in related fields.

## 2. The Chemical Composition and Biological Activity of Krill Oil

### 2.1. Primary Chemical Components

Krill oil is an extraordinary marine lipid, principally composed of Omega-3 polyunsaturated fatty acids, phospholipids, and astaxanthin. Among these, the Omega-3 fatty acids stand out as one of the most pivotal components of krill oil, particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). According to recent research data, the content of EPA and DHA in krill oil typically ranges between 25% and 40%, indicating an exceptionally high concentration of Omega-3 fatty acids. This rich concentration not only provides substantial nutritional value but also exhibits notable anti-inflammatory and immune-modulatory effects. In contrast to conventional fish oil, the Omega-3 fatty acids in krill oil are more readily absorbed and utilized by the human body, primarily due to their presence in the form of phospholipids rather than triglycerides. Phospholipids are another critical constituent of krill oil, comprising approximately 40% to 50% of its composition. Not only are they integral components of cell membranes, but they also

boast excellent bioavailability and stability, significantly enhancing the absorption efficiency of Omega-3 fatty acids. The presence of phospholipids enables krill oil to penetrate cells more effectively, improving the fluidity and permeability of cell membranes, thereby augmenting the functionality of immune cells. Furthermore, phospholipids exert antioxidant and anti-inflammatory properties, providing multi-faceted support for immune system health [1]. Astaxanthin, the third significant component of krill oil, is a natural carotenoid with exceptionally potent antioxidant capabilities. Studies reveal that astaxanthin's antioxidant power is over 100 times greater than that of vitamin E, effectively neutralizing free radicals and safeguarding cells from oxidative damage. The astaxanthin content in krill oil is approximately 500 to 800 µg/g, a concentration of substantial importance for enhancing the immune system's antioxidative capacity. Additionally, astaxanthin boosts the activity of immune cells and optimizes the efficiency of immune responses. These unique chemical constituents endow krill oil with exceptional prowess in immune modulation, rendering it highly sought after in the realm of health foods and supplements.

### 2.2. Biological Activity

Phospholipids, as another key component in krill oil, not only provide rich nutrition but also play a vital role in the maintenance and repair of cell membranes. Phospholipids can improve the fluidity of cell membranes, enhance cellular permeability and function, thereby promoting the normal operation of immune cells. For example, phospholipids can increase the activity of T cells and B cells, promoting the efficiency of immune responses. Additionally, phospholipids have antioxidant and anti-inflammatory effects, supporting the health of the immune system on multiple levels. Astaxanthin is a natural potent antioxidant that can effectively eliminate free radicals in the body, reduce cellular oxidative damage, thereby protecting immune cells from harm caused by environmental and metabolic produced harmful substances. Research has shown that astaxanthin can also enhance the phagocytic ability of phagocytes, promoting the overall function of the immune system. Moreover, astaxanthin has demonstrated significant efficacy in the prevention and treatment of oxidative stress-related diseases,

such as cardiovascular diseases and neurodegenerative diseases. The combined effects of these bioactive components make krill oil exhibit unique advantages in immune regulation.

### **3. The Effects of Krill Oil on the Immune System**

#### **3.1. Protective Effects on Immune Organs**

The protective effects of krill oil on immune organs should not be underestimated, particularly in an era characterized by environmental pollution and increasingly unhealthy lifestyles. The Omega-3 fatty acids, phospholipids, and astaxanthin contained within krill oil synergistically provide robust protection for immune organs. Omega-3 fatty acids, especially EPA and DHA, significantly alleviate chronic inflammation and safeguard the liver from inflammatory damage. Studies reveal that continuous supplementation with krill oil for three months leads to a marked decline in liver function indicators such as ALT and AST, effectively curbing liver inflammatory responses. Phospholipids play a crucial role in maintaining the structural and functional integrity of immune organs. They enhance the fluidity of cell membranes, shielding immune cells in the spleen and bone marrow from external disruptions, thereby ensuring these cells can perform their immune functions efficiently. Experimental data indicate that phospholipid supplementation significantly boosts the quantity and activity of immune cells in the spleen and bone marrow, thereby enhancing the overall efficacy of the immune system [2]. Astaxanthin, a natural and potent antioxidant, effectively neutralizes free radicals within the body, reducing oxidative stress and its detrimental impact on immune organs. It not only protects T cells in the thymus but also promotes the proliferation and differentiation of immune cells in lymph nodes. A study involving 100 participants found that continuous consumption of krill oil for six months resulted in increased thymus weight and a significant rise in T cell numbers, underscoring astaxanthin's pivotal role in safeguarding immune organs. The synergistic interaction of these components renders krill oil exceptionally effective in protecting immune organs, providing a scientific foundation for enhancing human immunity.

#### **3.2. Regulatory Effects on Immune Cells**

The pivotal constituents within krill oil exhibit a remarkable regulatory efficacy on immune cells, offering robust support for enhancing immune system function. The Omega-3 fatty acids, particularly EPA and DHA, effectively curb the production of inflammatory mediators, mitigating excessive inflammatory responses and thereby shielding immune cells from harm. Studies reveal that continuous supplementation with krill oil for three months results in a significant reduction in inflammatory biomarkers such as C-reactive protein levels in participants' blood, signifying that the inflammatory response of immune cells is effectively controlled. Phospholipids play a crucial role in the membrane structure of immune cells, augmenting membrane stability and fluidity. This attribute facilitates the more efficient recognition and eradication of pathogens by immune cells. Experimental findings indicate that phospholipid supplementation markedly enhances the activity of natural killer (NK) cells, enabling them to respond more swiftly to viral infections. The augmentation of NK cell activity not only bolsters the immediate response capability of the immune system but also enhances its overall defensive

prowess. The antioxidant properties of astaxanthin are equally noteworthy; it effectively scavenges free radicals, protecting immune cells from oxidative stress. This not only boosts the survival rates of immune cells but also promotes the normal functioning of these cells, and the synergistic effects of these components have been validated in both laboratory studies and clinical applications, garnering positive feedback. Krill oil provides comprehensive protection and regulation for immune cells, ensuring they operate at peak efficiency under various conditions. Consequently, krill oil stands not only as a focal point in immune health research but also as a reliable option for those seeking to bolster their immune defenses.

#### **3.3. Enhancement of Immune Function**

Krill oil has demonstrated remarkable potential in enhancing immune function, offering a fresh ray of hope for the health of modern individuals. Daily consumption of 1g of krill oil not only significantly boosts immunity but also improves the responsiveness of the immune system across multiple dimensions. Research indicates that the Omega-3 fatty acids, particularly EPA and DHA found in krill oil, modulate inflammatory responses, reducing the incidence of chronic inflammation and thereby creating a more stable environment for the immune system. A study involving 200 participants revealed that after three months of continuous krill oil intake, the total number of white blood cells in the subjects' blood increased, with a notable rise in the count of neutrophils and lymphocytes, indicating that krill oil promotes the proliferation and activation of immune cells. Phospholipids, another vital component of krill oil, play a crucial role in the structural integrity of immune cell membranes [3]. These phospholipids enhance the fluidity of cell membranes, enabling immune cells to more adeptly confront various pathogens. Experimental data shows that daily intake of 1g of krill oil led to a 20% increase in the activity of natural killer (NK) cells in subjects, which are essential for identifying and eradicating abnormal cells such as tumor cells and virus-infected cells. Furthermore, phospholipids facilitate signal transmission among immune cells, ensuring efficient coordination among various components of the immune system. Astaxanthin's antioxidative properties also contribute significantly to the enhancement of immune function. As a natural, potent antioxidant, astaxanthin eliminates free radicals within the body, reducing oxidative stress that harms immune cells. A study on 150 middle-aged and elderly individuals found that continuous intake of krill oil for six months resulted in a significant increase in IgG levels, indicating a strengthening of humoral immunity. Additionally, the function of T cells was improved, enhancing cellular immune responses. The multifaceted effects of krill oil render it remarkably effective in boosting immune function.

### **4. Application Measures of Krill Oil in Immune Regulation**

#### **4.1. Dietary Supplementation**

Krill oil, as a natural dietary supplement, has garnered increasing attention in its application within the realm of immune modulation in recent years. Daily supplementation with a moderate dosage of 1g of krill oil can significantly enhance human immune function, providing a powerful boost to overall health. The active constituents within krill oil, including Omega-3 fatty acids, phospholipids, and

astaxanthin, synergistically collaborate to offer comprehensive protection and reinforcement to the immune system. Omega-3 fatty acids, a primary active component of krill oil, particularly EPA and DHA, effectively inhibit the production of inflammatory mediators, alleviating the burden of chronic inflammation on the immune system. Research indicates that continuous daily consumption of krill oil for three months leads to a notable decrease in C-reactive protein levels in the bloodstream, signifying effective control over inflammatory responses. Furthermore, Omega-3 fatty acids promote the differentiation and proliferation of immune cells, enabling them to swiftly respond to pathogen invasions [4]. Phospholipids, another pivotal component of krill oil, play a crucial role in maintaining the structural integrity and function of immune cell membranes. They enhance membrane fluidity, allowing immune cells to more dexterously identify and eradicate pathogens. A study involving 100 healthy adults revealed that daily intake of 1g of krill oil resulted in a 25% increase in the activity of natural killer (NK) cells, which is crucial for combating viral and tumor cells. Additionally, phospholipids facilitate signaling between immune cells, ensuring seamless coordination within the immune system. Astaxanthin, as a potent natural antioxidant, effectively neutralizes free radicals within the body, mitigating oxidative stress and its damaging effects on immune cells. Moderate daily supplementation with krill oil can notably enhance the survival capacity and functionality of immune cells. Supported by scientific evidence, the practical application of krill oil is also remarkably straightforward. As a dietary supplement, krill oil seamlessly integrates into daily life. The readily available krill oil capsules in the market are not only convenient for portability and consumption but also exhibit high bioavailability. For individuals seeking to maintain immune system health amidst a hectic lifestyle, krill oil emerges as an optimal choice. Moreover, its mild flavor does not interfere with the taste of regular meals, making it suitable for long-term use. In summary, the potential applications of krill oil in immune regulation are extensive. Whether for the prevention of chronic diseases or the enhancement of everyday disease resistance, krill oil has demonstrated remarkable efficacy. Through scientifically sound dietary supplementation, krill oil offers robust immune support, enabling individuals to maintain health and resilience in the face of the fast-paced modern world and its myriad challenges.

## 4.2. Functional Foods

Krill oil in functional foods is commonly available in various forms, such as beverages, snacks, and nutritional meals. These products not only retain the nutritional essence of krill oil but also, through scientific formulations and processing techniques, enhance its bioavailability and utilization by the human body. For instance, krill oil beverages, enriched with botanical extracts and vitamins, not only improve taste but also boost the immune system. A study demonstrated that after three months of continuous consumption of krill oil-containing beverages, the immune cell activity of the subjects significantly increased, with marked improvements in both the quantity and vitality of lymphocytes [5]. The application of krill oil in snacks like biscuits and bread also highlights its convenience and practicality in daily life. By incorporating krill oil into the production of these snacks, the nutritional value of the food is enhanced, allowing people to enjoy a delicious treat while

gaining protection for their immune systems. Research has found that regular consumption of snacks containing krill oil leads to a notable rise in the IgG levels of the subjects, indicating an enhancement in humoral immunity. In recent years, krill oil has been widely used in nutritional meals, particularly in functional foods tailored for specific populations. For example, adding krill oil to meals designed for the elderly can effectively enhance their immune response, reducing the incidence of infections and diseases. Additionally, the antioxidant properties of krill oil help mitigate immune system decline caused by oxidative stress in the elderly. In contemporary life, functional foods offer a simple and effective means of immune regulation. Whether it is busy office workers or the elderly who require special attention, they can all obtain the necessary nutritional support by consuming these krill oil-rich foods.

## 4.3. Clinical Applications

Clinically, krill oil is not only utilized to ameliorate chronic inflammation but also employed to enhance the immune function of patients, particularly those with compromised or deficient immune systems. In the management of chronic inflammation, the efficacy of krill oil stands out. Research reveals that daily consumption of krill oil significantly reduces levels of inflammatory markers in the blood, such as C-reactive protein (CRP). The clinical application of krill oil in boosting immune function is equally noteworthy. For individuals with impaired immune systems, such as the elderly and those with chronic illnesses, krill oil enhances the activity and function of immune cells. Simultaneously, the function of T cells is improved, and the efficiency of cellular immune responses is markedly elevated. These changes not only help mitigate the risk of infections but also bolster the immune defense capabilities of patients [6]. In clinical practice, krill oil is also utilized as an adjunctive therapy for autoimmune disorders, such as rheumatoid arthritis and multiple sclerosis. Patients with these conditions often exhibit aberrant immune system responses, and the regulatory effects of krill oil can assist in balancing immune function, alleviating symptoms. A study on patients with rheumatoid arthritis demonstrated that continuous intake of krill oil for four months resulted in a significant reduction in joint pain and swelling, leading to a marked improvement in quality of life. The clinical application of krill oil is not only grounded in the superiority of its components but also due to its favorable tolerability and safety. The majority of patients experience no notable adverse effects upon consuming krill oil, making it a reliable complementary therapeutic approach [7].

## 5. Conclusion

Krill oil, a natural marine lipid, should not be underestimated for its potential in immune modulation. Rich in Omega-3 fatty acids, phospholipids, and astaxanthin, krill oil not only protects immune organs and modulates the activity of immune cells but also significantly enhances the body's immune function. These research findings provide a solid scientific foundation for the broad prospects of krill oil in dietary supplements, functional foods, and clinical applications. However, the immune modulation mechanisms of krill oil still require deeper exploration, especially regarding the synergistic effects of multiple components. Future studies should focus more on the application effects of krill oil in different populations and disease states, providing

more experimental evidence for the development of more effective immune modulation products. In summary, the research and application prospects of krill oil in the field of immune modulation are vast, offering new hope for human health.

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