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Features of the flexor retinaculum and its individual variation in carpal tunnel syndrome predisposition - a systematic review

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Abstract

The flexor retinaculum is a structure located in the wrist, which spreads between the bones forming the carpal tunnel. Its task is to maintain the relative stabilization and protection of incorporated structures. It is also an attachment for the thenar muscles, causing biomechanical interactions in the wrist. Pathologies occurring in the carpal tunnel structures often cause pressure increase, leading to compression of the median nerve, causing carpal tunnel syndrome (CTS). This work aims to review literature knowledge and compile research outcomes in the PubMED and Google scholar databases.

The results indicate the variability in size and aspects of flexor retinaculum due to gender, and the relationship between gender and the incidence of CTS. The data also show the flexor retinaculum's molecular variability and environmental factors' potential impact on these changes. This article demonstrates how anatomical conditions and physical features influence CTS development.

Running title: Flexor retinaculum and carpal tunnel syndrome

Keywords: carpal tunnel syndrome, CTS, flexor retinaculum, manual therapy

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Introduction

The flexor retinaculum (FR) is an extension of the fascia of the forearm flexors [1]. It is a fibrous band that closes the carpal groove. The flexor muscles of the forearm, the median nerve and the vessels of the radial side of the wrist are localized in its proximity [2]. Its attachment points are located on the carpal bones: the palmar surface of the scaphoid, trapezius, pisiform and hook of the hamate [3]. The authors divide the structure into superficial and deep parts, separated by the tendon of the radial flexor muscle [3]. There is also a division into proximal, middle and distal portions, differing in thickness and the arrangement of connective tissue fibres. The transverse carpal ligament (TCL) is the thickest segment of the middle portion, separated by a layer of adipocytes [1]. There is no agreement between the authors regarding standard nomenclature. The name FR is often used interchangeably with TCL, so this term will also be unified for easier understanding of the work.

The mesoderm-derived collagen tissue is the main component that builds the structure of the retinaculum. Most of the fibers building the texture of the described structure are directed transversely [4]. The variability of the structure and the fiber arrangement will be presented later.

FR is also related to important biomechanical functions. First, the formation of a trochlea system for the forearm muscles' tendons, along with carpal tunnel stabilization [5]. It is also the attachment of the muscles of the palmar side of the hand (thenar and hypothenar eminences muscles), thus ensuring the biomechanical interactions of these structures [6]. It ultimately constitutes a protective layer for the carpal tunnel contents.

Compressive neuropathy, pain and tingling resulting from pressure on the median nerve in the carpal tunnel are most commonly observed. This histological feature is a non-inflammatory thickening of the synovial connective tissue. The hypothesis states that the injuries resulting from repetitive movements and ageing contribute to carpal tunnel syndrome (CTS) [6]. It can be assumed that hypertrophy, stiffening, increased pressure in the wrist canal and increased volume of the canal content lead to changes in the structure of tissues such as TCL. [6]. Other sources indicate the anthropometric values of the hand and wrist as a factor predisposing to CTS [7].

Additionally, obesity, diabetes and other metabolic disorders can lead to CTS [3]. Gender differences in the incidence of CTS also have been proved. Women are more likely to suffer from the disease, which is explained by the anatomical differences between genders [8].

This study aims to present the current knowledge regarding the differences in the flexor retinaculum's structure and to consider the potential impact of anatomical and biomechanical changes on the likelihood of developing CTS.

Materials and methods

Presented information was organized based on a review of materials collected on the PubMed and Google Scholar databases. Specific keywords were used to perform the research: "Anatomy of the flexor retinaculum", "sexual differentiation of the flexor retinaculum", and "biomechanical differences of the flexor retinaculum".

Results

Variability of the FR in terms of gender

In measurement research, the individual ratio of the TCL length to the arm length was calculated by dividing these values by oneself. A variability, more specifically a correlation, was demonstrated between the proximo-distal length of the flexor retinaculum and the arm's length. This proportion is shorter for women.

Averagely, the length of the flexor retinaculum was 14% for the right arm and 15% for the left arm. Nevertheless, studies show a gender difference [9], which may affect the incidence of CTS in the female population.

It has also been shown that females have a smaller carpal arch than males, as well as a lower distal arch height, resulting in reduced hand flexion and a smaller arch area [10]. Less compliance has also been demonstrated [11]. The authors propose a potential correlation between the width of the wrist, the height of the flexor retinaculum arch, the possibility of compression of the median nerve and the occurrence of CTS.

Variability of FR in terms of physical features: stress modulus in terms of fiber arrangement, flexibility and thickness

When analyzing FR, the structure of collagen fibers, layer thickness, and physical aspects such as flexibility and stiffness cannot be ignored. These marks of connective tissue structure led researchers to establish the elastic modulus of FR.

Arrangement of the collagen fibers

For the connective tissue to acquire its attributes, it needs not only an appropriate composition, type and quality of proteins that build it (i.e., collagen fibers), but also their appropria-

te shape and distribution, and therefore an adequately constructed tissue architecture [4]. This directly translates into the tissue's features and may influence entire segment functioning, especially in biomechanics, where in the case of FR, there is the optimal functioning of the wrist in the appropriate structure of the carpal tunnel.

Four types of fiber arrangement in FR have been described. The authors noticed a tendency to form "lamellae" that followed a characteristic bundled pattern.

The classical division is as follows:

- TYPE I - the most common arrangement of the bundle, distal-transverse and elbow-oblique lamina;
- TYPE II – distal-transverse and oblique--ulnar laminae were visible in the superficial layer, and proximal-transverse and radial-oblique laminae in the deep layer;
- TYPE III - in the superficial layer, distal--transverse and oblique-ulnar laminae and both types of transverse laminae in the deep layer;
- Type IV - had transverse laminae at any depth and no distinct oblique laminae [12].

The presence of fibers without bone connection was also found.

Researchers speculate on the influence of specific weaving and the contribution of various types of plaque architecture to the stabilization and biomechanics of carpal tunnel [13].

Changes in thickness and flexibility

After identifying gender and FA conformation differences, the next step in our considerations is to compare its flexibility, which is determined by the thickness and structure. It was noted that the lamellas with distal transverse shapes were the thickest among all FR types [12].

Characteristic changes in thickness have been observed in patients suffering from CTS [14,15]. Other studies report that the ligament is thicker proximally than distally, and the radial and ulnar segments are thicker than the medial one [16].

When it comes to stiffness, one should consider the adaptability of the connective tissue under the influence of demanding mechanical conditions and forces applied to the tissue [17]. It has been noticed that continuous work and flexed position enhance the ligament's interaction with the flexor tendons, causing an increase in adaptive stiffness. Interestingly, the stiffness was more significant in the radial than in the ulnar part.

These data bring us to the conclusion that the processes that take place in the structure of FR may be biased, and the mechanical aspects may change depending on the location [18].

It should also be expected that mechanical changes resulting from changes in thickness and stiffness may lead to mechanical changes in the entire carpal tunnel, potentially even if the pressure remains unchanged [19].

Stretch response

The biaxial stretching model was used to test the ligament's elasticity because of the pressure in the wrist, which increases in the course of CTS. This pressure may change the geometry of the wrist arch and the ligament itself [20].

A change in the elasticity of the ligament in various locations was demonstrated. Because of that, the need to divide the structure into radial, middle and ulnar parts occured. The studies showed a significantly increased elasticity model in the mediolateral than in the proximo-distal direction. This fact was related to the variations of these fibers, i.e., the dominance of the lamellar system in the medio-lateral direction.

Moreover, an increased stiffness modulus on the ulnar side may be related to additional fibers without bone attachment. Interestingly, the female samples showed greater stiffness [21]. The proximal segment has also been shown to be stiffer than the distal segments, while the center of the ligament had the lowest stiffness [16].

Researchers suggest that the increased incidence of CTS in the female group is associated with greater stiffness, with the risk increasing after menopause [21].

Discussion

Impact of anatomical and histological differences (*as an outcome of gender differences*) on the occurrence of carpal tunnel syndrome

Based on the presented studies, it is possible to conclude a significant influence of the anatomical and histological conditions predisposition to CTS. The authors describe the female gender as predisposed to a greater exposure to CTS [10,11], which may be due to the smaller area of the carpal tunnel, greater structural stiffness [21], lower compliance [19], as well as smaller dimensions of the hand and the canal by itself [9].

On the other hand, data suggest that increased mobility predisposes women to a greater risk of developing CTS. The authors speculate about the influence of increased mobility and frequent position holding on the development

of CT compression and, consequently, the development of CTS [3,7].

The impact of the Body Mass Index (BMI) on the incidence of CTS is also suggested [7,22]. It has been shown that overweight and obese people have a greater predisposition to CTS without differentiation by gender [23]. However, the authors do not indicate its mechanism, suspecting that the adipose tissue increases the pressure inside the wrist. It has also been suggested that metabolic syndromes contribute to neuropathy [24].

As already mentioned, CTS is often observed in postmenopausal women [21]. Other researchers note an increased number of women suffering from CTS correlating with long-term hormonal changes related to pregnancy. They also noted that women suffering from CTS reached menopause earlier [25]. Subsequent studies suggest that hormone therapy may reduce the risk of CTS in postmenopausal [26].

CTS treatment

To treat CTS, orthopedics use the flexor retinaculum intersection to reduce the pressure generated by the stiffening and pathologically changed surface, which acts on the median nerve[27] [15]. However, such surgery action could affect the functioning of the wrist.

Knowing that the function of ligaments is to stabilize and protect the structures inside the tunnel, biomechanical changes seem inevitable. Indeed, the researchers proved that changes in structural mechanics, function and capacity were calculated from the changes in wrist width. Additionally, a complete transection of FR has more benefits than its partial form, which may result in worse structural adaptations [28].

Another form of treatment or support for the effects of this invasive approach is non-invasive physiotherapy. Manual therapy, including neurodynamic techniques, enables pain reduction, and supports conduction (an increase of sensory conduction velocity by 34% after treatment) [29]. However, self-stretching was found to be ineffective [30].

It has also been proven that using manual therapy techniques focusing on the neck and median nerve has similar effects in reducing pain as surgery [31]. Researchers also encourage the use of conservative treatment before surgery [32].

A treatment that is also beneficial but more invasive than classic physiotherapy is dry needling. The effectiveness of that type of therapy has also been proven, specifically concerning the diagnosis of CTS. However, no beneficial effect has been demonstrated in upper limb pain [33], with the technique of dry needling with fascia winding is suggested is such conditions [34]. Furthermore, an important type of therapy commonly used in pain ailments is massage therapy, that significantly reduces symptoms in a short time [35].

Changes in tendon structures caused by massage combined with physical effort have been proven by study results. The changes occur under the influence of mechanical force applied on the cell and cause the expression of genes responsible for angiogenesis and proliferation, leading to regeneration [36,37].

Conclusions

The purpose of the article was to review the literature related to the anatomy and morphology of FR, its variability, and the potential impact of the described differences on the development of Carpal Tunnel Syndrome. The data showed significant gender, structural and physical variance that could correlate with the development of CTS. Research focused on these factors could identify the causes of such a multifactorial phenomenon as the development of CTS. Another crucial task is to determine the impact of physiotherapy and its methods on CTS recovery. Conclusions on this topic could lead to a change in the approach to physiotherapy in connective tissue diseases and to determine the possible molecular impact of a physiotherapeutic stimulus on tissues. Ultimately, a comparison of the retinaculum of a large group of healthy individuals, with little environmental diffrentiator or age variation, with focus on an anthropomorphic measurement, would give an understanding of trends in intact tissues, where only gender can determine the variability.

Ethical approval

The conducted research is not related to either human or animal use.

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Not applicable.

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Conflicts of interest

All authors declare that they have no conflicts of interest.

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