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The Impact of Oral Collagen Supplementation on Joint Function, Muscle Recovery, and Musculoskeletal Health in Athletes: A Narrative Review

Wpływ doustnej suplementacji kolagenem na funkcjonowanie stawów, regenerację mięśni i zdrowie układu mięśniowo-szkieletowego u sportowców: przegląd narracyjny

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Streszczenie

Celem tej pracy przeglądowej jest ocena wpływu doustnej suplementacji kolagenu na funkcję stawów, regenerację mięśni oraz ogólne zdrowie układu mięśniowo-szkieletowego u sportowców. Kolagen, kluczowe białko w organizmie, jest niezbędny dla zdrowia stawów, mięśni i tkanek łącznych. Wraz z wiekiem produkcja kolagenu maleje, co sprawia, że suplementacja staje się obiecującą strategią poprawy wydolności sportowej i zmniejszenia ryzyka kontuzji. Przegląd ten analizuje najnowsze badania opublikowane od 2016 roku, koncentrując się na wpływie suplementacji kolagenu, szczególnie w połączeniu z regularnym treningiem. Badania obejmowały kompleksowe przeszukanie bazy danych MEDLINE, początkowo identyfikując 82 rekordy, z czego 39 poddano ocenie jakości. Ostatecznie 26 badań spełniło kryteria włączenia i zostało uwzględnionych w końcowej analizie. Wyniki wskazują, że peptydy kolagenowe znacznie poprawiają stabilność stawów, redukują ból i przyspieszają regenerację po urazach, takich jak tendinopatia Achillesa. Ponadto, suplementacja kolagenem w połączeniu z treningiem siłowym wykazała lepszą poprawę siły mięśni, składu ciała oraz markerów regeneracji niż sam trening. Przegląd podkreśla również rolę kolagenu w remodelowaniu macierzy zewnątrzkomórkowej oraz odpowiedziach przeciwzapalnych, co może przynieść korzyści w naprawie tkanek i zapobieganiu urazom. Wyniki te sugerują, że suplementacja kolagenem może być cennym dodatkiem do programów treningowych sportowców, co uzasadnia dalsze badania nad optymalizacją strategii dawkowania oraz zrozumieniem mechanizmów jego działania.

Abstract

The purpose of this review is to evaluate the effects of oral collagen supplementation on joint function, muscle recovery, and overall musculoskeletal health in athletes. Collagen, a key protein in the body, is essential for the health of joints, muscles, and connective tissues. As

collagen production declines with age, supplementation has become a promising strategy for improving athletic performance and reducing injury risk. This review analysed recent studies published from 2016 onwards, focusing on the impact of collagen supplementation, particularly in combination with regular training. The research involved a comprehensive literature search in the MEDLINE database, initially identifying 82 records, with 39 undergoing quality assessment. Ultimately, 26 studies met the inclusion criteria and were included in the final analysis. The findings indicate that collagen peptides significantly enhance joint stability, reduce pain, and accelerate recovery from injuries such as Achilles tendinopathy. Moreover, collagen supplementation combined with resistance training was shown to improve muscle strength, body composition, and recovery markers more effectively than training alone. The review also highlights collagen's role in extracellular matrix remodelling and anti-inflammatory responses, offering potential benefits in tissue repair and injury prevention. These results suggest that collagen supplementation could be a valuable addition to athletes' training regimens, warranting further research to optimize dosing strategies and explore its mechanisms of action.

Introduction

Collagen is a crucial protein produced by the human body, primarily composed of the amino acids glycine (33%), proline, and hydroxyproline (22%) [1–4]. Nearly 28 types of collagen have been identified, with type I being the most prevalent, found in the skin, bones, teeth, tendons, ligaments, and vascular ligaments [1,2,5]. Type II collagen is present in cartilage, while type III is commonly found in the skin, muscles, and blood vessels [1]. Type IV is located in the basement membrane and basal lamina that separate epithelial tissues [1]. Type V is a major component of the cell surface and placenta [1].

As the main component of the extracellular matrix (ECM), collagen is essential for maintaining this tissue's strength, regulation, and regeneration. It also makes up approximately 65-80% of the dry weight of tendons, where collagen crosslinks help the tendon structure withstand resistance from high-impact stresses and shear forces [2].

The body's collagen production begins to decline between the ages of 18-29, with an estimated annual loss of about 1% after the age of 40 [1,5]. Factors such as free radicals, poor diet, smoking, alcoholism, and disease can exacerbate this loss [1]. Collagen's role in the body is vital for organ growth, wound and tissue healing, and the repair of the cornea, gums, and scalp [1,2,5]. It also assists in the repair of bones and blood vessels and is involved in essential

cellular functions such as proliferation, cell survival, and differentiation [1,5]. This widespread presence throughout the human body underscores its importance [1,2,4].

This review aims to examine and synthesize the existing literature on the effects of oral collagen supplementation on joint function, muscle recovery, and overall musculoskeletal health in athletes. By analysing recent studies, this review aims to provide a comprehensive overview of how collagen supplementation, particularly when combined with regular training, can enhance athletic performance, support tissue repair, and prevent injuries. The findings will help to identify potential benefits, optimal dosing strategies, and the specific mechanisms by which collagen peptides influence musculoskeletal health in athletic populations.

Materials and methods

We conducted a literature search on the MEDLINE database in August 2024, utilizing keywords including 'collagen', supplementation', ‘athlete', and 'sport' to identify pertinent documents. Initially, 82 records were identified, of which 39 underwent quality assessment. The search focused on articles published from 2016 onwards. Ultimately, 26 studies met the inclusion criteria. Articles not related to the topic of the study, non-English language publications, or those without full-text availability were excluded from the analysis.

Collagen sources

Native collagen can be sourced from various materials, with bovine sources being the most common due to their availability and biocompatibility [1]. Collagen is typically extracted from tissues such as bone, tendons, lung tissue, and connective tissue [1]. Another frequent source is porcine by-products, which yield collagen very similar to human collagen [1]. Its widespread use, including tendon reinforcement, hernia repair, and skin and wound healing in plastic and reconstructive surgery, is facilitated by the absence of allergic restrictions [1].

Alternative sources of native collagen that are not derived from bovine or porcine origins have also been developed [1]. These include sheep tendons and hides, fish tissues like bones, skin, and scales, as well as by-products from chicken, duck, rabbit, or fish skin [1].

Traditionally, collagen is sourced from animal bones and cartilage. However, vegan and vegetarian alternatives are now being produced using genetically modified yeast and bacteria, making collagen accessible to a wider audience [2].

Indication

We can identify several general indications for collagen supplementation, which are outlined below:

Osteoporosis

Osteoporosis is characterized by a reduction in bone mass and deterioration of the structural integrity of bones, leading to increased fragility and fracture risk. This condition predominantly affects older women, as reduced postmenopausal estrogen production accelerates bone loss [6]. Collagen intake has been demonstrated to support bone repair [1].

Osteoarthritis

Knee pain in osteoarthritis patients is partly due to collagen disruption [6].

Post-surgery

Collagen may aid in recovery, particularly of the skin and scars, following procedures like arthroscopy or hip replacement. It significantly benefits the hip area and improves biomechanical properties [7].

The Elderly

Elderly individuals often suffer from degenerative joint diseases, with predominant issues being rest pain and limited joint mobility [4].

Athletes

Athletes, who subject their knee joints to significant stress through intensive sports activities, often take collagen supplements [4].

Effects of collagen supplementation on joint function and recovery from joint injuries in athletes

Tendons and ligaments are crucial components of the musculoskeletal system, essential for maintaining joint mobility and stability [9]. Collagen peptide supplementation has emerged as a promising strategy for enhancing the structure and function of these tissues, potentially offering relief from stress-related joint issues [9]. The recent clinical trial by Shaw et al. demonstrated that collagen peptide supplementation boosts collagen biosynthesis, which could play a vital role in injury prevention and tissue repair [4]. In a study by Zdziebik D. et al., a 12-week regimen of collagen peptide supplementation led to significant improvements in joint stability, reduced activity-related joint discomfort, and decreased reliance on alternative pain management therapies [4,9].

The positive impact of collagen on joint function, including extended pain-free physical activity and faster recovery, especially from Achilles tendinopathy and in the knee extension

range, has been corroborated by other research [4,9,10]. Furthermore, Dressler et al. reported that young athletes who supplemented with collagen showed improved ankle function and a lower incidence of recurrent ankle injuries after suffering from chronic ankle instability [3,11].

Effects of collagen supplementation on muscle soreness and regeneration in athletes

Given that human tendons are composed of 60–85% collagen, supplementing with collagen peptides may be a promising strategy for enhancing tendo-muscular properties [3]. Collagen's significant impact on tendon tissue suggests that it could enhance the tendons' reactive power, particularly when combined with exercise [12]. Centner C. et al.'s study found that high-load exercise combined with CP supplementation significantly upregulated myocellular pathways, increasing gene expression signalling of anabolic pathways in human skeletal muscle [4,12].

The higher bioavailability of collagen peptides could facilitate the development of an amino acid pool, supporting connective tissue regeneration through fibrocytes [4]. Studies involving groups of individuals taking specific collagen peptides (SCP) reveal a greater capacity for muscle regeneration, reflected in notable improvements in biomechanical parameters such as maximum voluntary contraction and rate of force development, with recovery occurring significantly faster at each measurement point [4,13]. Bischof K. et al., study showed that prolonged SCP intake reduced cell damage markers and positively impacted muscle stress response and early-phase muscle recovery [14]. Similar findings were described in the Lopez et al. study where it was demonstrated that plasma biomarkers for muscle damage and inflammation were lower in the group supplemented with oral collagen [1].

Moreover, collagen may expedite the protective adaptation known as the 'repeated bout effect,' potentially enhancing musculoskeletal recovery through ECM remodelling [10]. This remodelling, particularly in passive/elastic tissues, was more rapid in the SCP group, leading to increased force output and power production [10,13]. The repeated bout effect (RBE), a recovery-specific concept and complex physiological mechanism not yet fully understood, offers enhanced protection after unaccustomed eccentric exercise [13]. It is believed that the RBE results from neural adaptations, ECM remodelling, and changes at the muscle-tendon junction, especially after supplementation [13,14].

Effects of collagen supplementation on reducing pain in athletes

A possible explanation for the reduction in joint pain is that the oral collagen supplementation can stimulate primary fibroblasts to synthesize essential components of the ECM, including type I, II, and IV collagen, proteoglycan, and elastin synthesis in the articular cartilage [5,10,14–17]. This effect may counteract cartilage wear and tear, aiding in the repair of micro-injuries, reducing tissue damage and results in alleviating pain [17]. Additionally, collagen peptides may have anti-inflammatory properties, with glycine playing a role in inhibiting the release of pro-inflammatory cytokines [10,11,14]. Glycine is also known to enhance collagen matrix strength and influence tenocyte metabolism in tendons [10,11].

In Zdzieblik D. et al.'s study involving a young, physically active population, twelve weeks of daily SCP supplementation significantly reduced knee joint pain compared to the placebo group [9,15,17,18]. In addition, positive effects of hydrolyzed collagen supplementation have also been observed in the recovery from Achilles tendinopathy, with significant improvements in pain, daily function, and physical activity [9,15–21]. Moreover, oral administration of collagen led to a significant increase in the cross-sectional area of the Achilles tendon, alongside adaptations that improved patellar tendon morphology which makes it a promising option for treating joint pain induced by physical stress [5,17,20,21].

Oral collagen supplementation combined with training

Recent studies have highlighted the positive effects of SCP supplementation combined with long-term resistance training on body composition, muscle mass, and muscle strength across various populations, including both men and women of different ages [22,23]. Individuals in the collagen-supplemented group exhibited a significantly higher number of upregulated proteins and more pathways associated with resistance exercise indicating stronger effects from the combination of strength training and supplementation on the skeletal muscle proteome than from strength training alone [22]. Notably, resistance training paired with SCP supplementation has shown a significantly higher upregulation of key anabolic pathways in human skeletal muscle, significantly improved markers of recovery, and reactive strength [4,10,12,13,15,17,22,24]. This moderating effect is likely due to increased blood flow and the enhanced delivery of amino acids and bioactive peptides to connective tissues during exercise, which are otherwise poorly vascularized and supports muscular adaptations by facilitating the remodelling of the ECM [10,13,15,22,24] . Furthermore, particularly when paired with vitamin C, seems to aid collagen synthesis in athletes [9,10,25].

Fat-free mass plays a crucial role as a primary determinant of resting metabolic rate [3]. The supplementary intake of SCP following endurance training appears to further enhance the benefits of training and lead to a significant increase in fat-free mass and muscular endurance [3,21–23]. These results were shown in Jerger S. et al.'s study of recreationally active women compared to a control group and reported by Zdzieblik D. et al. [10,21–23]. Additionally, Praet et al. demonstrated that daily collagen supplementation, combined with calf-strengthening exercises, facilitated a quicker return to running for athletes suffering from Achilles tendinopathy [10,18].

Conclusions

This study highlights the significant benefits of oral collagen supplementation for athletes, particularly in improving joint function, accelerating injury recovery, and enhancing overall musculoskeletal health [3,4,9,10]. When combined with regular training, collagen peptides support tendon and ligament health, aid muscle regeneration, and reduce exercise-induced muscle soreness [9]. The supplementation has shown promising results in reducing joint pain and preventing injury recurrence, particularly in athletes experiencing chronic conditions such as Achilles tendinopathy [3,9,13,16,17]. The supplementation has also shown promise in reducing joint pain and preventing injury recurrence, especially in chronic conditions like Achilles tendinopathy [9,15,17,19,26]. These findings suggest collagen supplementation could be a valuable addition to athletic training regimens, offering enhanced tissue repair, injury prevention, and improved performance. Future research should focus on the mechanisms of collagen's effects and optimal dosing strategies for different athletes.

Author's contribution

Conceptualization: JM and JG; methodology: JM and JG; check: JM and JG; formal analysis: JM and JG; investigation: JM; resources: JM, JG, AS, PG, MD, OD and DM; data curation: JG; writing-rough preparation: JM, JG, AS, PG, MD, OD and DM; writing-review and editing: JM, JG, AS, PG, MD, OD and DM; visualization: JM and JG; supervision: JM and JG.

Legend: JM - Julia Mężyk, JG - Joanna Gołda, AS - Aleksandra Snopkowska, PG -Piotr Gacka, MD – Marcin Dołęga, OD – Olgierd Dróżdż, DM – Dominika Musialska

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