

# Mechanizmy uszkodzenia i regeneracji narządu ruchu

w procesie treningowym - najnowsze  
doniesienia naukowe

Mechanisms of damage and regeneration of the  
musculoskeletal system in the training proces  
- the latest scientific reports

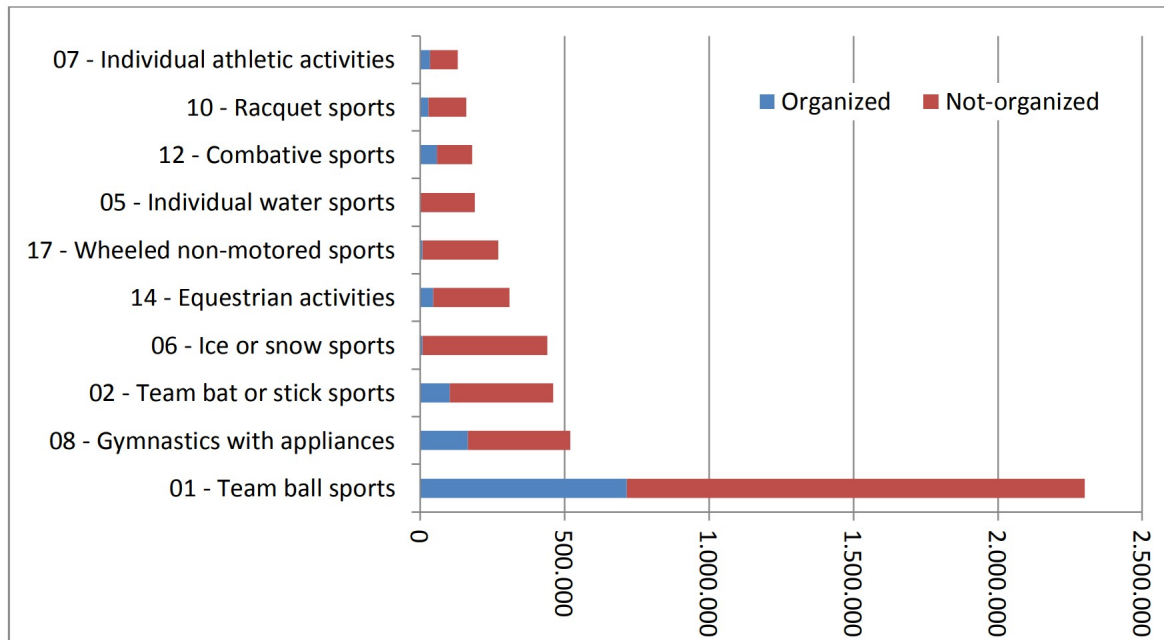
*Assoc. Prof. Michał Dwornik PhD, DO, PT*

*Assoc. Prof. Sebastian Szajkowski PhD, DO, PT*

# Epidemiology of sports injuries in the EU [1]

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Table/figure 9: Estimated number of hospital treated injuries in the EU-27 by organizational framework (from: Bauer & Steiner 2009, figure 13)

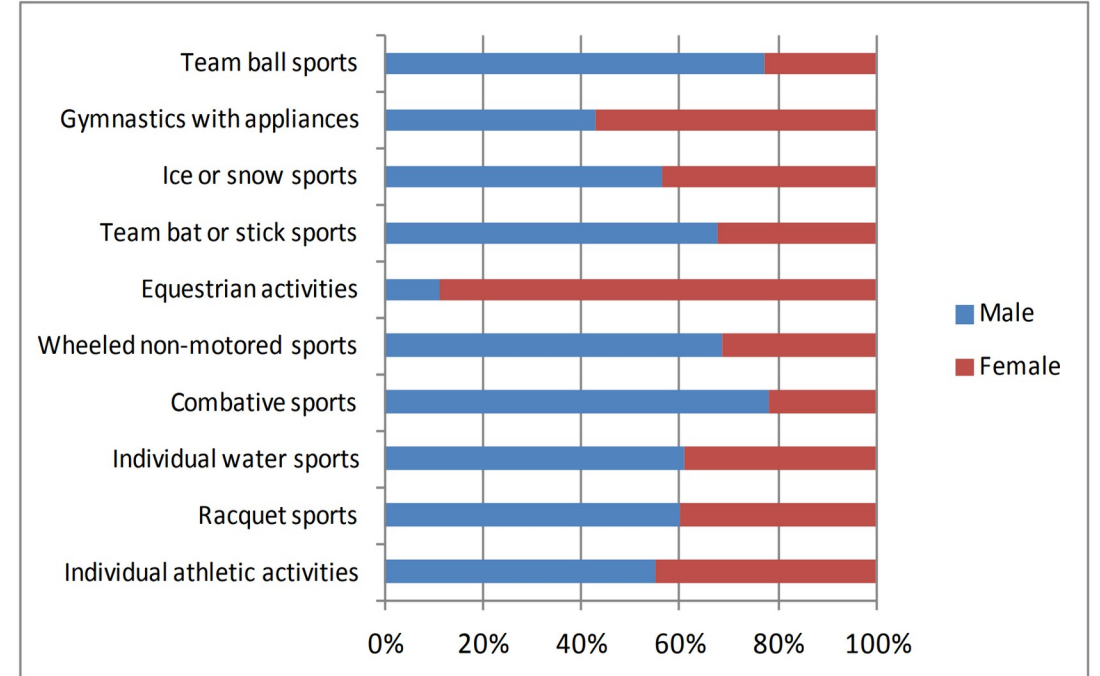
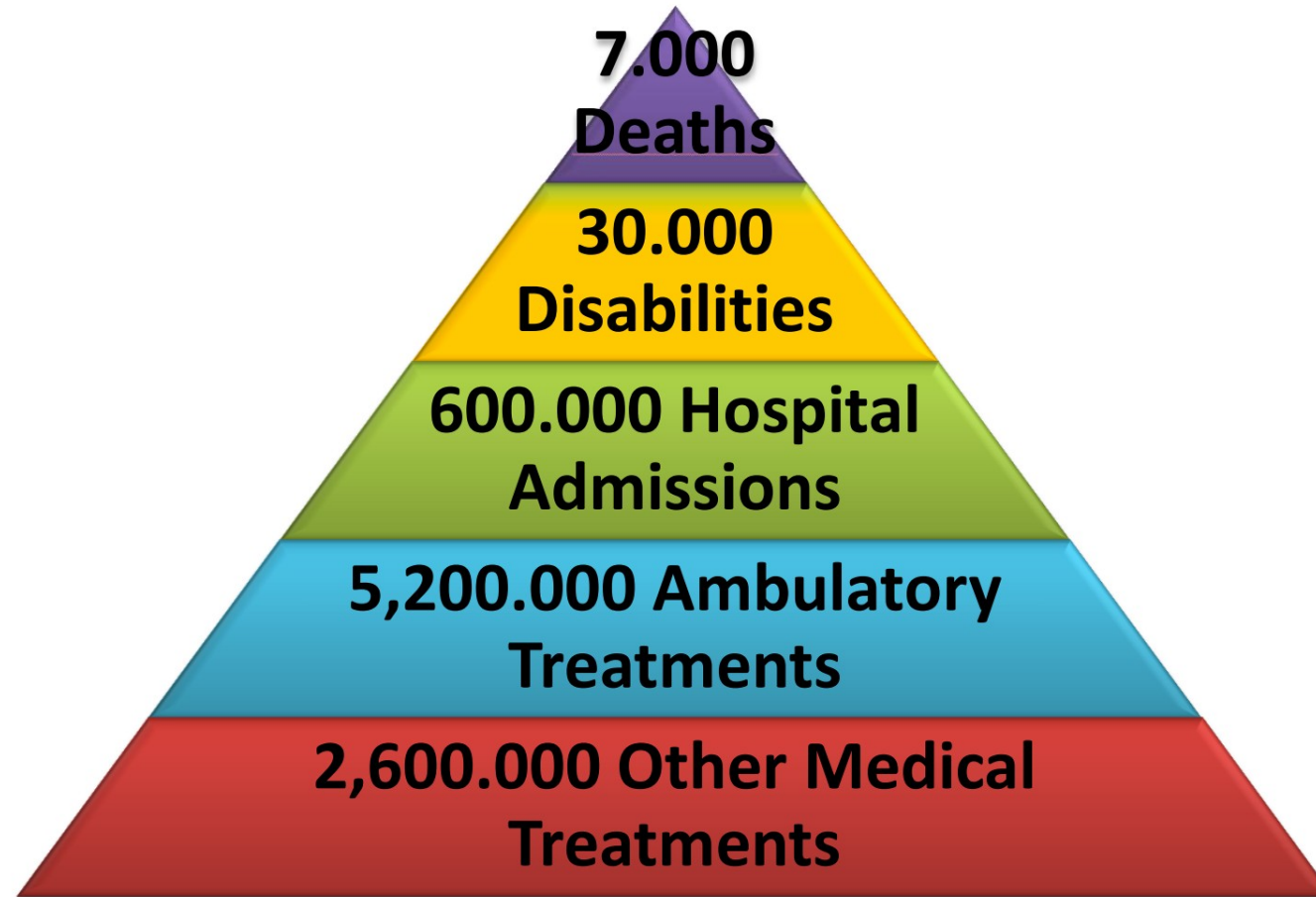


Figure 10: Estimated number of hospital treated injuries in the EU-27 by gender

# Epidemiology of sports injuries in the EU



Table/figure 17: The Sport injury Pyramid for the European Union (EU-27) including disabilities

# Epidemiology of injuries in CrossFit

In all **Systematic Review and Meta-analysis**

CrossFit® training has an injury incidence rate similar to:

weightlifting and powerlifting [1], other common recreational sports [2], olympic weightlifting, distance running, track and field, rugby, football, ice hockey, soccer or gymnastics [3]

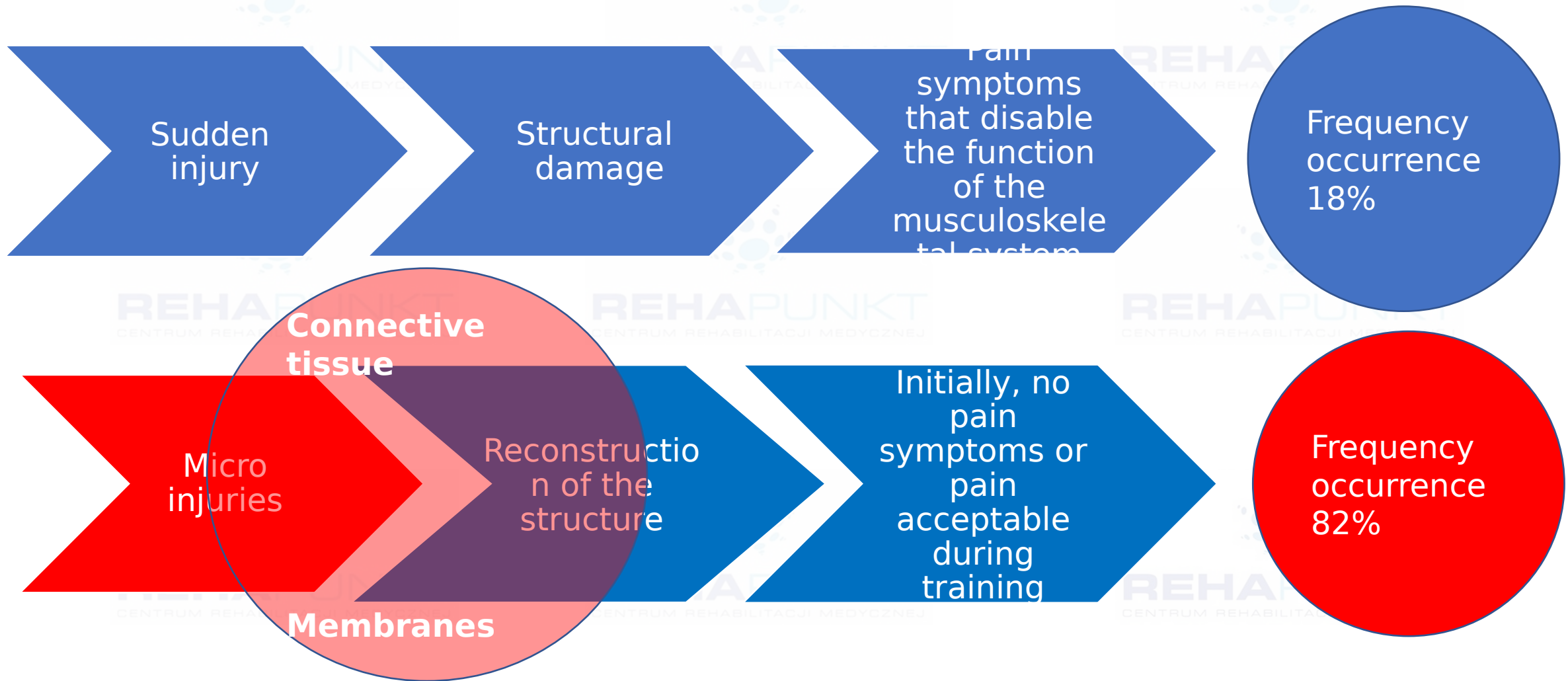
but

**based on 204 scientific publications**

- the number of injuries that affect CrossFit participants varies between 19% and 74%

[4]

# Etiology of musculoskeletal disorders in sport [1]



# Musculoskeletal system - connective tissue

Muscles, tendons and  
fascia

Peripheral nerve fibers

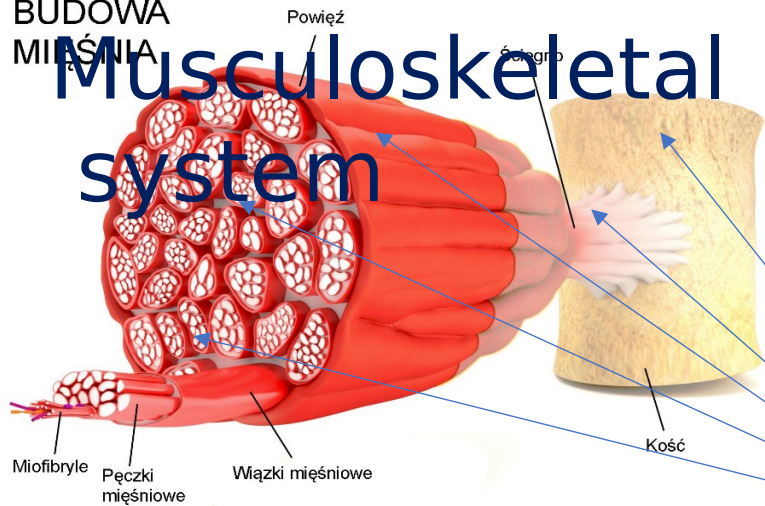
Connective  
tissue

Bone tissue

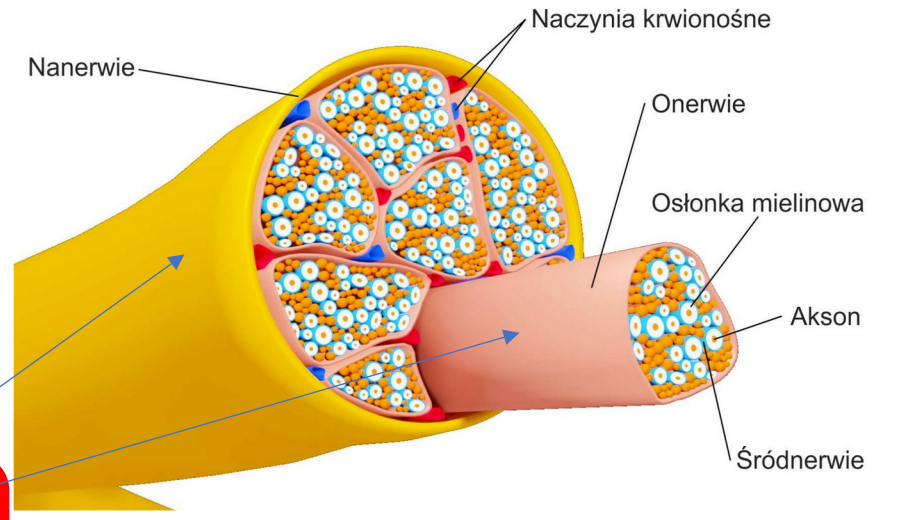
Joint capsule, ligaments  
and intra-articular  
connective tissue  
elements

BUDOWA  
MIĘŚNIA

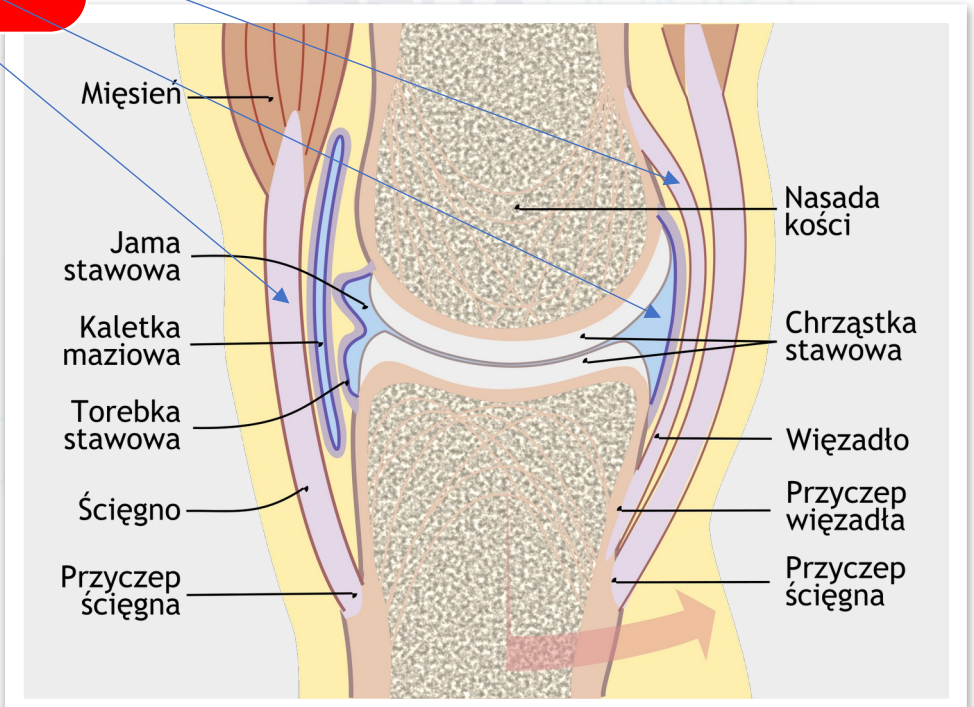
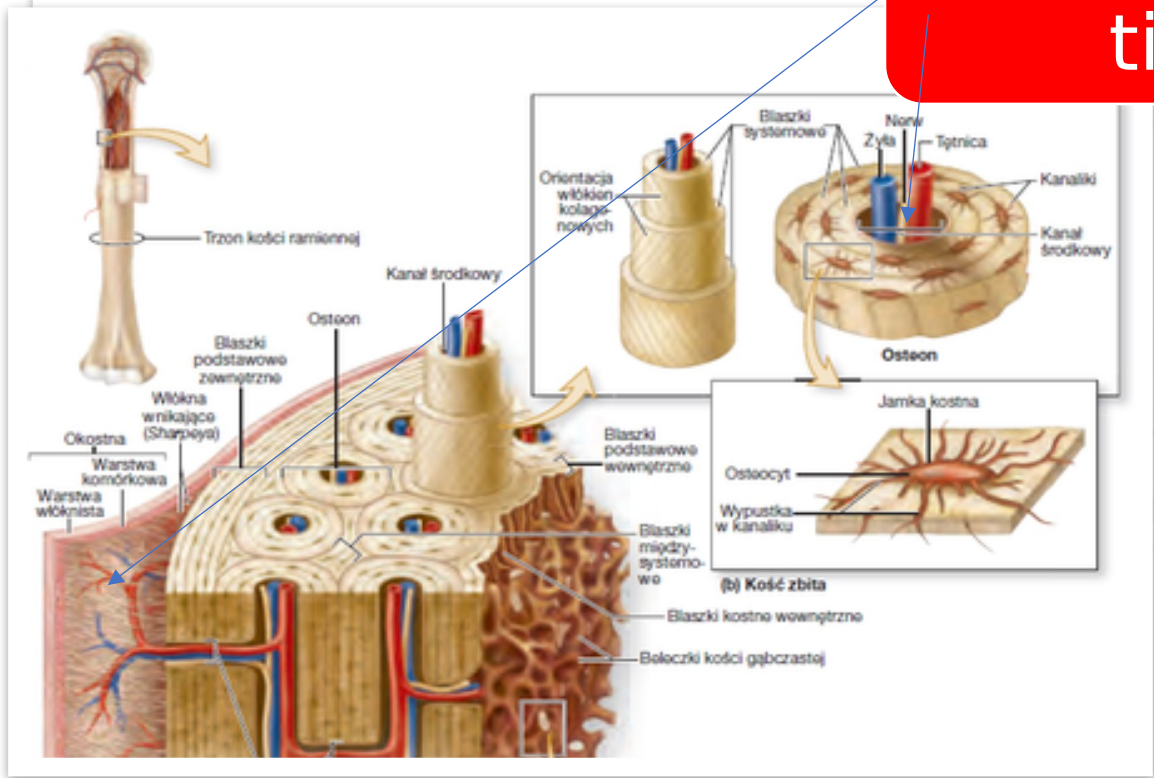
# Musculoskeletal system



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CENTRUM REHABILITACJI MEDYCZNEJ



## Connective tissue



# Etiology of micro-injuries /injuries of the musculoskeletal system - connective tissue

Cumulative specific physical efforts without sufficient rest and recovery

Micro-injuries – most often not visible in imaging examination (MRI, CT, ultrasound, X-ray) – pain symptoms

trauma – the worst case scenario is the summation of micro-injuries, the development of chronic inflammation that creates permanently damaged, weak and non-functional connective tissue – seen in imaging



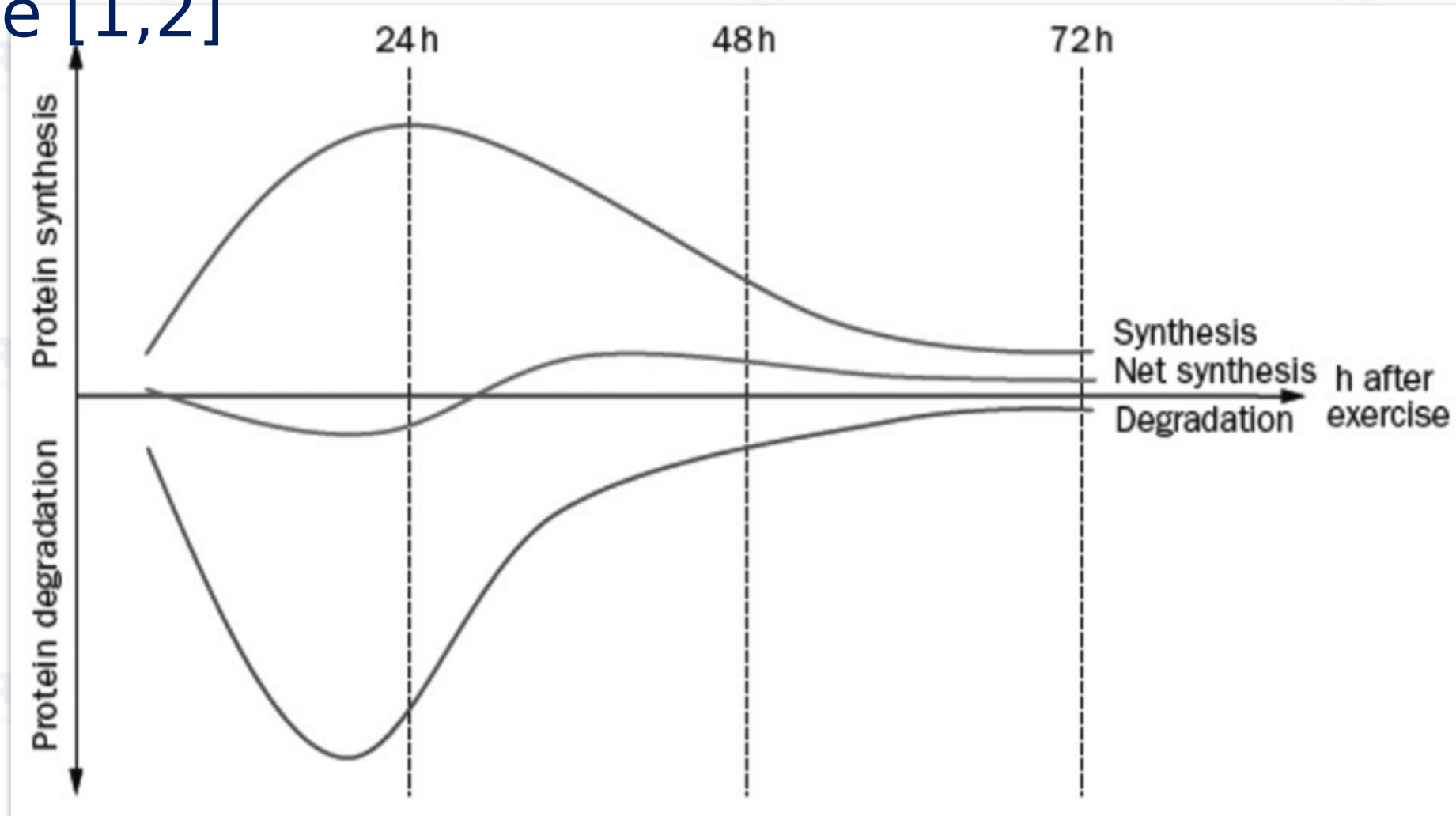
# Etiology of micro-injuries of musculoskeletal system- connective tissue

*Mechanical loading is a factor that can damage the tissues of the musculoskeletal system, but it is also a known external factor regulating the synthesis of the connective tissue structure.*

*Question: what, when, how many and how to load ?*

# Pathogenesis of micro-injuries

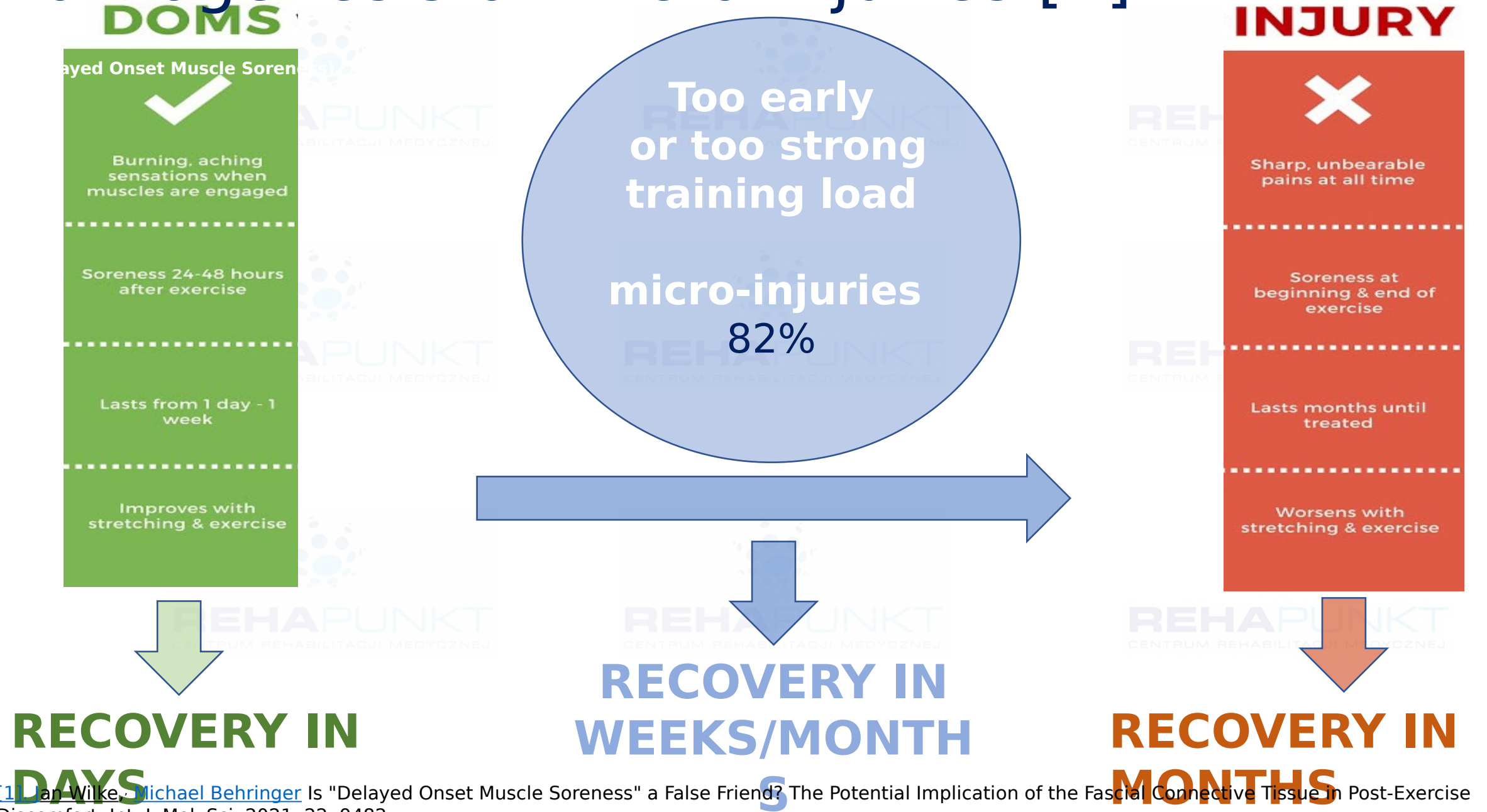
- Synthesis and degradation of collagen after physical exercise [1,2]



[1]. Magnusson SP, Langberg H, Kjaer M. The pathogenesis of tendinopathy: balancing the response to loading. *Nat Rev Rheumatol.* 2010;6(5):262-268.

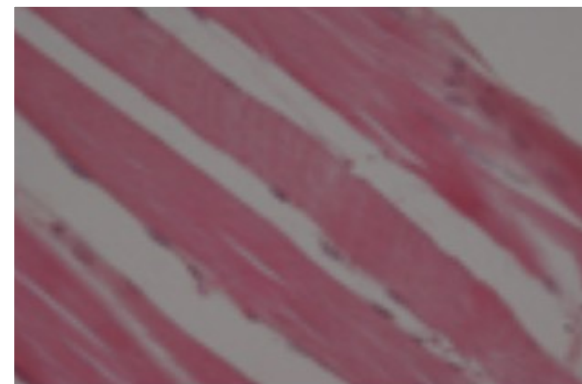
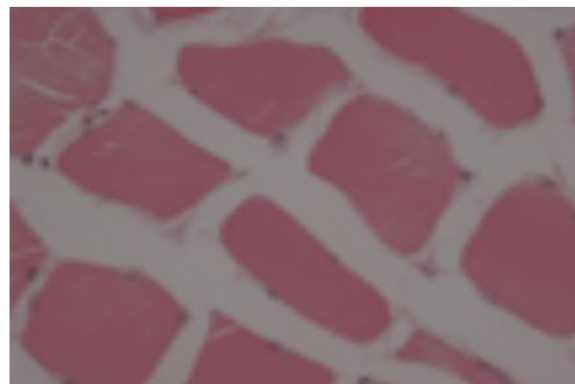
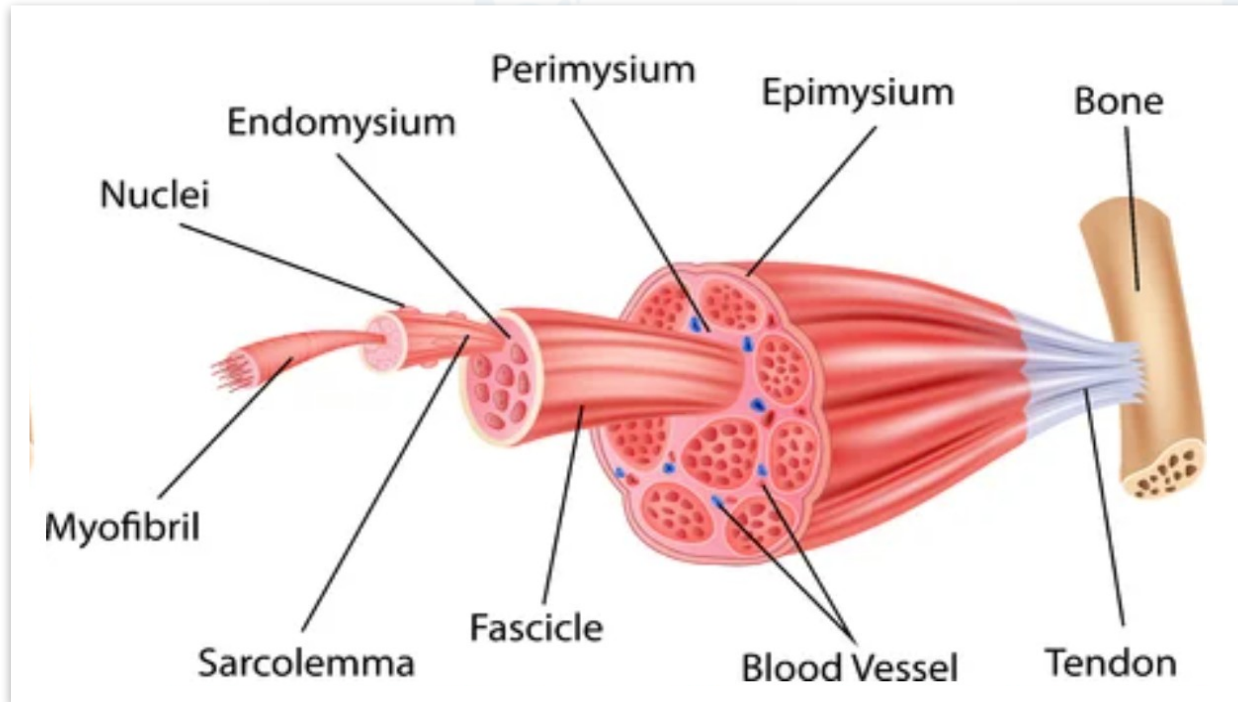
[2]. Ackermann PW, Renström P. Tendinopathy in sport. *Sports Health.* 2012 May;4(3):193-201

# Pathogenesis of micro-injuries [1]

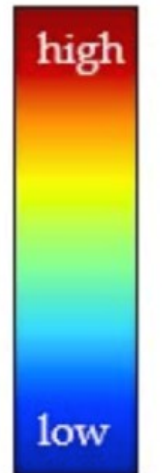
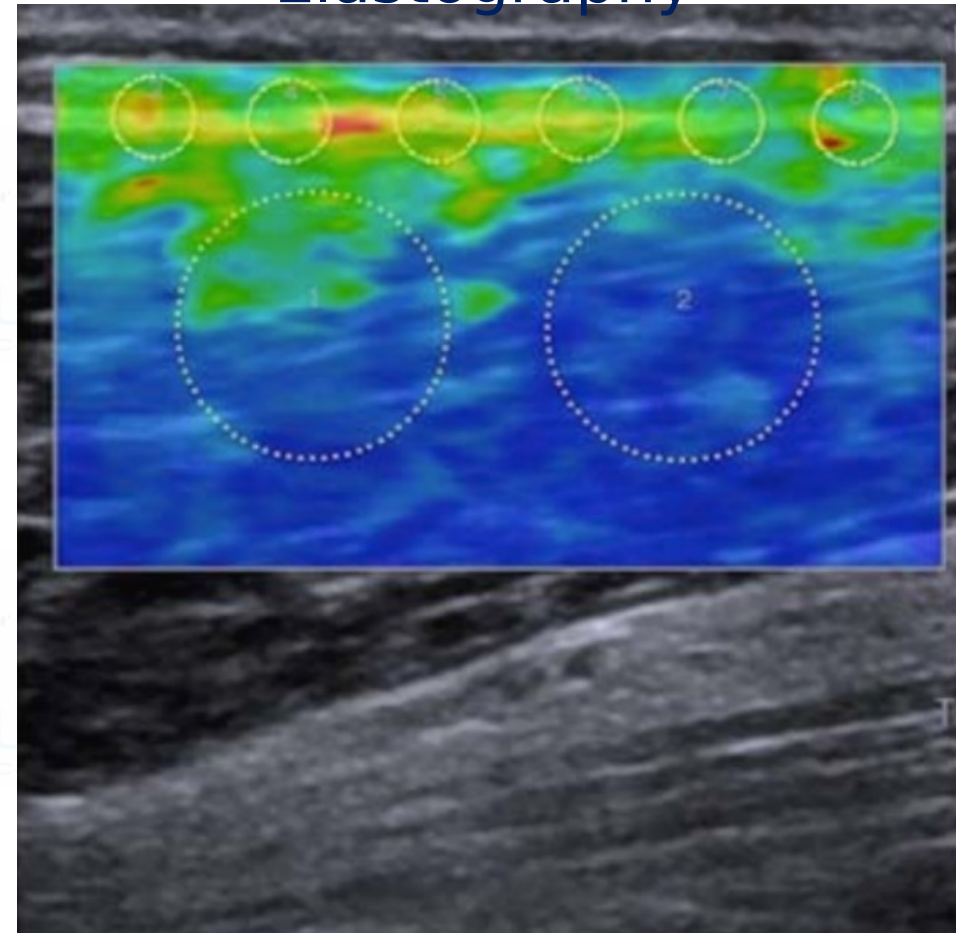


[1] Jan Wilke, Michael Behringer. Is "Delayed Onset Muscle Soreness" a False Friend? The Potential Implication of the Fascial Connective Tissue in Post-Exercise Discomfort. *Int J Mol Sci*. 2021; 22: 2492.

# DOMS (Delayed Onset Muscle Soreness) or DOSS (Delayed Onset Softtissue Stiffness) ? [1]



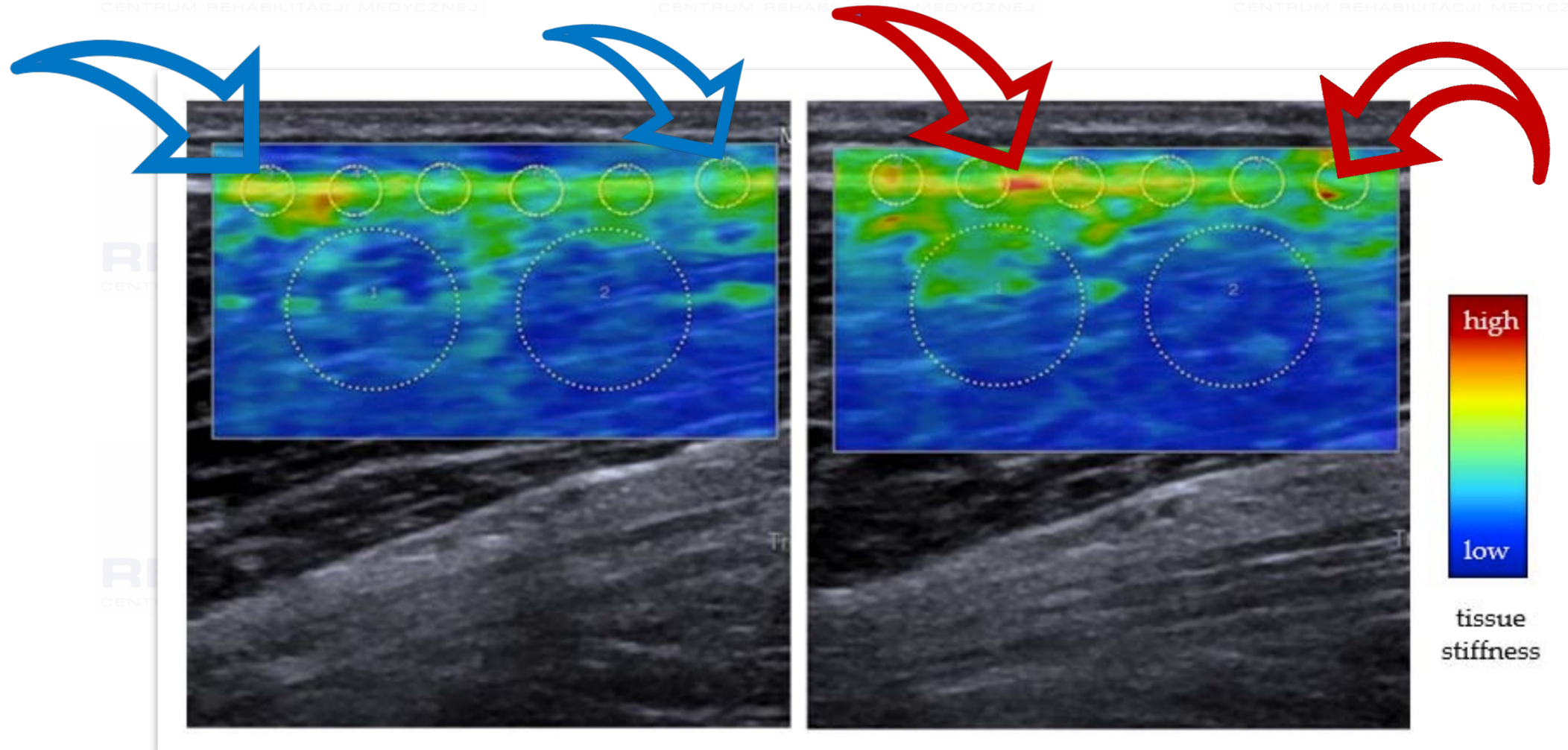
## Ultrasound Elastography



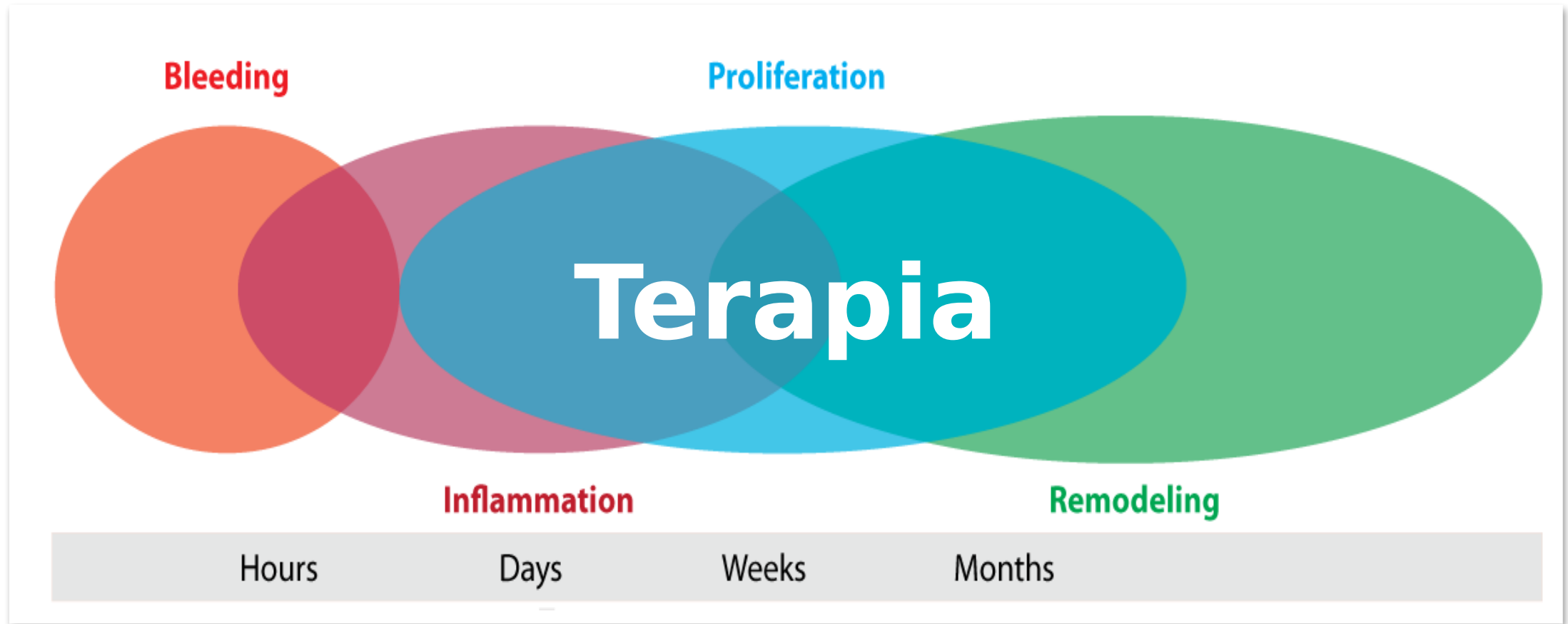
tissue stiffness

# How to diagnose micro-injuries?

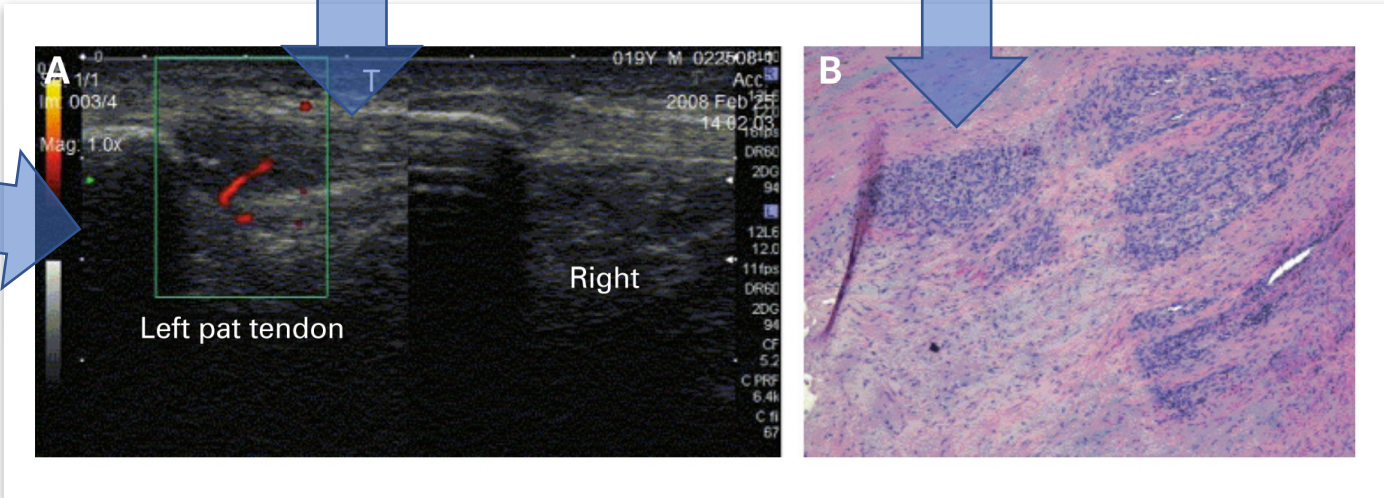
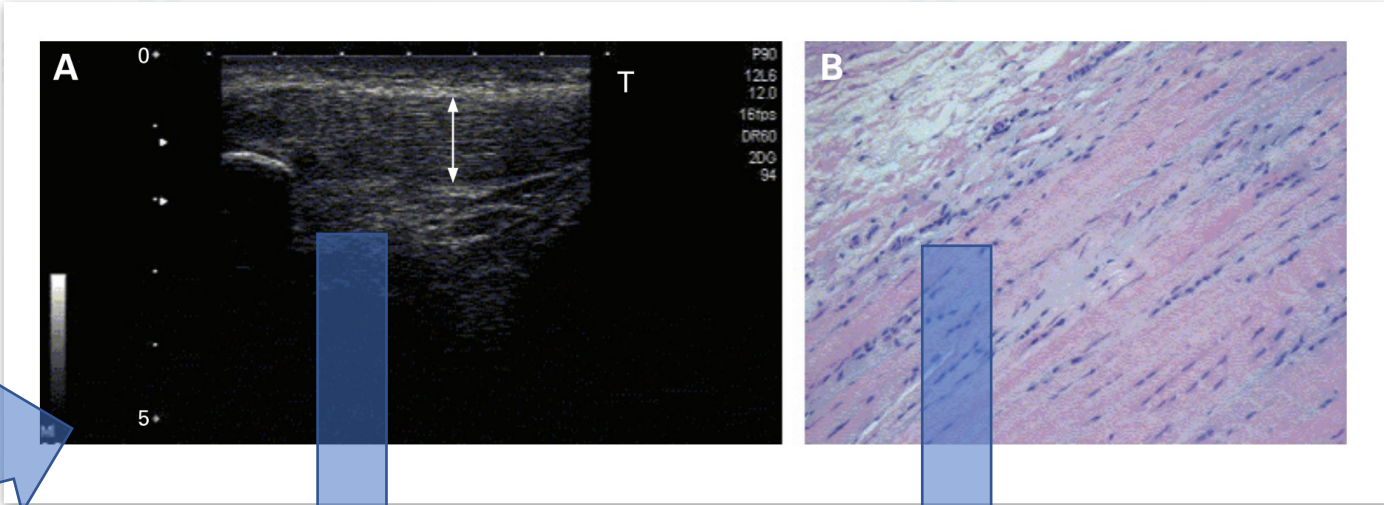
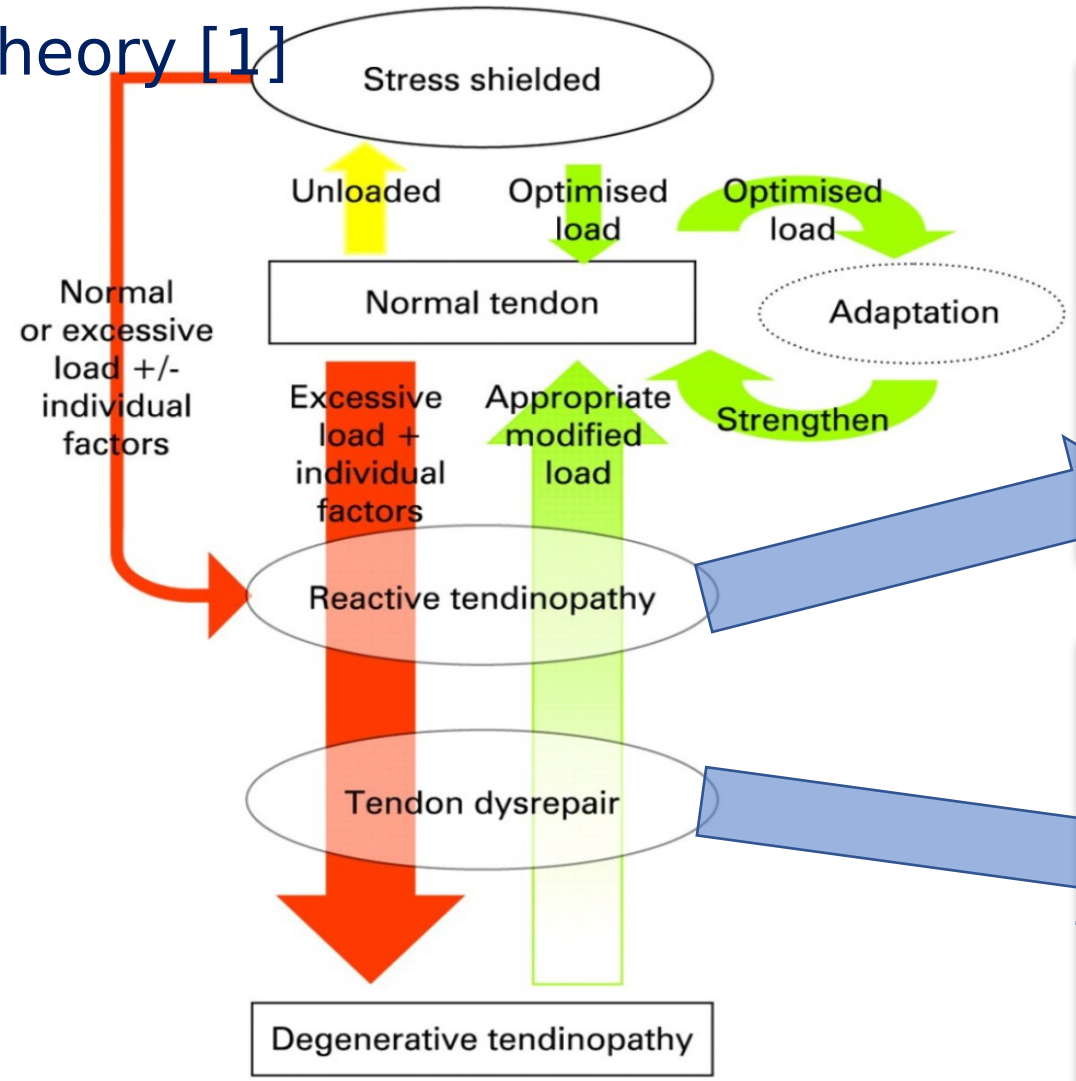
- Ultrasound elastography examination
- DOMS, DOSS → micro-injuries → Damage [1]



# Pathogenesis of micro-injuries - regeneration or reconstruction? [1]

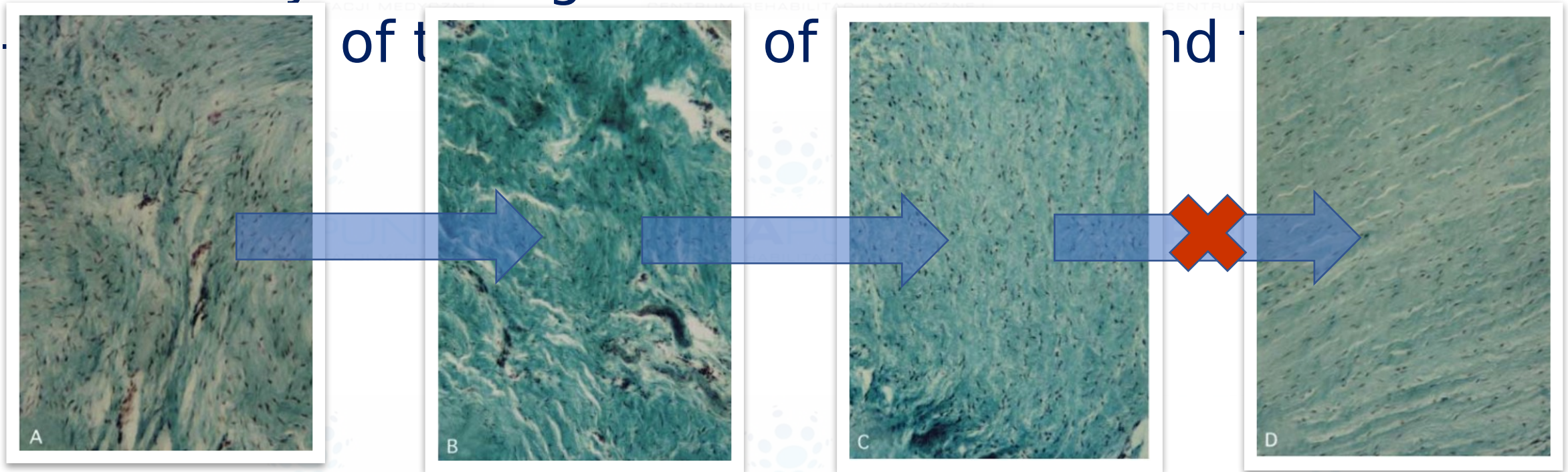


# Pathogenesis of micro-injuries - The farther into the micro-injuries, the more difficult it is to achieve reversibility of changes- 3-step continuum theory [1]



[1]. J L Cook<sup>1</sup>, C R Purdam. Is tendon pathology a continuum? A pathology model to explain the clinical presentation of load-induced tendinopathy. Br J Sports Med 2009;43:409-416.

# Pathogenesis of micro-injuries - The further into the micro-injuries - trauma, the more difficult it is for reversibility of changes



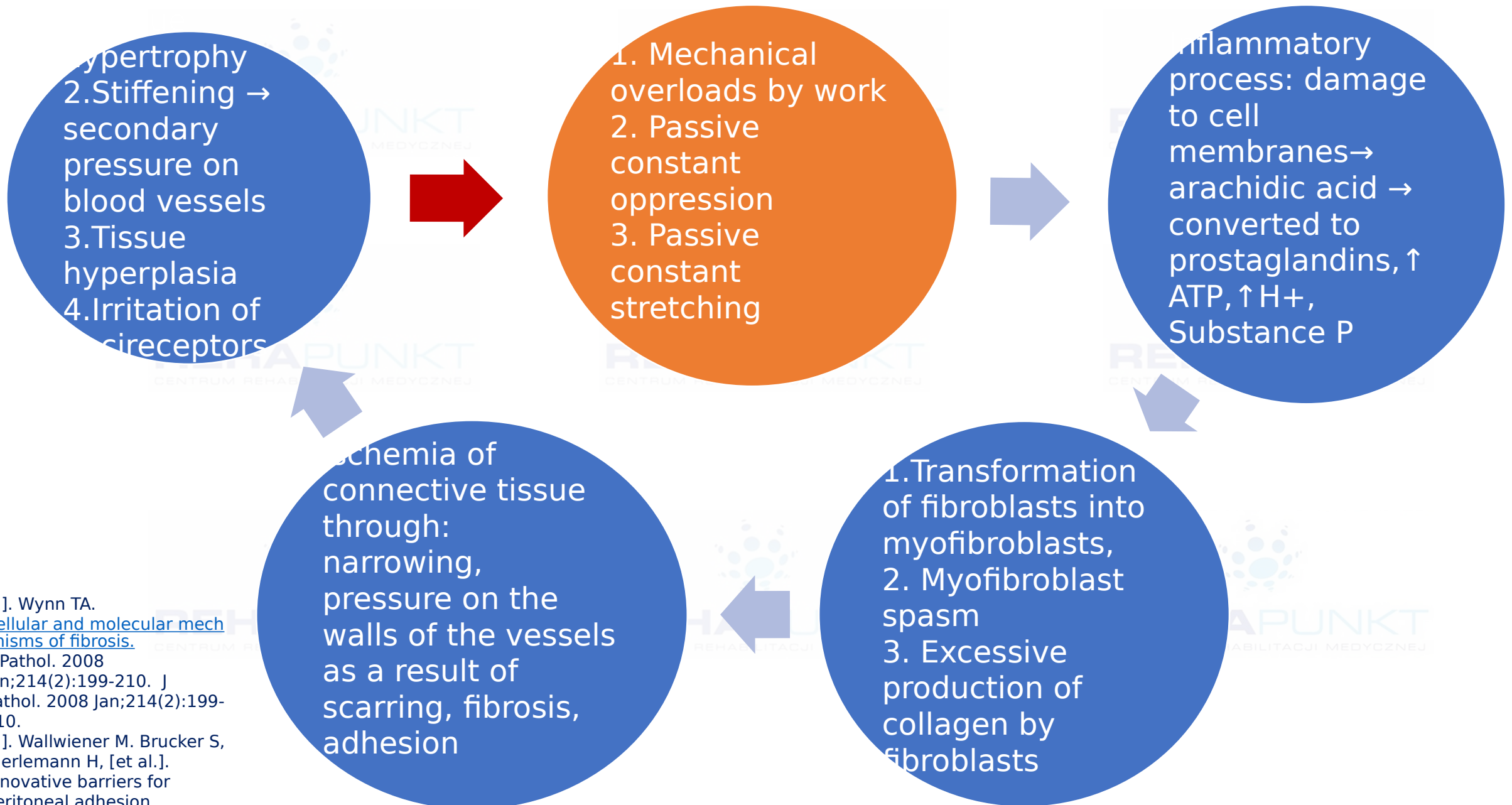
Histology of healed Achilles tendons 3 months (A), 6 months (B), 12 months (C), healthy tissue (D). [2]

[1]. P Sharma [1](#), N Maffulli [1](#) Biology of tendon injury: healing, modeling and remodeling. J Musculoskelet Neuronal Interact 2006; 6(2):181-190

[2]. J Bruns [1](#), J Kampen [1](#), J Kahrs [1](#), W Plitz [1](#). Achilles tendon rupture: experimental results on spontaneous repair in a sheep-model. Knee Surg, Sports Traumatol, Arthrosc (2000) 8 :364-369

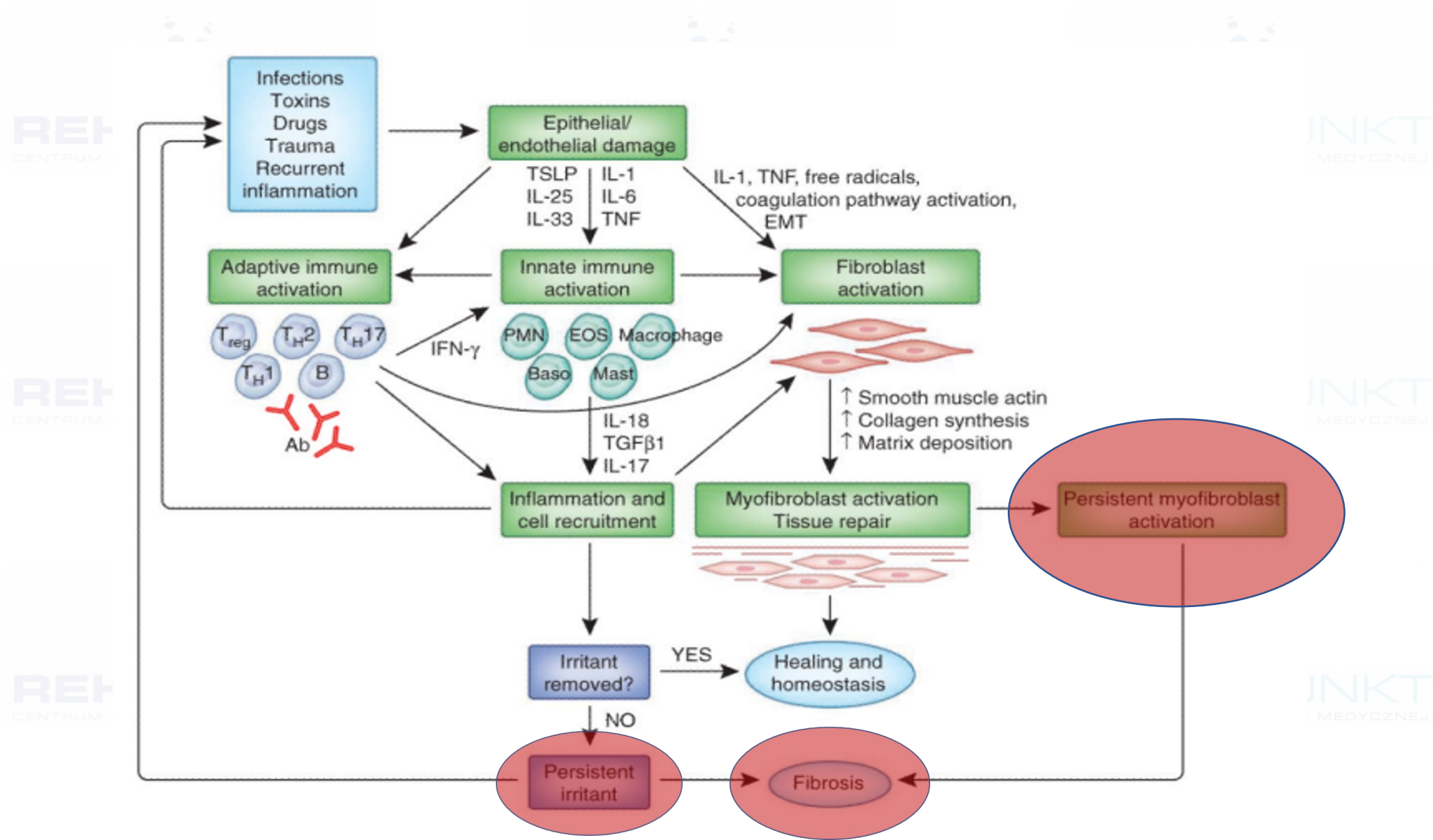


# Pathogenesis of micro-injuries - activation of the ADHESION process [1,2]



[1]. Wynn TA. [Cellular and molecular mechanisms of fibrosis.](#) J Pathol. 2008 Jan;214(2):199-210. J Pathol. 2008 Jan;214(2):199-210.  
[2]. Wallwiener M, Brucker S, Hierlemann H, [et al.]. Innovative barriers for peritoneal adhesion

# Pathogenesis of micro-injuries - continuous overloads



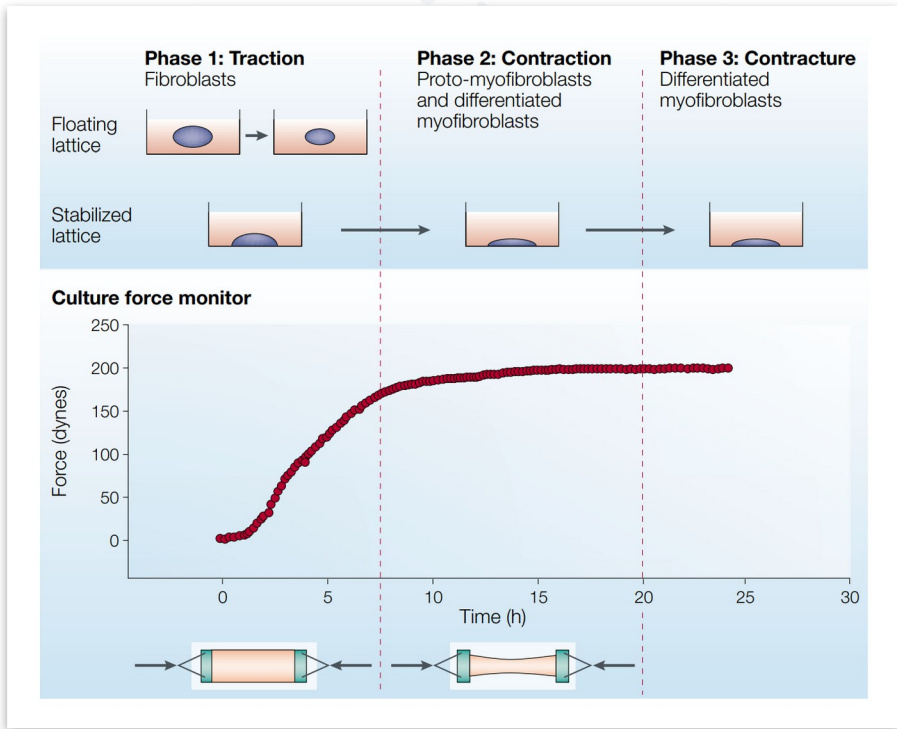
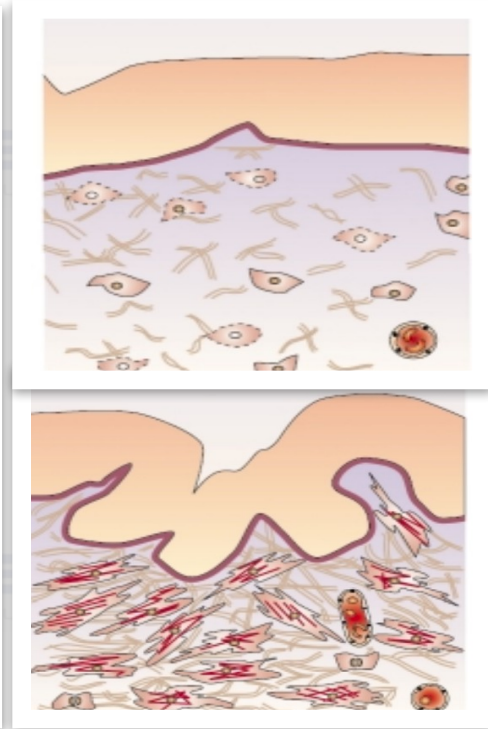
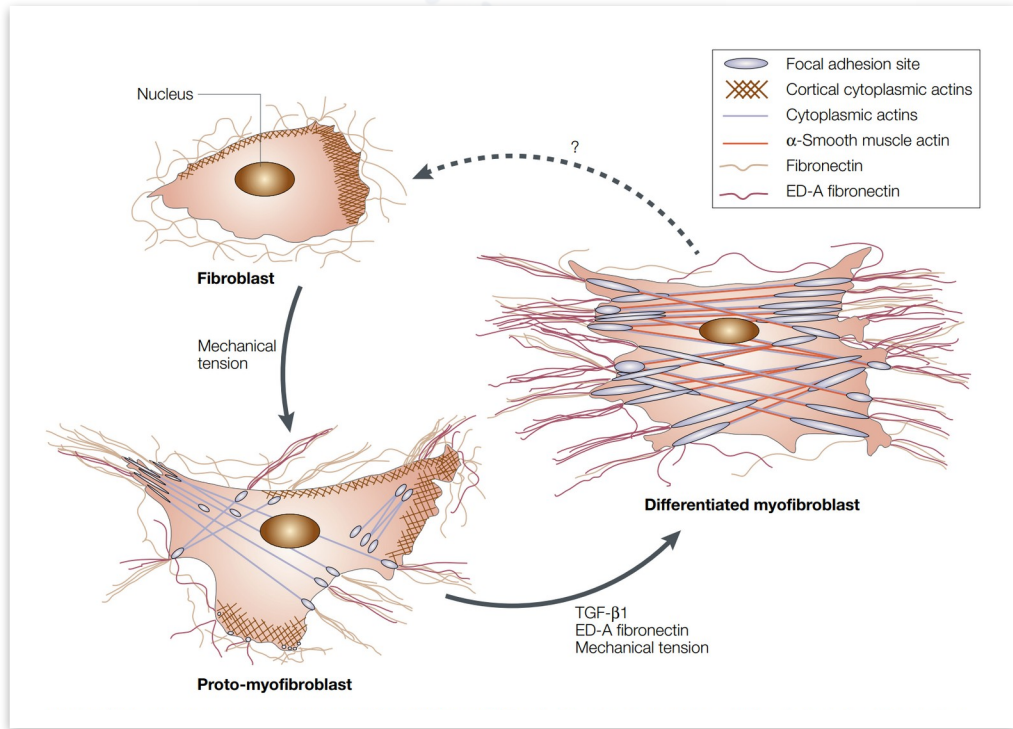
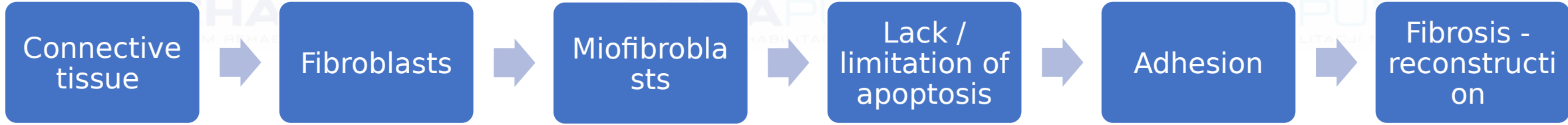
[1]. Connective tissue growth factor (CTGF) from basics to clinics. Ramazani Y, Knops N, Elmonem MA, Nguyen TQ, Arcolino FO, van den Heuvel L, Levtschenko E, Kuypers D, Goldschmeding R. Matrix Biol. 2018 Aug;68-69:44-66.

[2]. Ainsworth W, Gifford M, et al. British Medical Journal. 2010; 341(7774):171-172.

# Pathogenesis of micro-injuries

- multifactorial causes of adhesion [1]

## Myofibroblasts - good or bad?



[1] Tomasek JJ, Gabbiani G, Hinz B, Chaponnier C, Brown RA. [Myofibroblasts and mechano-regulation of connective tissue remodelling](#). Nat Rev Mol Cell Biol. 2002 May;3(5):349-63.

# Pathogenesis of micro-injuries

proper regeneration vs abnormal - CTGF [1,2,3,4]

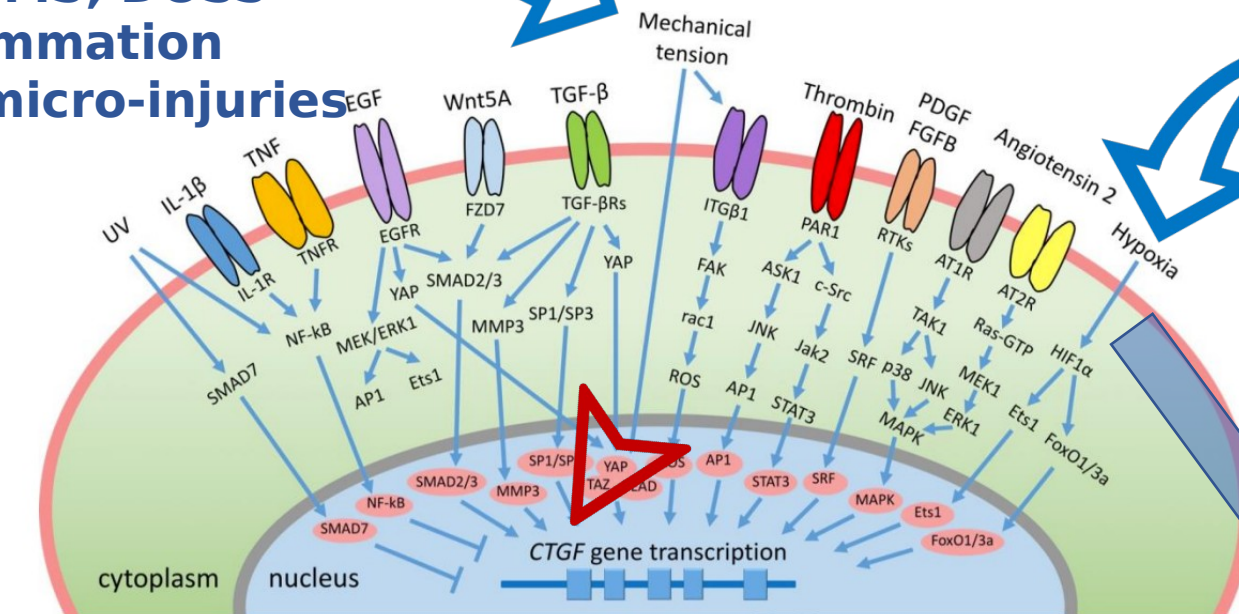
adhesions, fibrosis, calcification

DOMS, DOSS

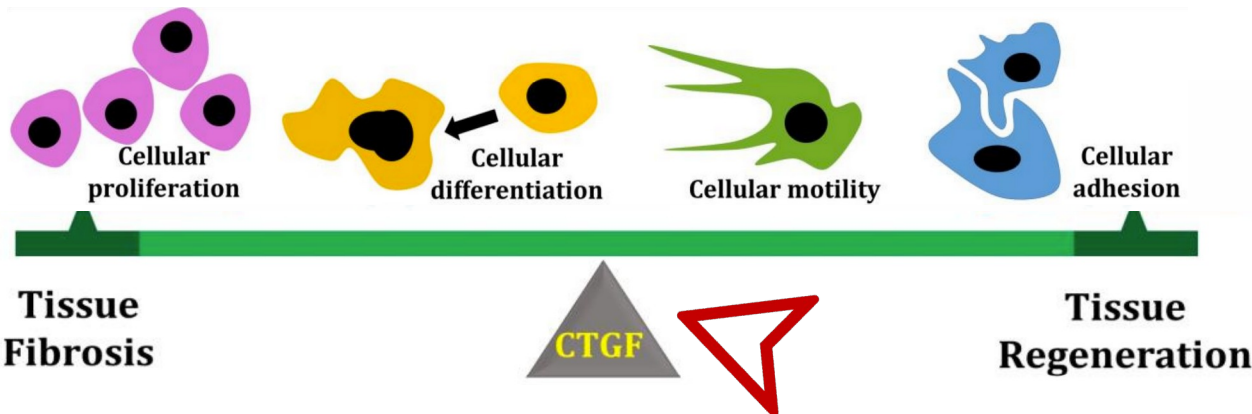
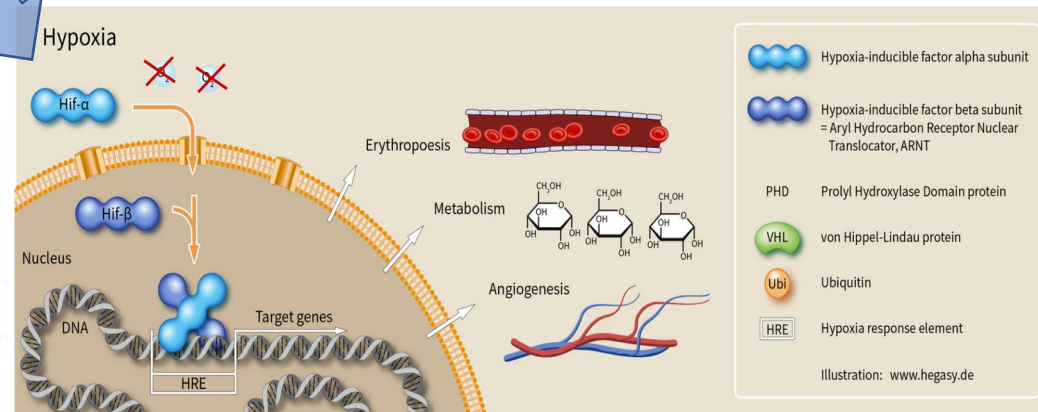
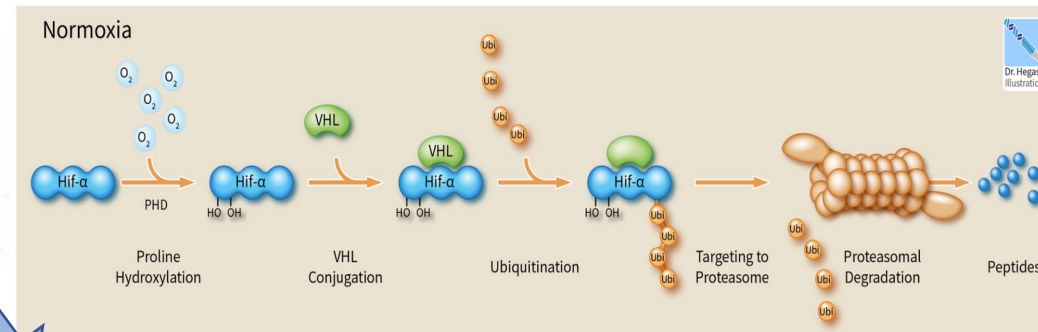
summation

- micro-injuries

Closure of blood vessels as a result of ADHESION - tissue hypoxia



Nobel Prize in Physiology or Medicine 2019: How Cells Sense and Adapt to Oxygen Availability  
Awarded to William G. Kaelin, Sir Peter J. Ratcliffe, and Gregg L. Semenza



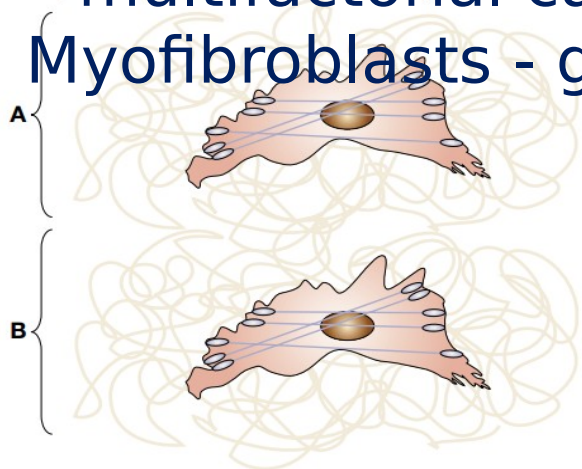
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 [2]. Arjan W. Griffioen · Joyce Bischof. Oxygen sensing decoded: a Nobel concept in biology. Angiogenesis. 2019 Nov;22(4):471-472.  
 [3]. S. Kubota, M. Takigawa, Cellular and molecular actions of Ccn2/CTGF and its role under physiological and pathological conditions, Clin Sci (Lond) 128 (2015) 181-196.

# Pathogenesis of micro-injuries

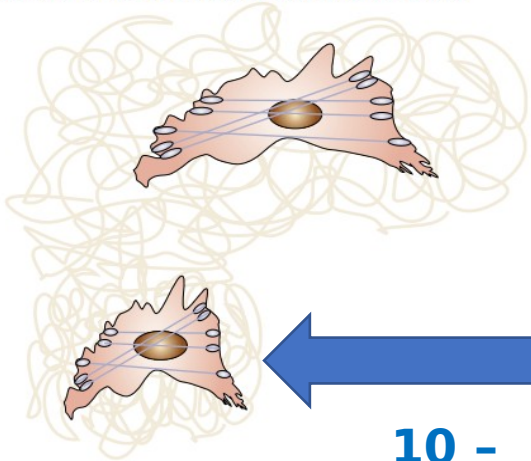
## multifactorial causes of adhesion

### Myofibroblasts - good or bad?

a Adjacent myofibroblasts attach to collagen network



b Myofibroblast B contracts, deforming network B



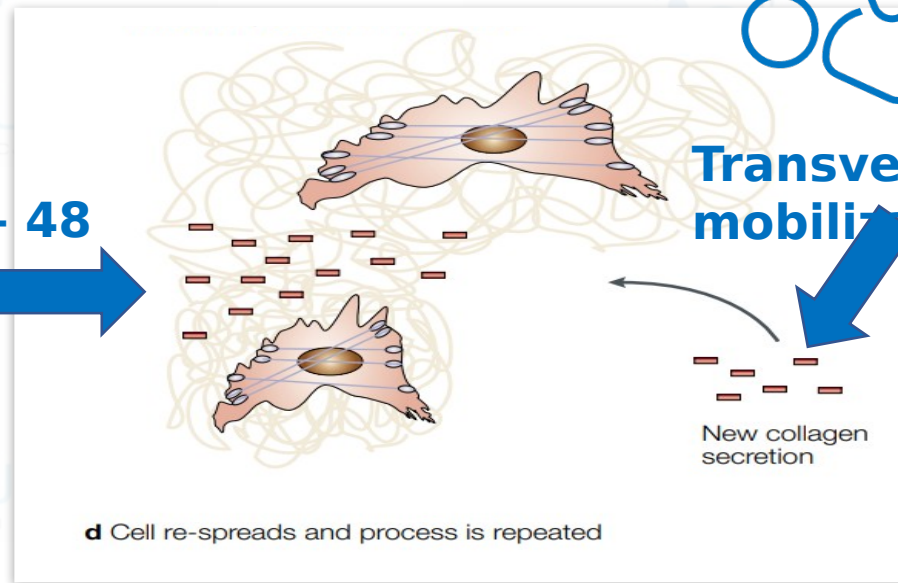
c New collagen secretion stabilizes contracted structure of network B, relative to network A

10 - 20 h



NM  
T

20 - 48

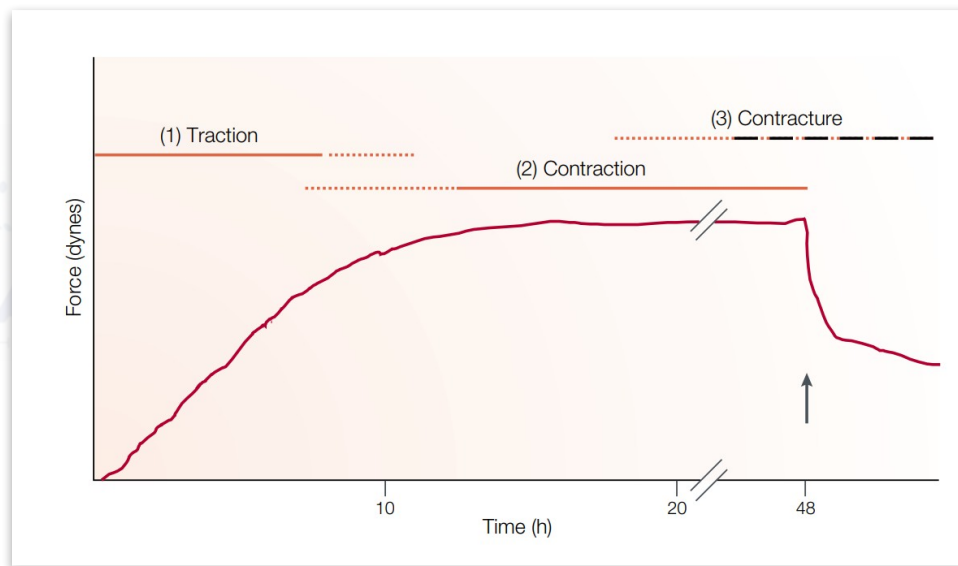


d Cell re-spreads and process is repeated

Transverse mobilization  
48 h - weeks



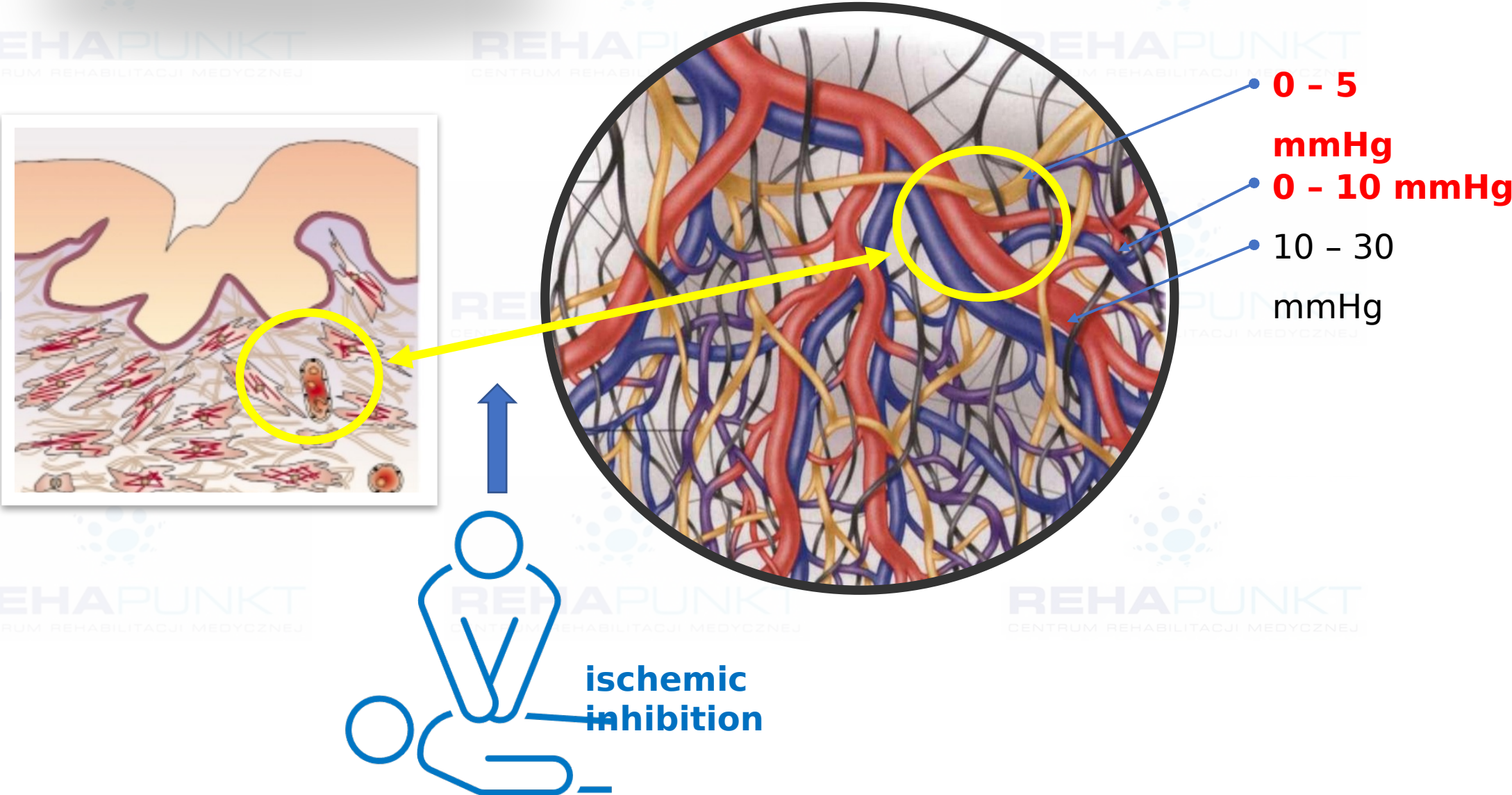
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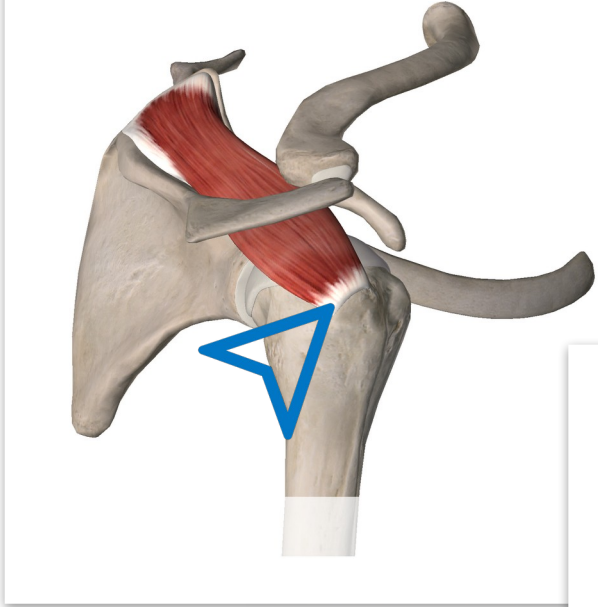
# Pathogenesis of micro-injuries

- multifactorial causes of adhesion

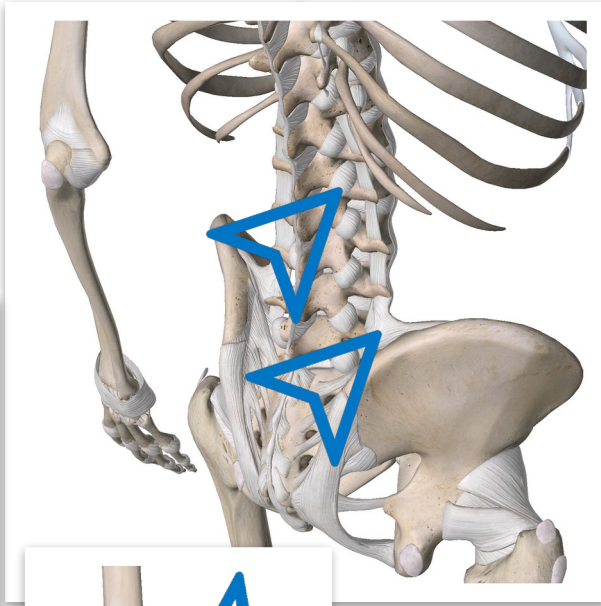
## Compression of blood vessels - ischemia



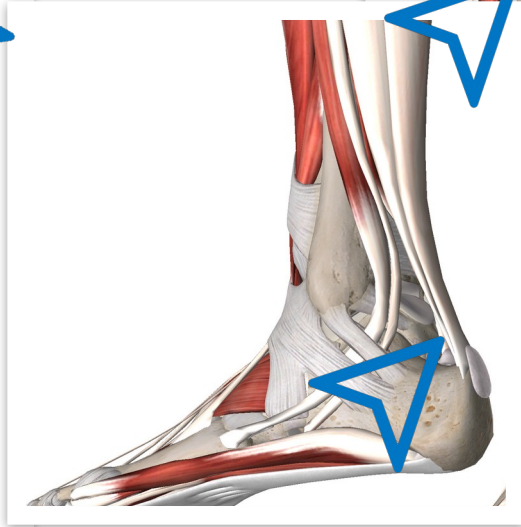
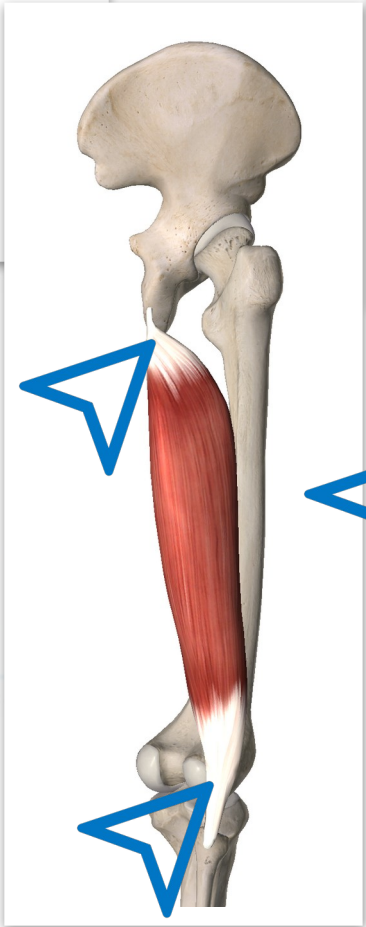
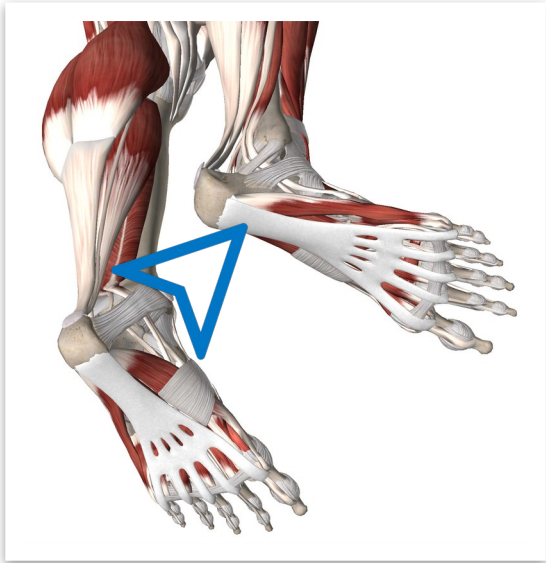
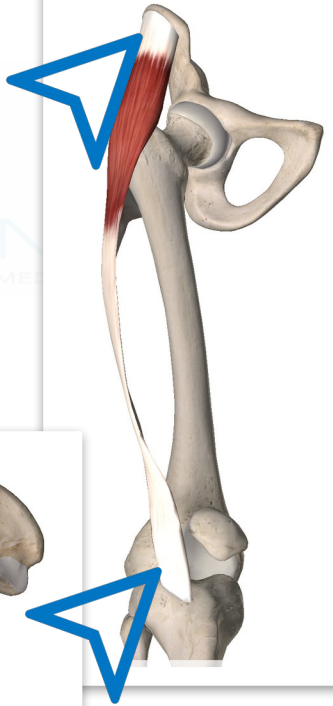
# The most common place of summation - DOMS, DOSS



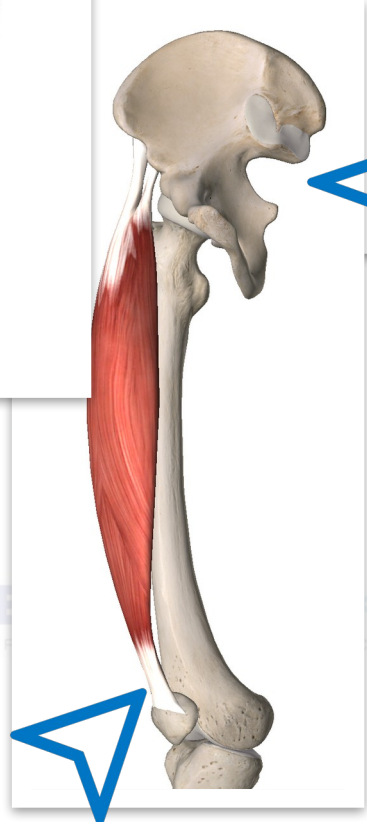
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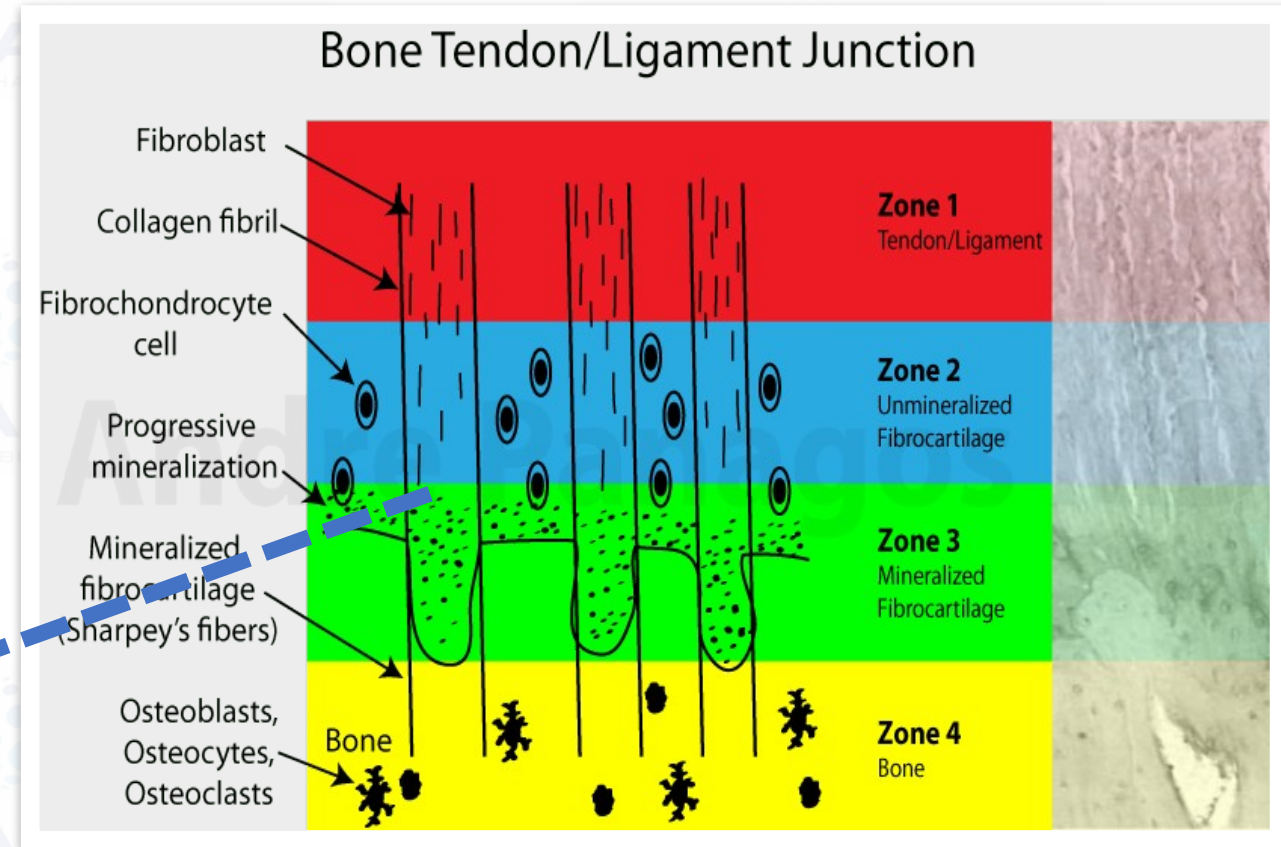
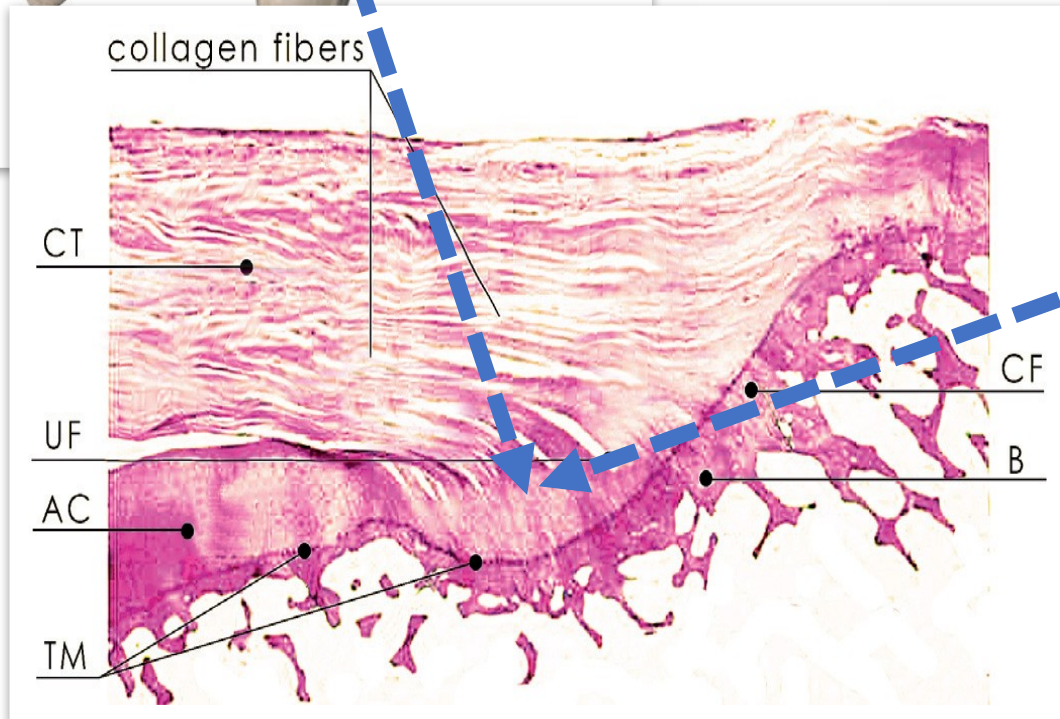
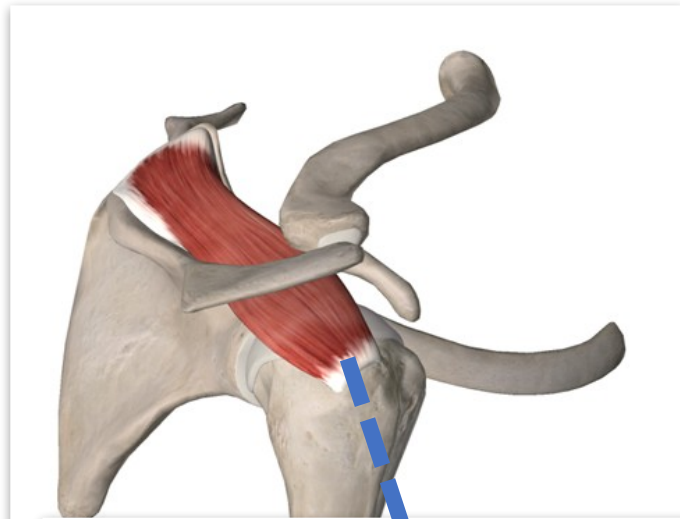


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# The most common place of summation - DOMS, DOSS





# Summing DOMS and DOSS - fibrosis and calcification

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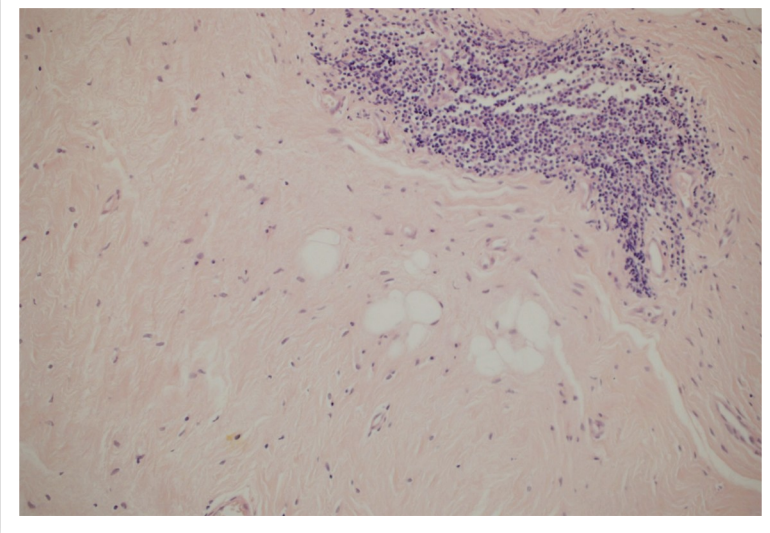
REHAPUNKT  
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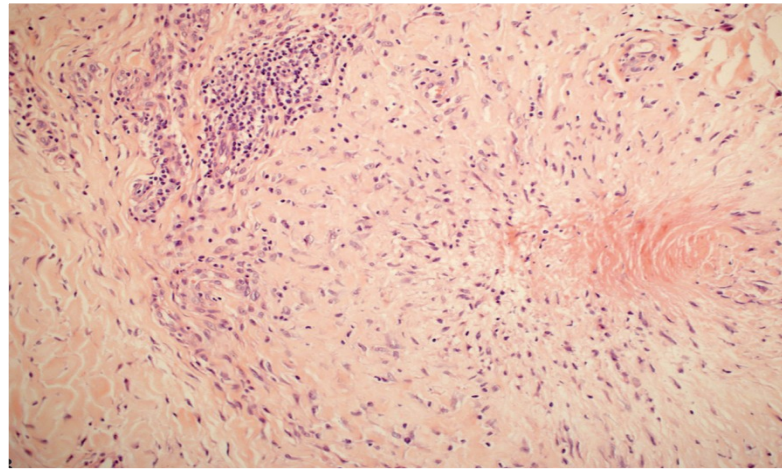
Mechanical overload  
DOMS, DOSS

Macrophage activation - pro-inflammatory secretion of cytokine (TNF- $\alpha$ , IL-18, 12, 23) prostaglandins (PGE2), nitric oxide, various growth factors( CTGF) - mediators of pain, matrix metalloproteinase, which degrade collagen and proteoglycans

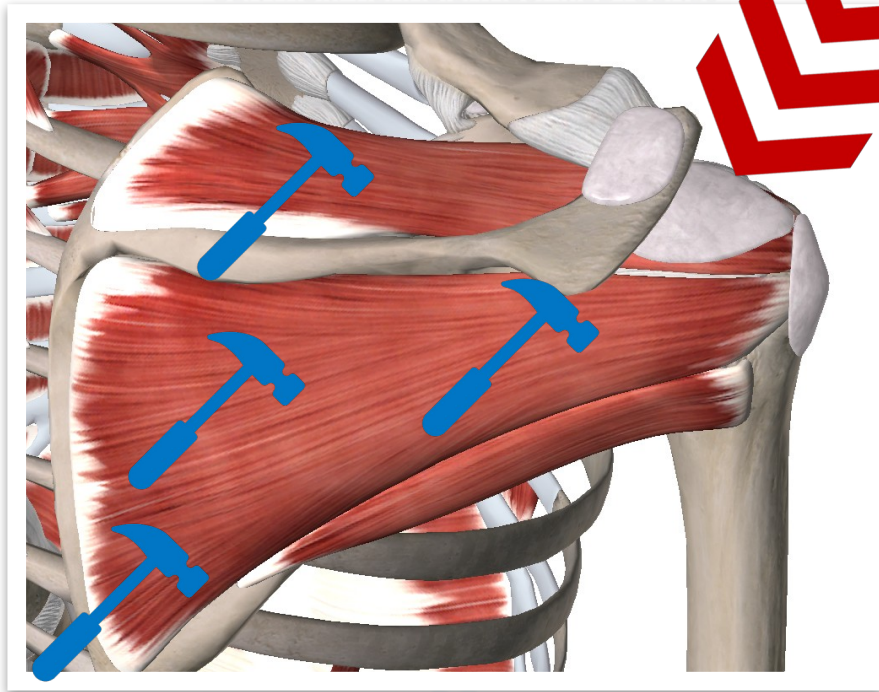
In normal situations - relief - there is a sequential secretion of immunosuppressive cytokines IL-10 and IL-13 - silencing of inflammation



Summing DOMS and DOSS - fibrosis, necrosis and calcification



# Summing DOMS and DOSS - fibrosis and calcification



MRI and ultrasound tests show that the primary cause - overload (DOMS, DOSS) - can begin outside of secondary changes in fibrosis and calcification [1]

The relationship between fibrosis and calcification and the adjacent bursa synovial membrane and adipose tissue - structures with inflammatory potential [1]

# Summing DOMS and DOSS - fibrosis and calcification - unsuccessful treatment or lack of treatment

REHAPUNKT  
CENTRUM REHABILITACJI MEDYCZNEJ

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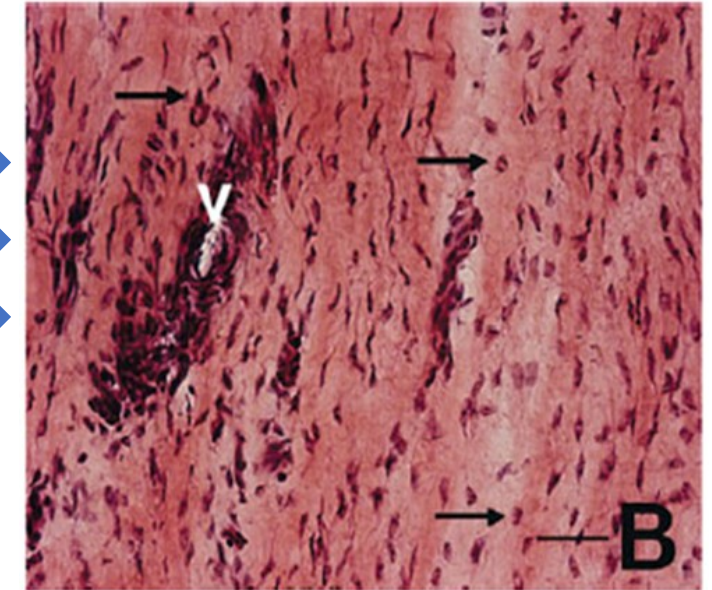
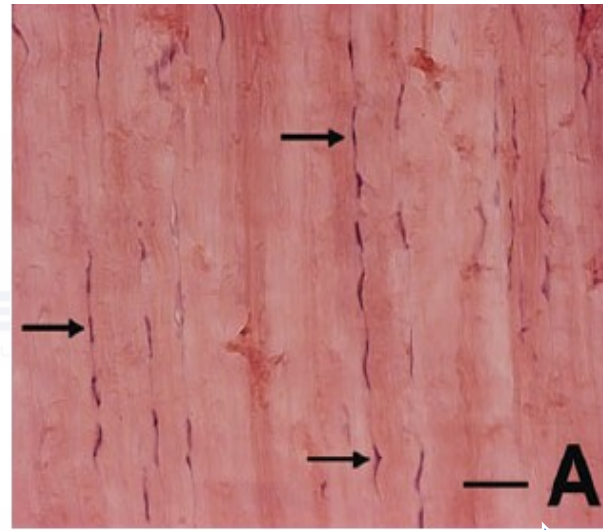


# Summing DOMS and DOSS - fibrosis and calcification [1,2]

REHAPUNKT  
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CENTRUM

REHAPUNKT  
CENTRUM REHABILITACJI MEDYCZNEJ



REHAPUNKT  
CENTRUM REHABILITACJI MEDYCZNEJ

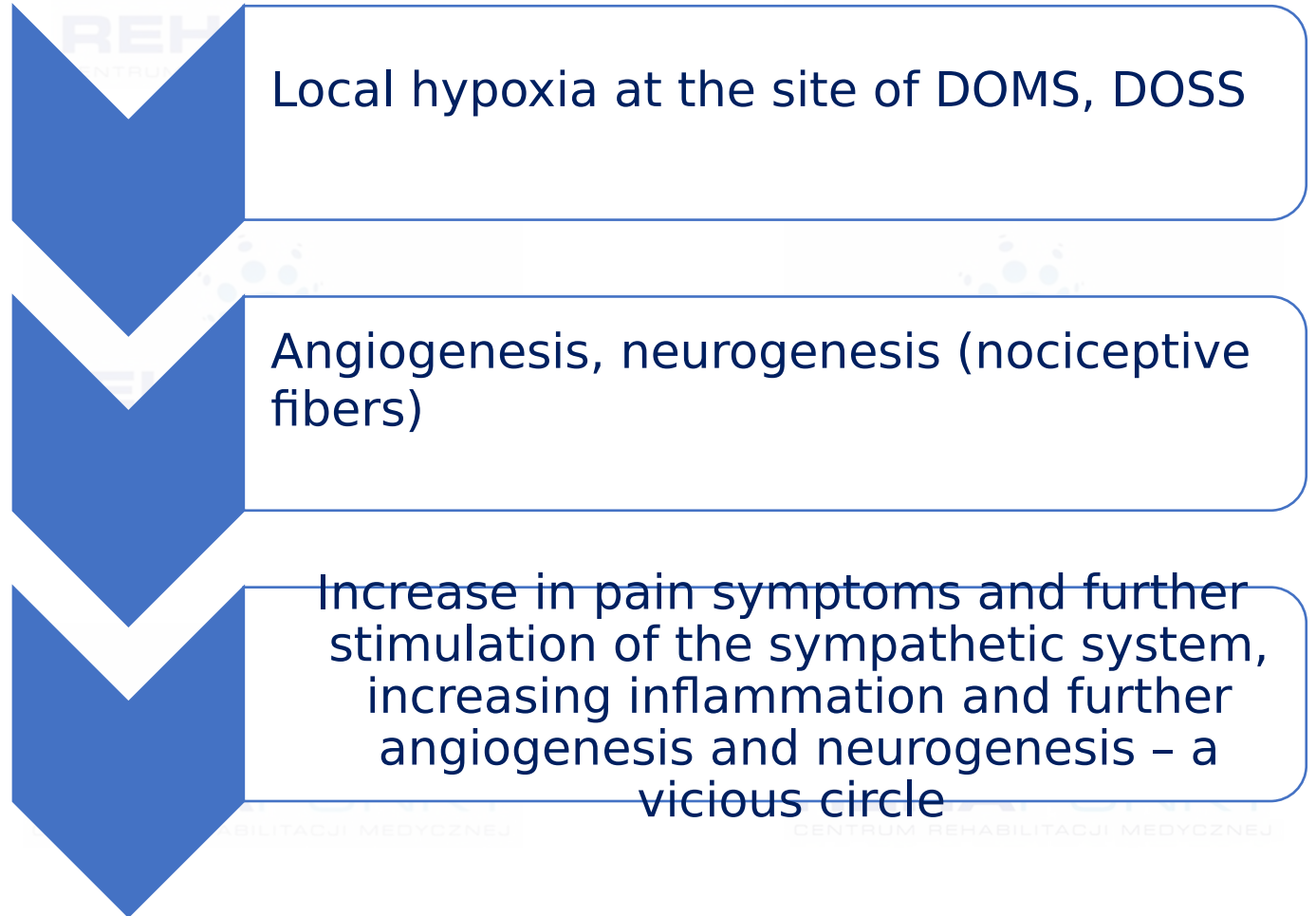
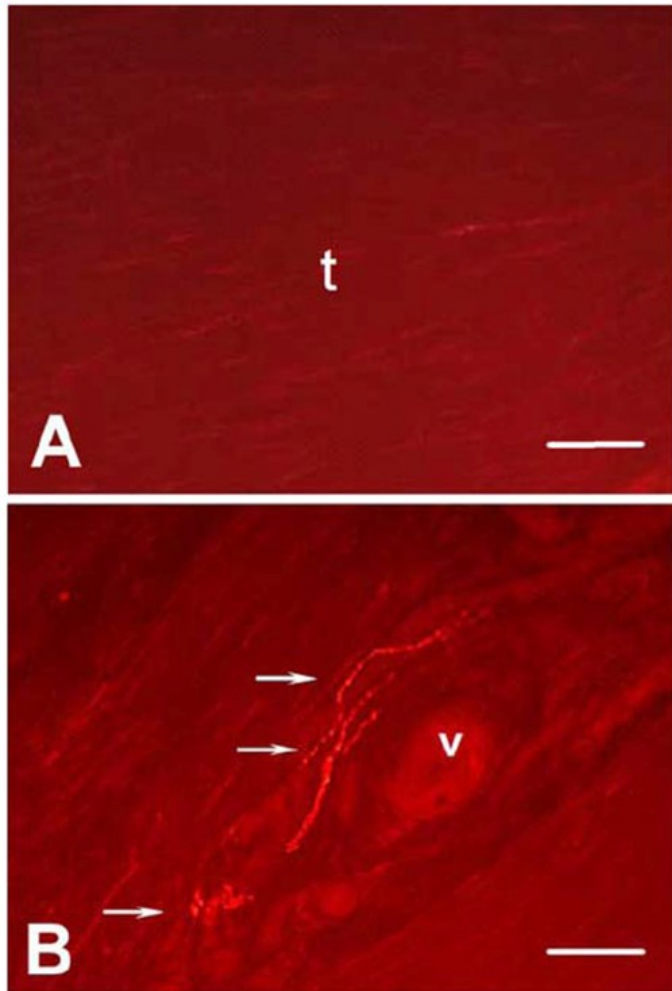
Myofibroblasts are important cells for the healing of connective tissue, probably also for tissue adaptation.

Once the healing process is complete and mechanical stresses are released on the myofibroblasts, these cells undergo programmed cell death (apoptosis)

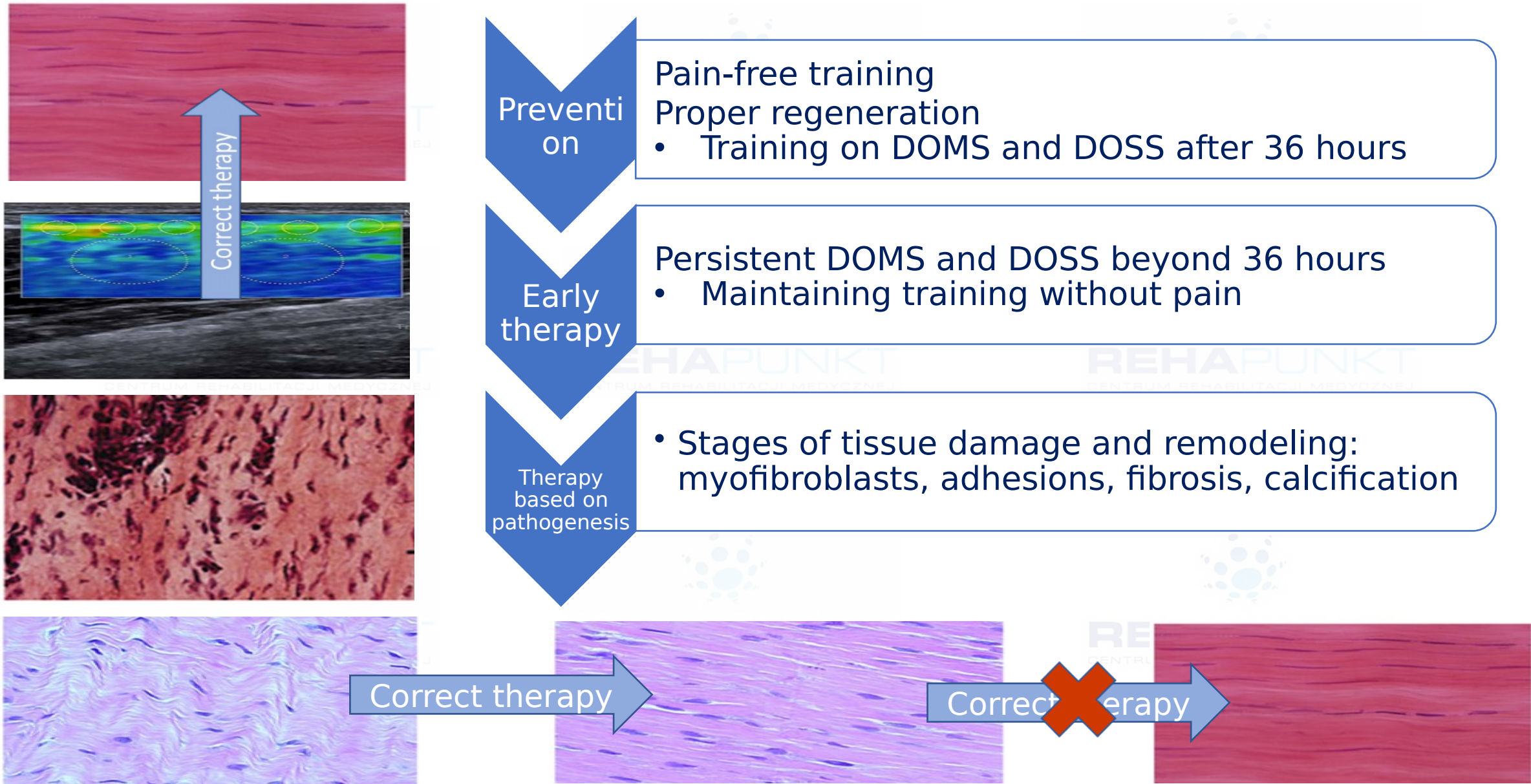
If this mechanism fails, myofibroblasts will propagate a hyperproliferative process, fibrosis, perceived as a clear histological feature of tendinopathy

[1]. Lian O, Dahl J, Ackermann PW, Frihagen F, Engebretsen L, Bahr R. Pronociceptive and antinociceptive neuromediators in patellar tendinopathy. Am J Sports Med. 2006  
[2]. Ackermann PW, Renström P. Tendinopathy in sport. Sports Health. 2012 May;4(3):193-201.

# Summing DOMS and DOSS - pain symptoms[1]



# Injury therapy - aggregating DOMS and DOSS

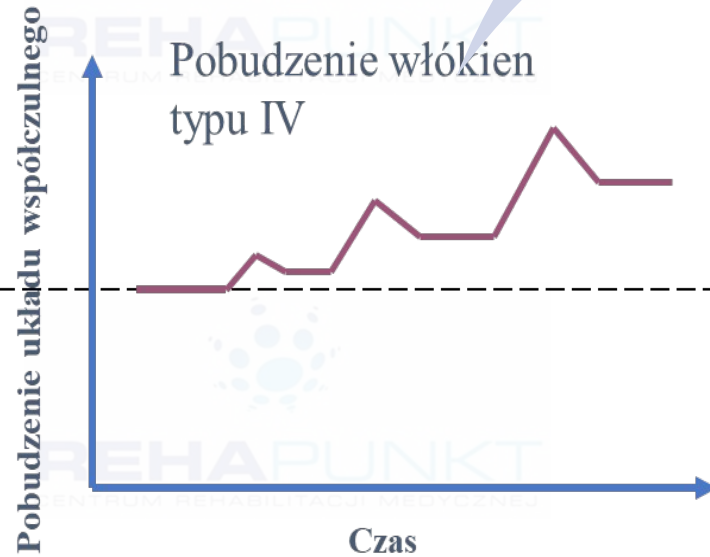
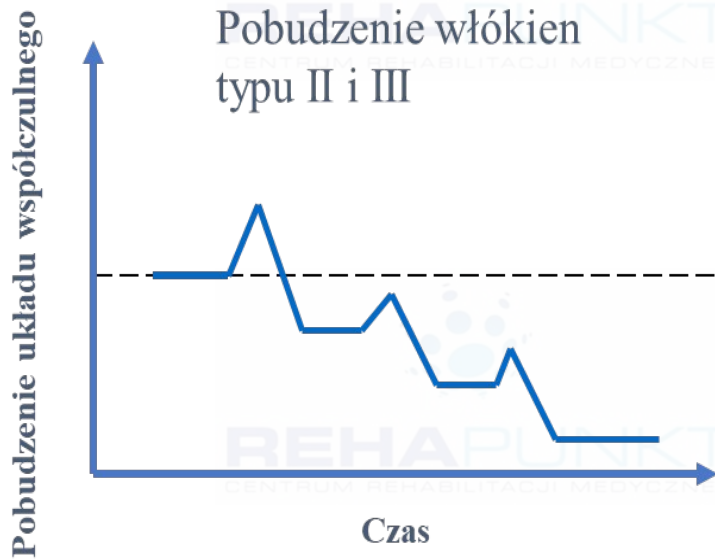


# Injury therapy - aggregating DOMS and DOSS

Prevention

Pain-free training [1]  
 Proper regeneration  
 • Training on DOMS and DOSS after 36 hours

- IV receptors
- Secondary
- Pain injuries
- Inflammation
- Fibrosis
- Calcification

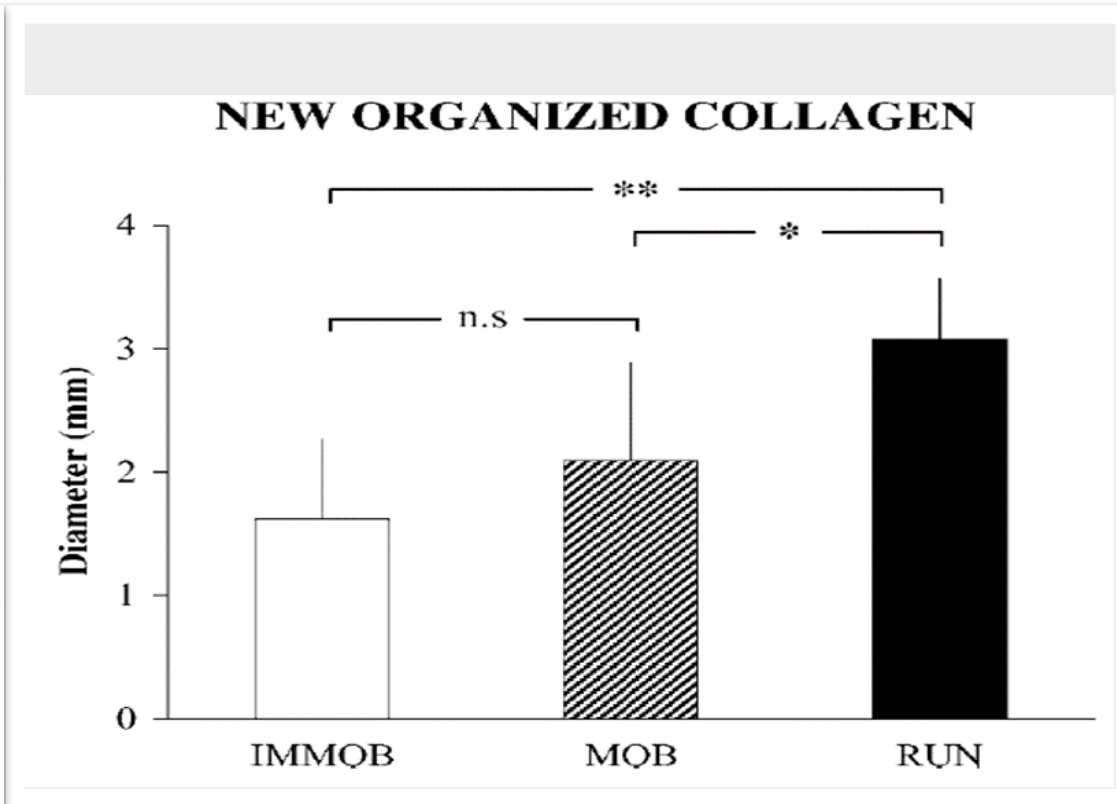
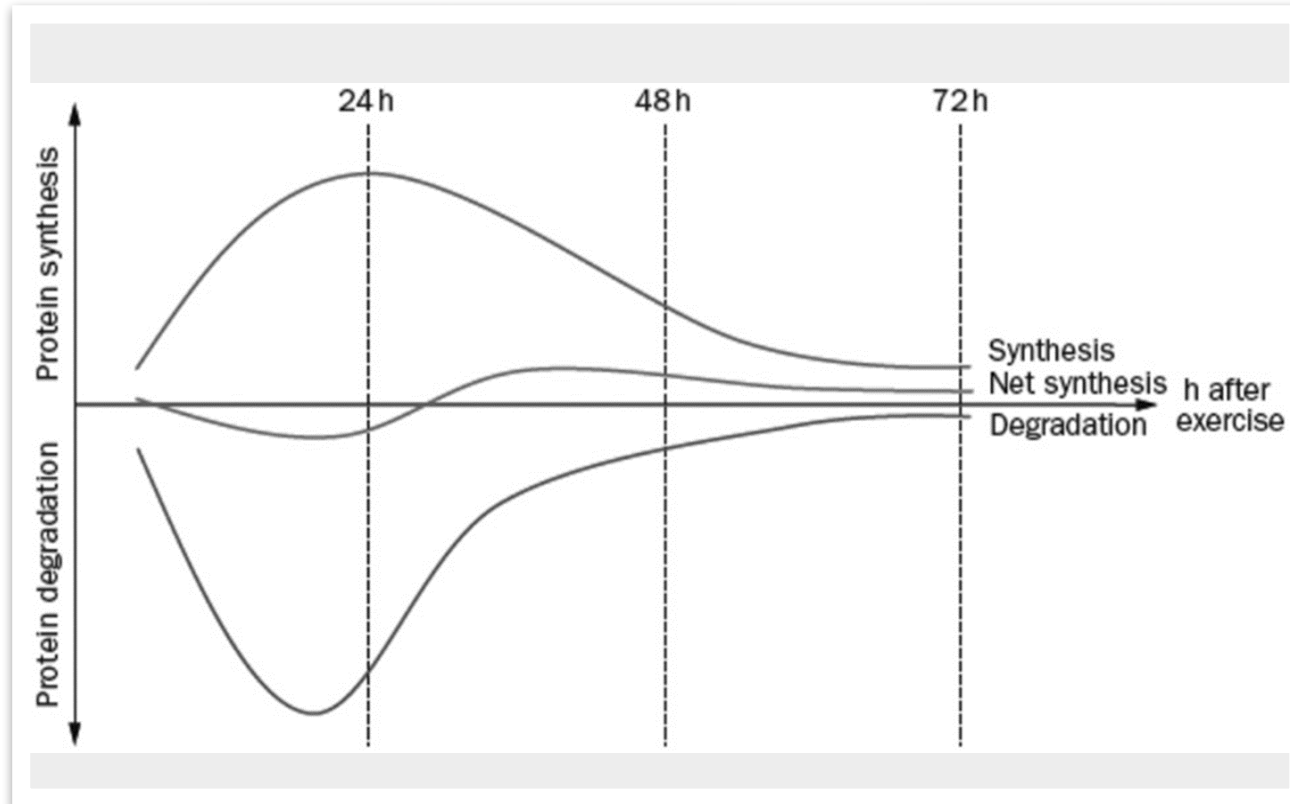


[1] Sato A., Schmidt R., Spinal and supraspinal components of the reflex discharges into lumbar and thoracic white rami, J Physiol. 1971, 212(3), 839-50  
 [2] Magnusson SP, Langberg H, Kjaer M. The pathogenesis of tendinopathy: balancing the response to loading. Nat Rev Rheumatol. 2010;6(5):262-268.  
 Ackermann PW, Renström P. Tendinopathy in sport. Sports Health. 2012 May;4(3):193-201

# Injury therapy - aggregating DOMS and DOSS

Early therapy

- Persistent DOMS and DOSS beyond 36 hours [1]
- Maintaining training without pain [2]





# Injury therapy - aggregating DOMS and DOSS

Therapy based on pathogenesis

Stages of tissue damage and remodeling: myofibroblasts, adhesions, fibrosis, calcification



**NMT**  
**Neuro-Muscular-Technique**  
**Augmented soft tissue mobilization (ASTM) [1]**



**Transverse mobilization [2]**



**Inhibition [3]**



**Ischemic inhibition [4]**



**Physical therapy [5]**  
- HIL laser  
- Shock Wave  
- Magnetic Field  
- Presotherapy

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# Conclusion

1

The training process at each stage should proceed without pathological pain

2

Regeneration of the musculoskeletal system occurs only at an early stage of micro - injury

3

Long-term damage to the musculoskeletal system is compensated with appropriate therapy

4

Compensated damage to the musculoskeletal system predisposes to more frequent subsequent damage



Thank you for your attention

