BRNO UNIVERSITY OF TECHNOLOGY

THESIS DEFENSE

The Influence of Hyaluronic Acid on Friction and Lubrication of Fascia

A journey into the hidden magic of human movement — where hyaluronic acid meets fascia.

Under the supervision of **Prof. Martin Vrbka** and **Assoc. Prof. David Nečas**.

Presented By Alexandra Streďanská

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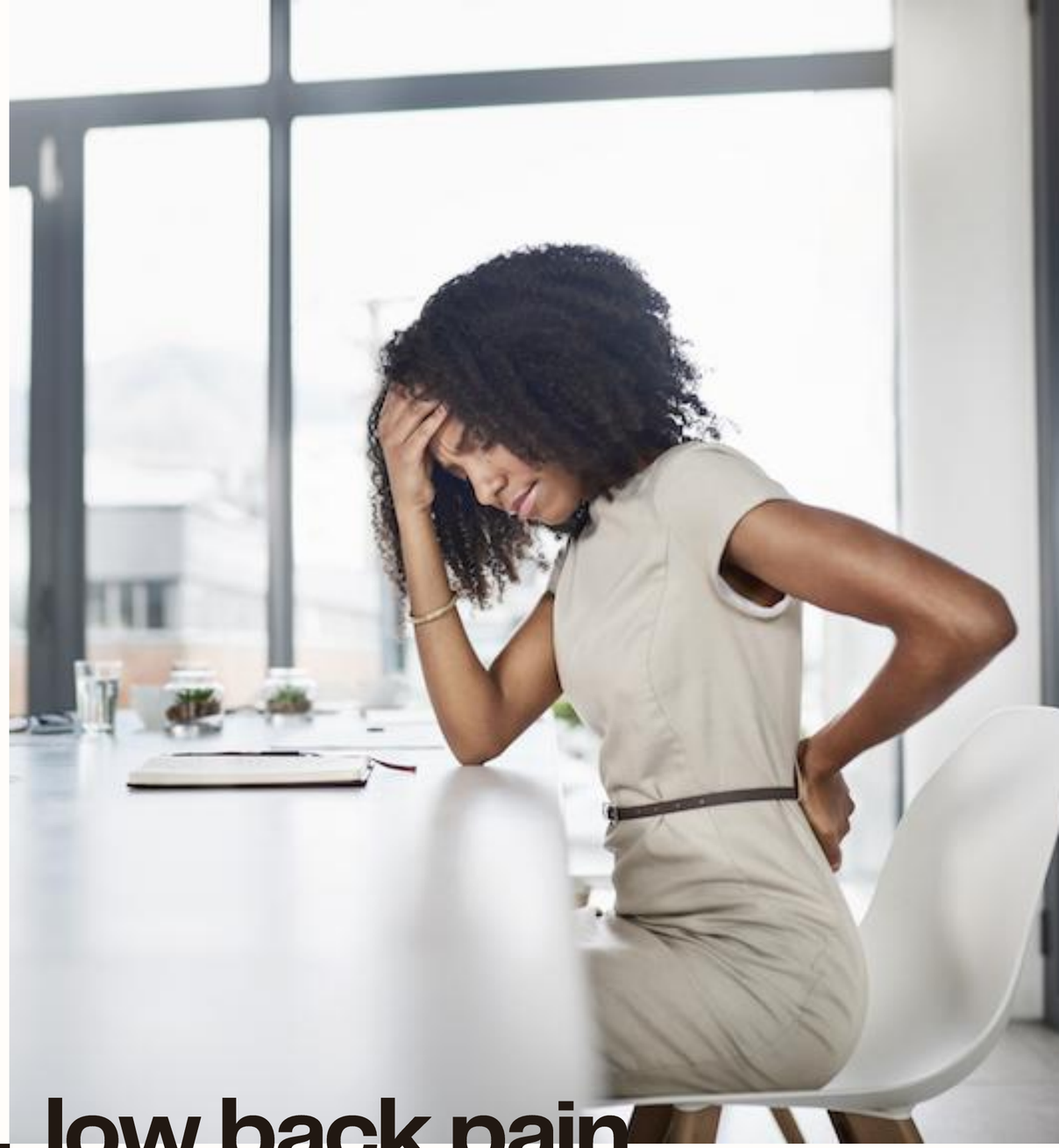
Introduction

- **Widespread** musculoskeletal **condition**.
- **Affects** people across **all age groups** and occupations.
- A **leading cause** of disability and reduced mobility.
- Common causes include poor posture, injury, and aging-related degeneration.
- Has **significant** personal, social, and economic **impacts**.



low back pain

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Motivation

8 in 10

will experience back pain in their lifetime

619 million

people around world are affected by back pain

5%

of people struggling with back pain will go on to develop chronic back pain

hundreds of bn

(USD) is the annual cost of back pain to the state economy

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Problems

~25–50%

TLF thickness is increased

~20–50%

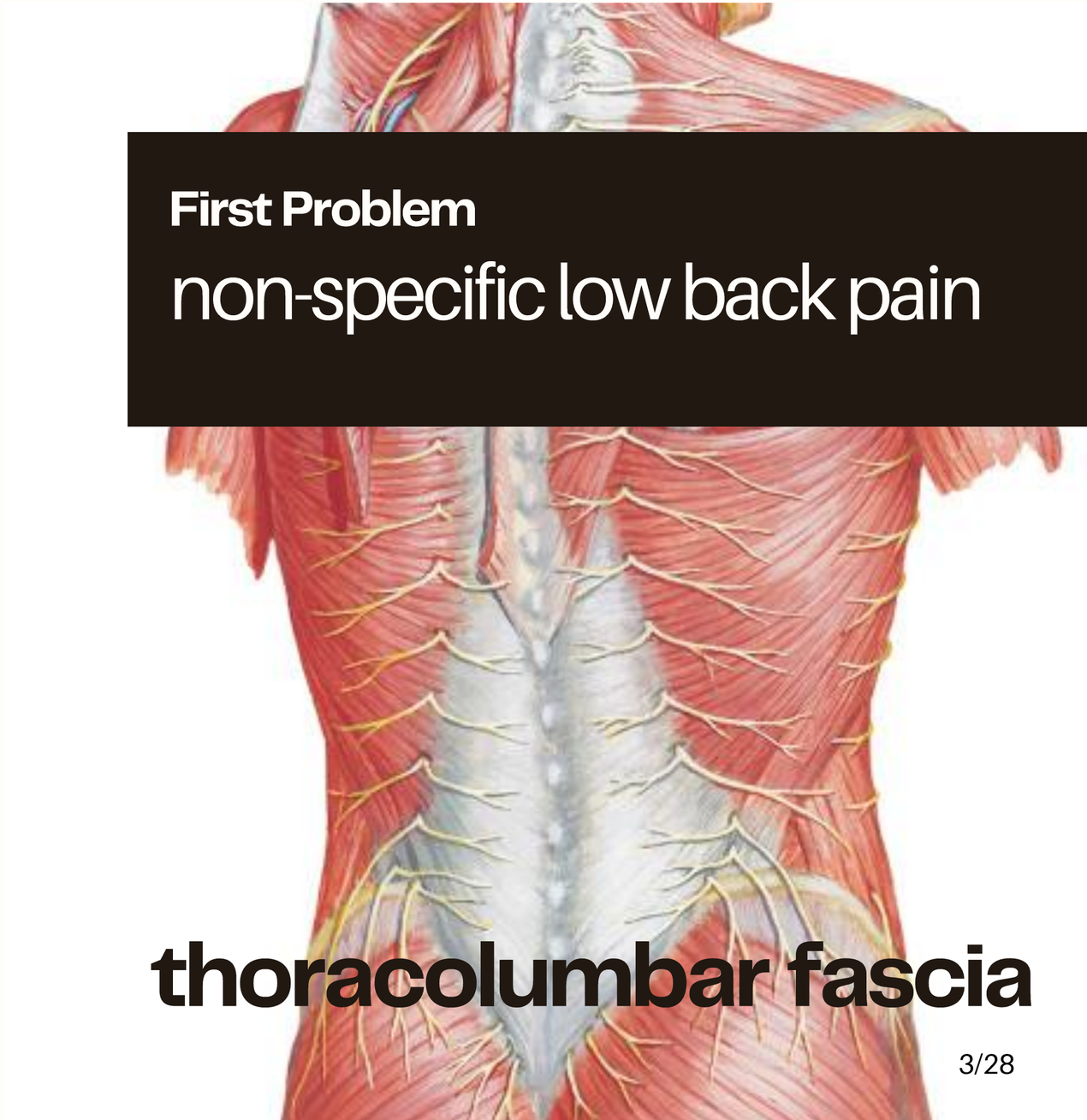
TLF shear strain is reduced

30%

of spinal load TLF can transmit up to

First Problem

non-specific low back pain



thoracolumbar fascia

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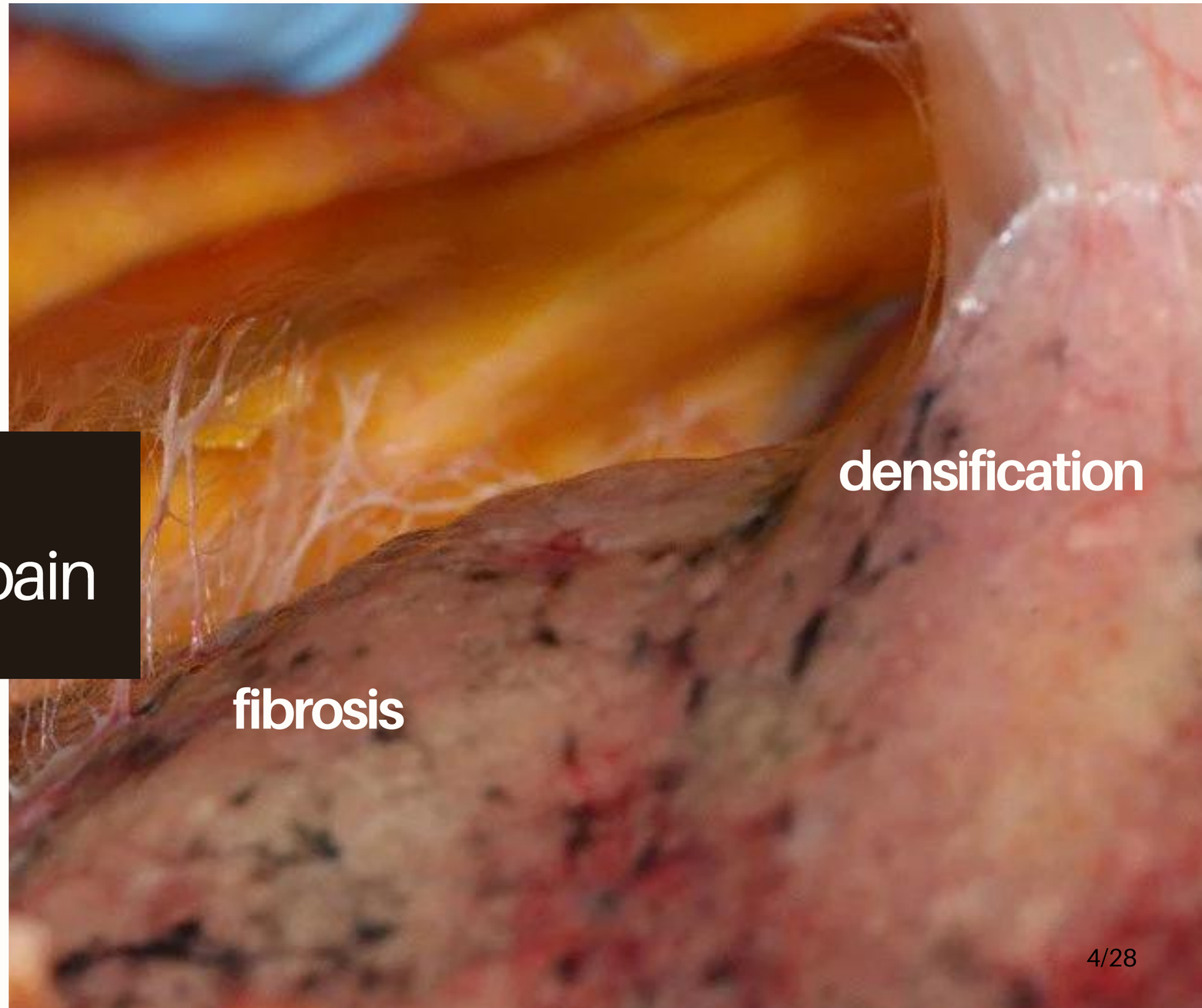
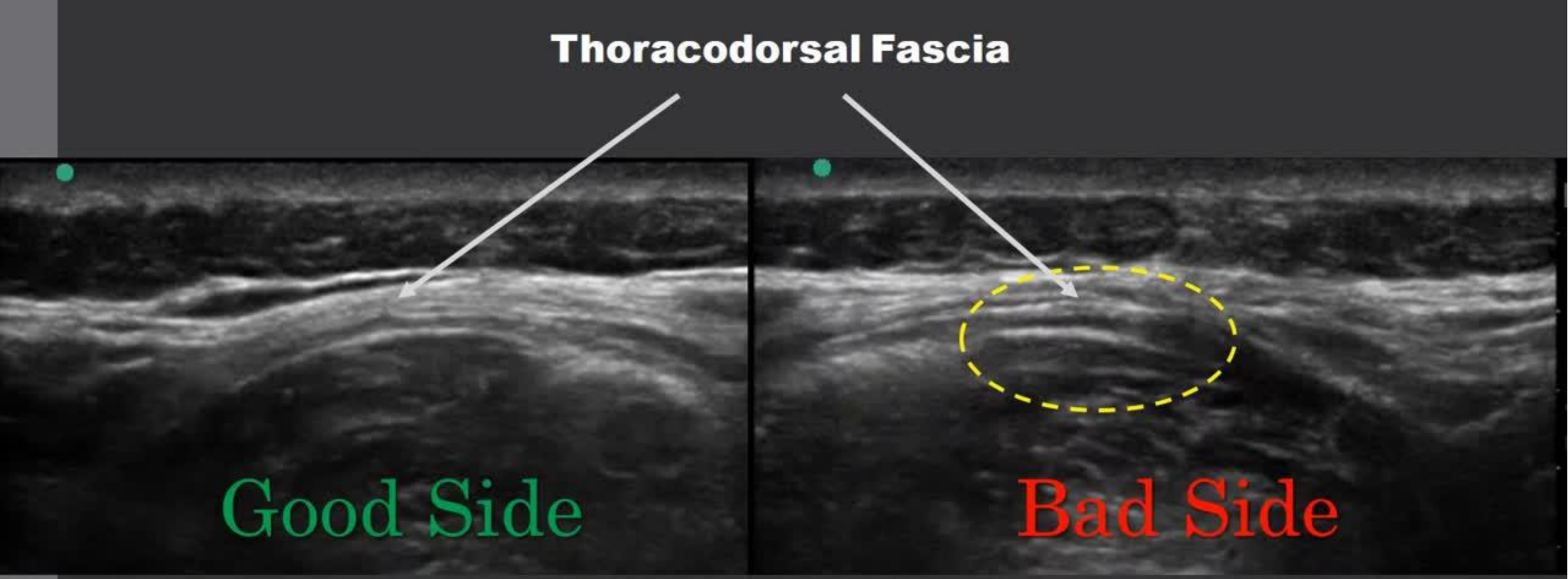
Problems

First Problem

non-specific low back pain





Active muscle contraction…

Problems

Second Problem

how to help?

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Literary Review

Literary Review – 1

Thoracolumbar fascia and low back pain therapies

Literary Review – 2

Hyaluronic acid and its role within the fascia friction

Literary Review – 3

Biotribological models and friction of compliant contacts

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Literary Review – 1

- What is TLF?
- Why it is conected to non-specific low back pain?
- Fascial therapy?

Literary Review – 1

Thoracolumbar fascia and low back pain therapies

Literary Review – 2

Hyaluronic acid and its role within the fascia friction

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Literary Review – 1

- What is TLF?
- Why it is conected to non-specific low back pain?
- Fascial therapy?

Literary Review – 1

Thoracolumbar fascia and low back pain therapies

Literature gap

Non–specific lower back pain

Urgent need to address its diagnosis and seek effective therapeutic solutions.

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Hyaluronic acid

Literary Review–2

Harmless for our Body

- high biocompatibility
- naturally occurring

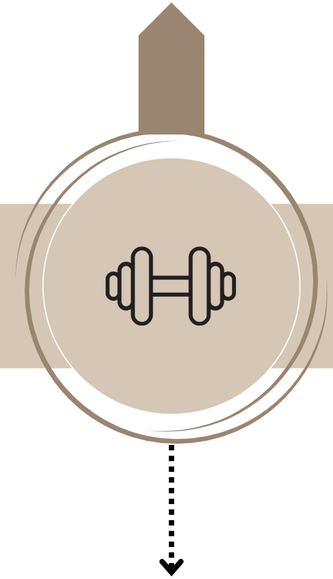
Therapeutic Effect

- knee viscosupplementation
- treatment of limb stiffness
- skincare

Modification

- rapid half-time
- chemical modification
- derivatives of HA

Viscoelasticity and Viscosity



- properties depend on molecular weight and concentration

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Hyaluronic acid

Literary Review–2

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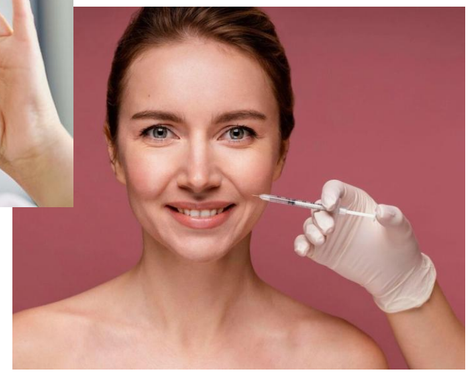

Modificatio

- rapid half-time
- chemical modi
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Hyaluronic acid

Literary Review–2

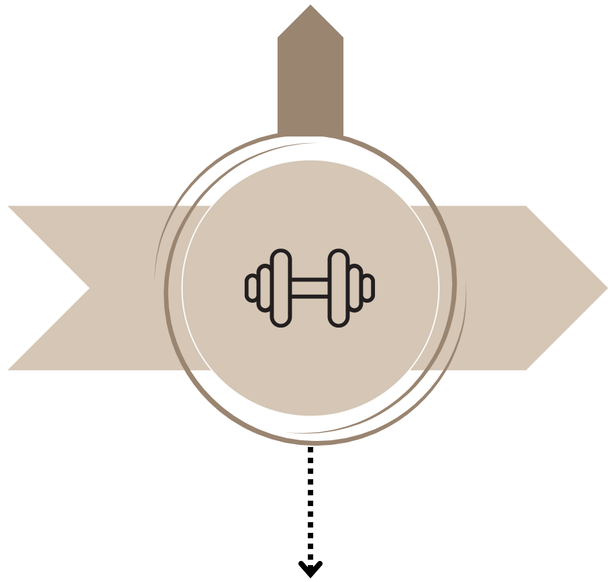
Effect

Modification

pplementation
mb stiffness

- rapid half-time
- chemical modification
- derivatives of HA

Viscoelasticity and Viscosity



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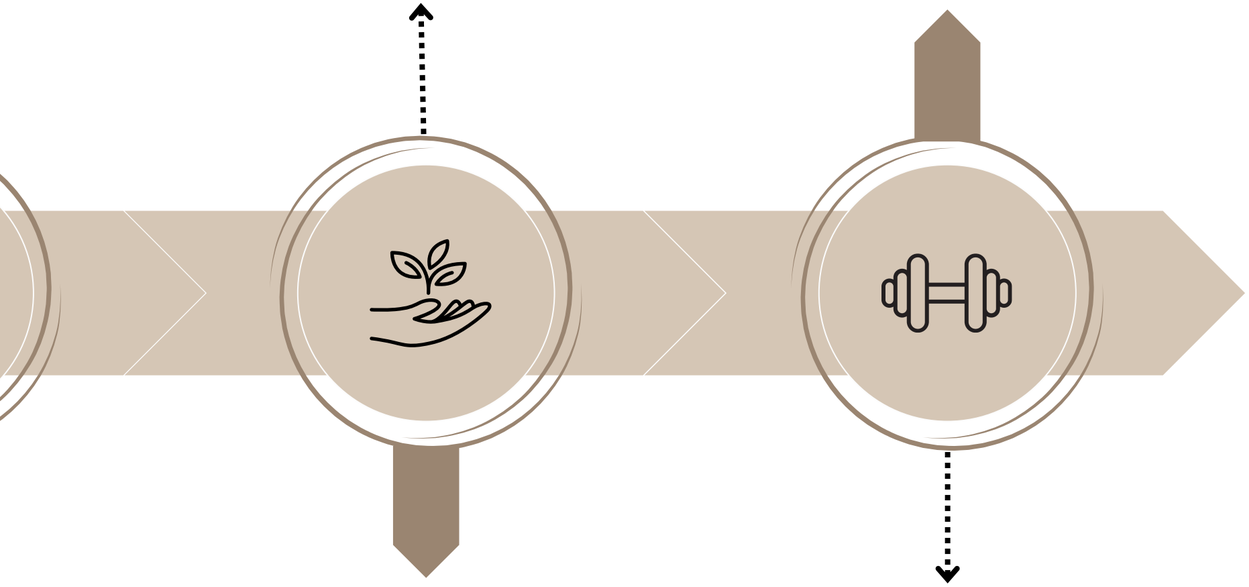
Hyaluronic acid

Literary Review–2

fect

Modification

Viscoelasticity and Viscosity



lementation
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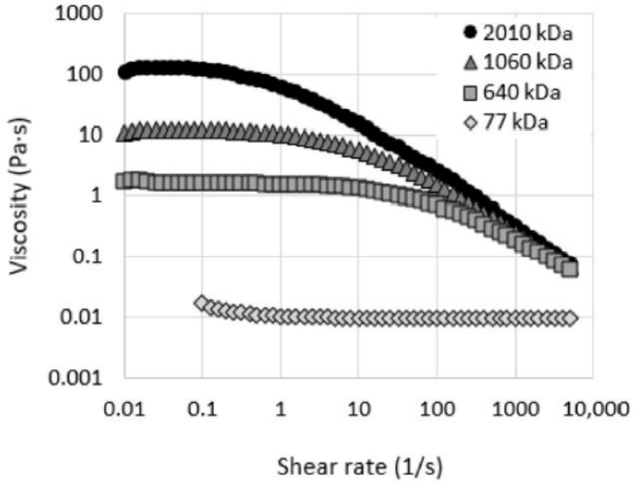
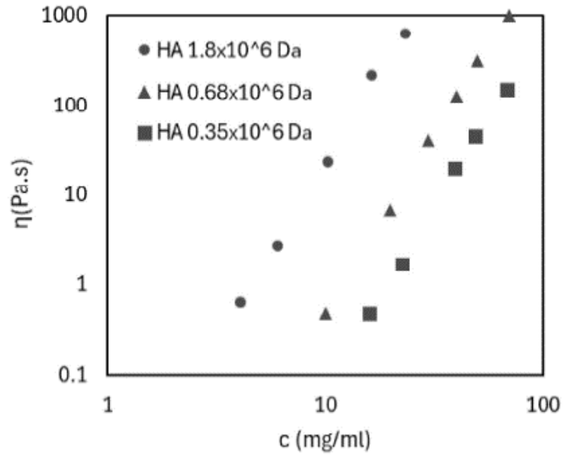
- rapid half-time
- chemical modification
- derivatives of HA

- properties depend on molecular weight and concentration

Rebenda et al. (2020)



Falcone et al. (2006)



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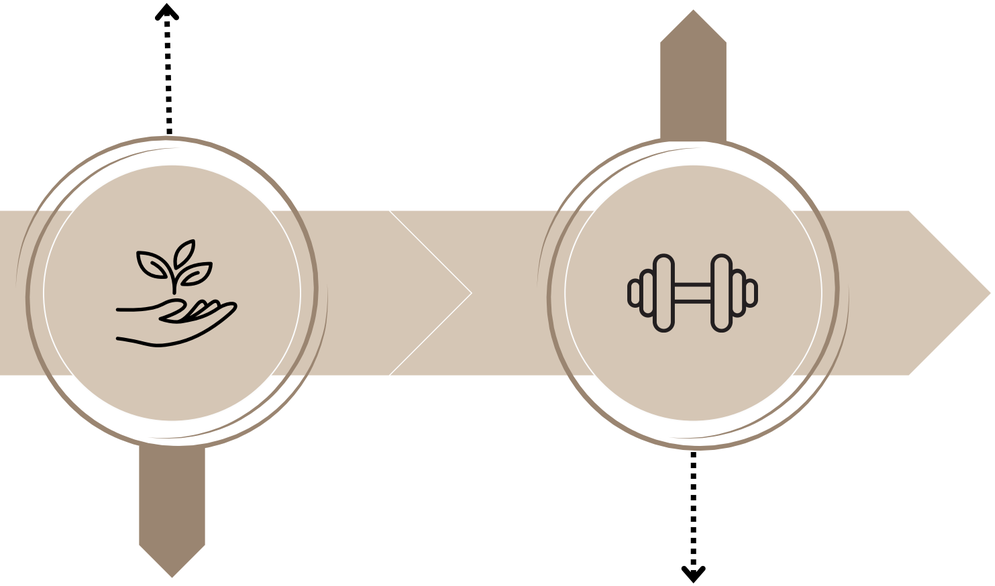
Hyaluronic acid

Literary Review–2

Modification



rapid half-time chemical modification derivatives of HA

Viscoelasticity and Viscosity

- properties depend on molecular weight and concentration

Literature gap

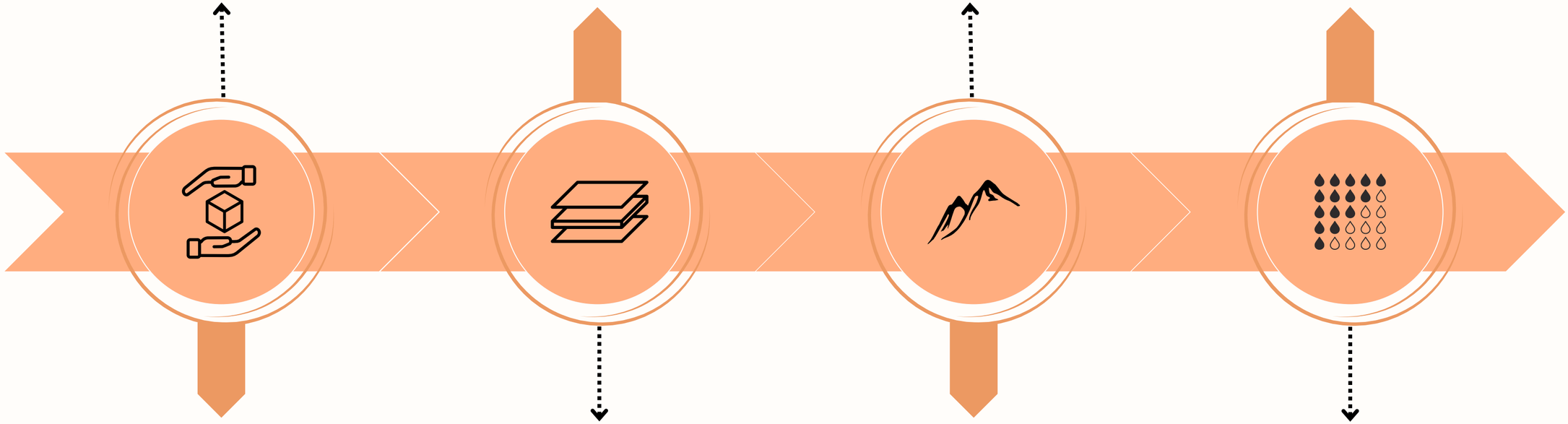
Hyaluronic acid

Optimal properties of HA for reducing fascial friction and adhesion remain unknown.

Biotribological models and friction of compliant contacts

Literary Review–3

Models



- artificial polymers, elastomers
- animal and cadaver tissues
- eyes, tongue, tendons etc.

Material Friction

- softer - high friction
- elasticity decreases - sliding friction increases, rolling friction levels off

Roughness

- reduces adhesion in stiff materials
- increases adhesion in soft materials

Wettability and Contact Angle

- lower contact angle - less friction

Biotribological models and friction of compliant contacts

Literary Review–3

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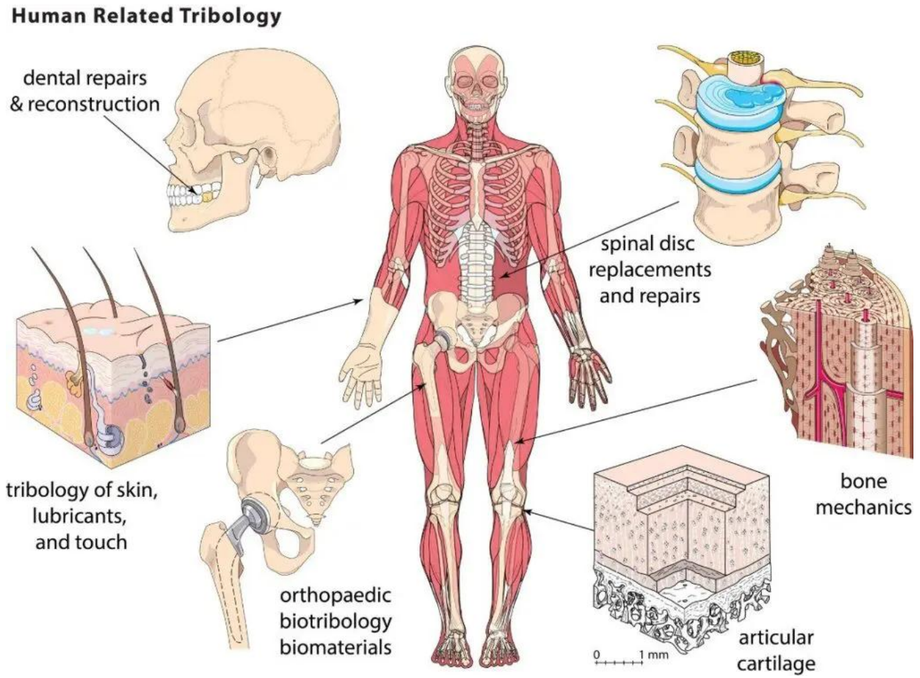

tribonet.org

Material Friction

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Biotribological models and friction of compliant contacts

Literary Review–3

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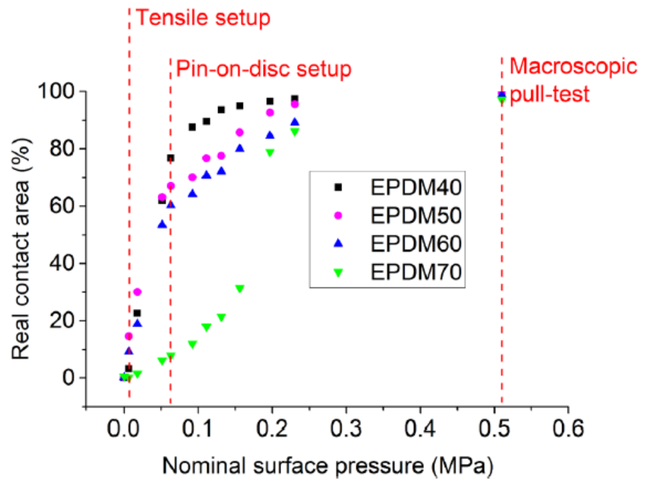
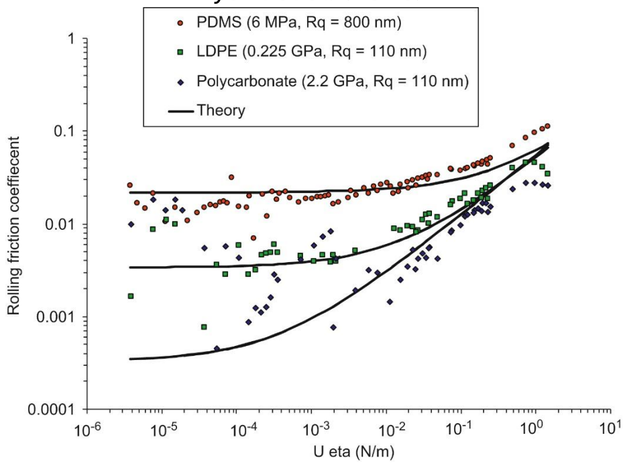
Adam et al. (2019)



Myant et al. (2010)



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Biotribological models and friction of compliant contacts

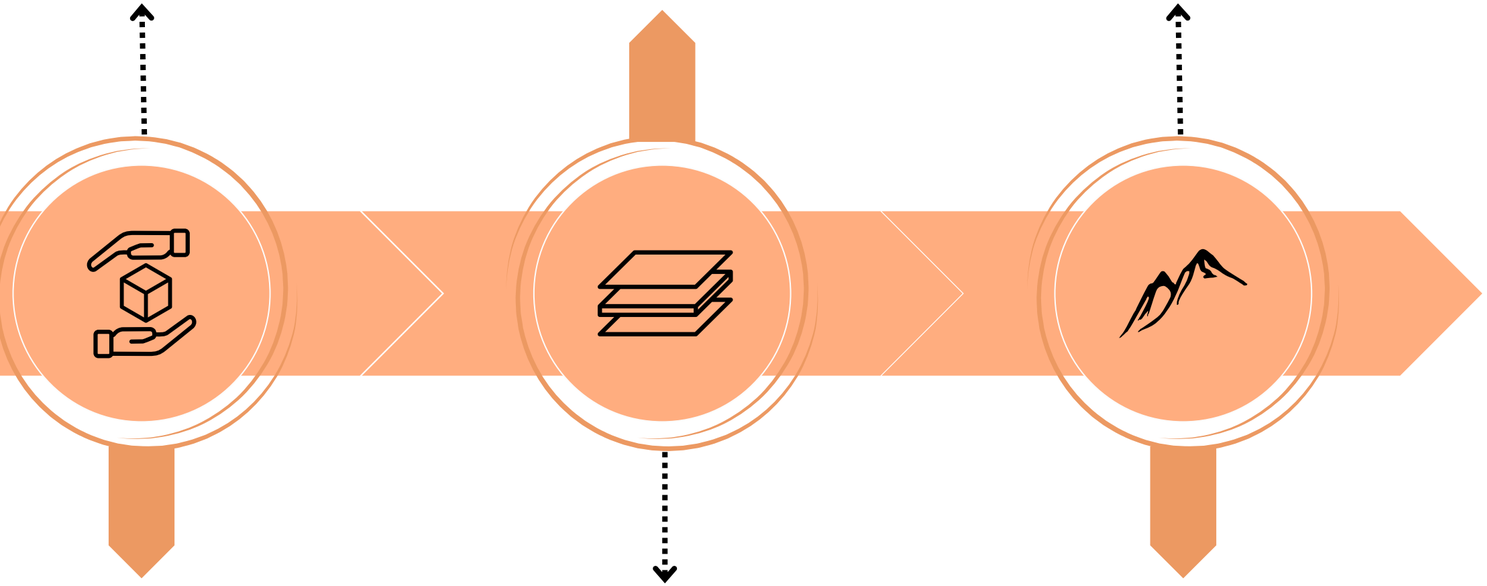
Literary Review–3

Models

Material Friction

Roughness

Wettabilit



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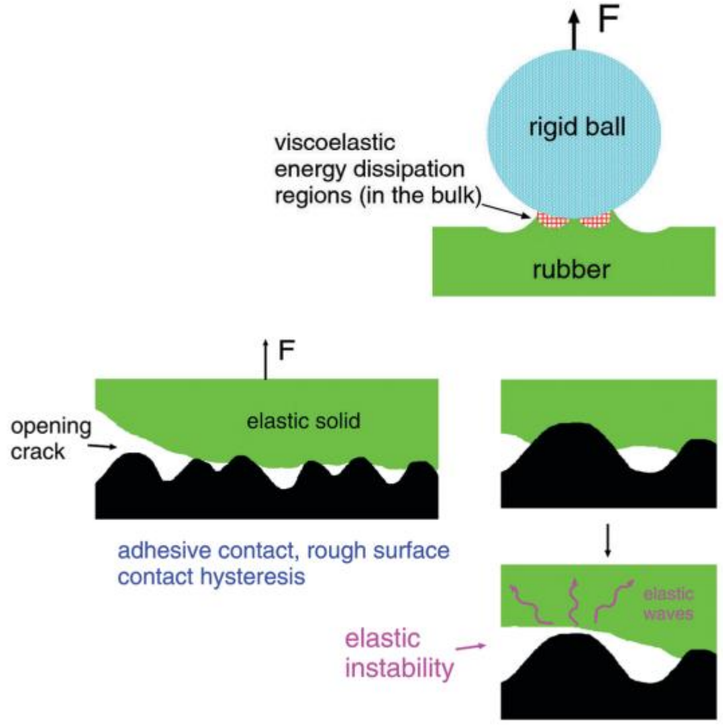


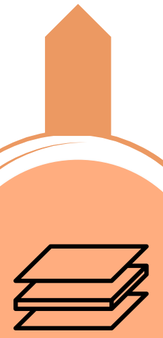
Tiwari et al. (2017)

- lowe
- roug for fu

Biotribological models and friction of compliant contacts

Literary Review–3

Material Friction



softer - high friction
elasticity decreases -
sliding friction increases,
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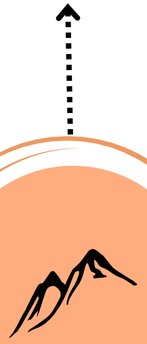
Roughness



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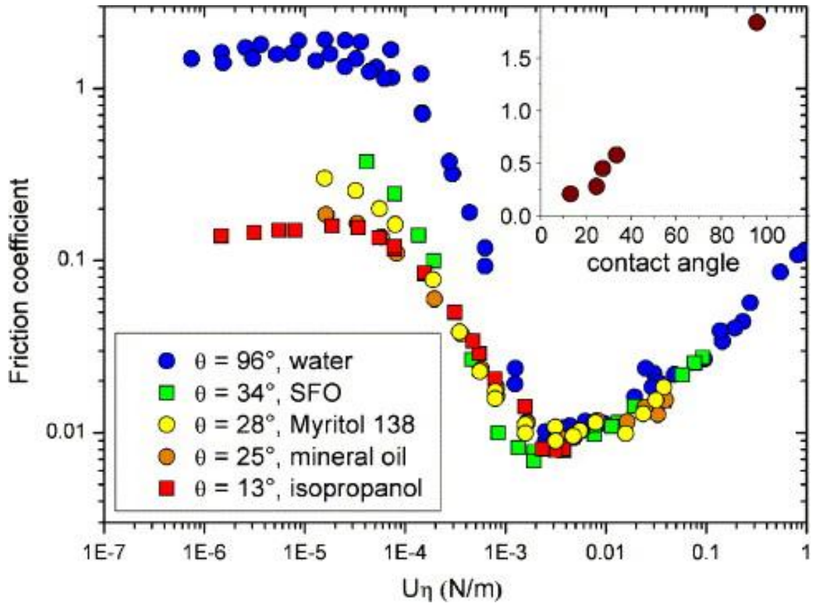
- increases adhesion in soft materials

Wettability and Contact Angle

- lower contact angle - less friction

Bongaerts et al. (2007)



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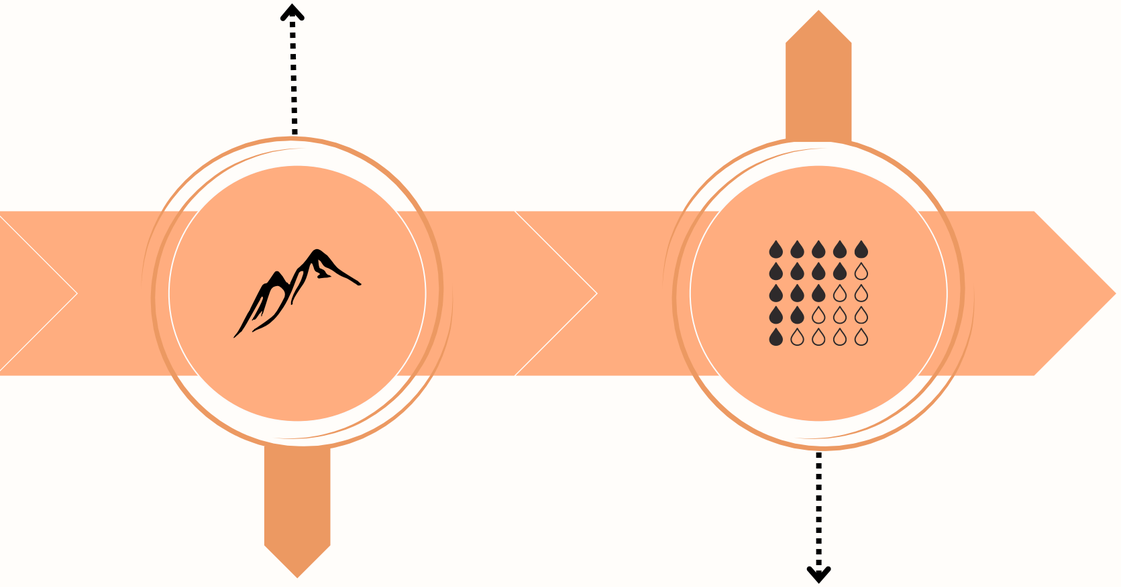
Biotribological models and friction of compliant contacts

Literary Review–3

Roughness



- reduces adhesion in stiff materials
- increases adhesion in soft materials

Wettability and Contact Angle

- lower contact angle - less friction

Literature gap

Tribological model

No research to date has specifically addressed TLF or utilized a tribological model for fascial tissues.

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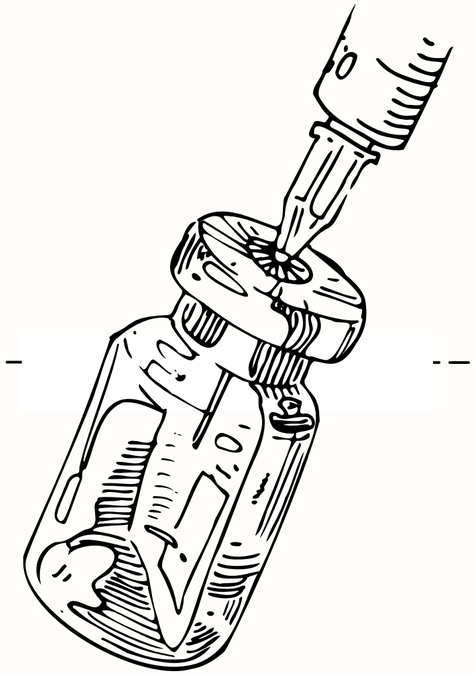
CONTIPRO

Objectives



1 DEVELOP
tribological model of fascial layers and underlying muscle

2 STUDY
effect of properties of hyaluronic acid solutions on the model

3 DEFINE
optimal properties of HA leading to decreasing friction

4 HELP
people to live without low back pain thanks to our HA-based treatment

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Questions & Hypothesis

Q1: What material parameters are crucial in developing a tribological model to accurately simulate fascial tissues and reliably identify the adhesive mechanisms in pathological conditions?

H1: mechanical properties (elastic modulus, tensile strength, viscoelasticity), surface characteristics (roughness, energy), and frictional behavior (COF, HA-based lubrication)

Q2: What is the mechanism of friction reduction of HA lubricated adhesive fascial tissue induced by various solution compositions?

H2: HA molecular weight and concentration, interaction with collagen fibers

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Machines

Bruker UMT TriboLab

Discovery HR-30 rheometer

MIRA3

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Models

R 8.6

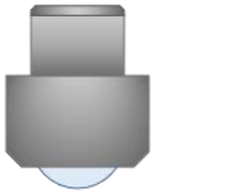

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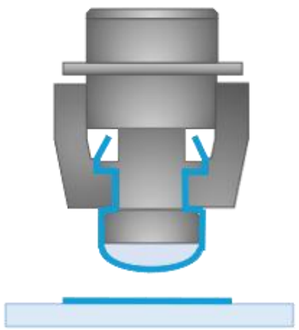
Plate: PDMS 10, 20, 30, 40, 50 ShA

A

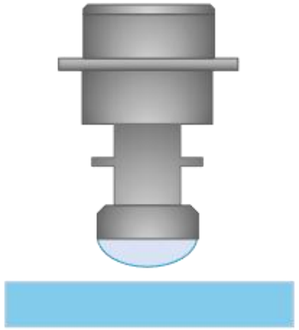
R30 & R 50



Pin: PDMS 10 ShA (muscle)
PU foil 75 Sh00 (fascia)
Plate: PDMS 10 ShA (muscle)
PU foil 75 Sh00 (fascia)

B

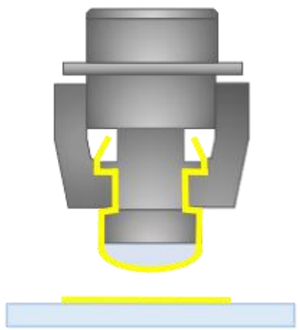
R 50



Pin: PDMS 10 ShA
Plate: PU foil 30 Sh00

C

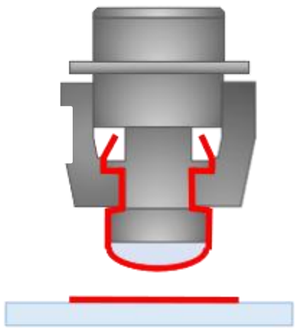
R 50



Pin: PDMS 10 ShA (muscle)
PVA hydrogel (fascia)
Plate: PDMS 10 ShA (muscle)
PVA hydrogel (fascia)

D

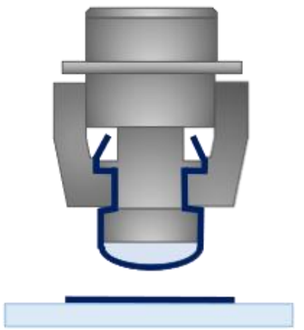
R 50



Pin: PDMS 10 ShA (muscle)
rabbit fascia
Plate: PDMS 10 ShA (muscle)
rabbit fascia

E

R 50



Pin: PDMS 10 ShA (muscle)
synthetic fascia
Plate: PDMS 10 ShA (muscle)
synthetic fascia

F

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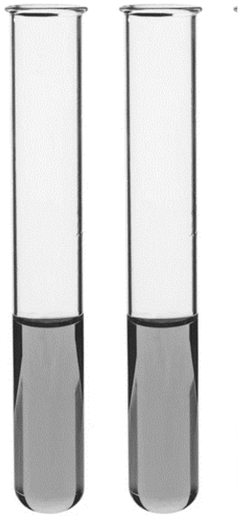
CONTIPRO

Lubricants

Native forms of HA

MW of 101, 316, 610, 2000 kDa; conc. 2%
MW of 316 kDa; conc. 1%

HA derivatives



HA-RED - MW of 275 kDa; conc. 2%
HA-C12 - MW of 318 kDa; conc. 0.3%

PBS

Low-viscosity mineral oil

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Thesis layout

Hyaluronic acid properties scale estimation
(Study II)

Phase – 2

Phase – 1

The influence of material hardness and motion speed on fascia model friction (Study I)

Phase – 3

Tribological model development (Study III)

Phase – 4

Hyaluronic acid frictional properties (Study III and Study IV)

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Results[I]

The influence of material hardness and motion speed on fascia model friction

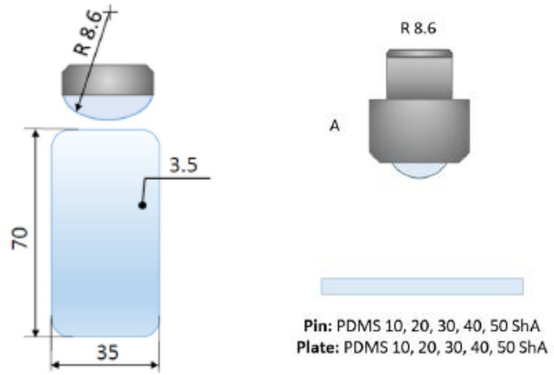

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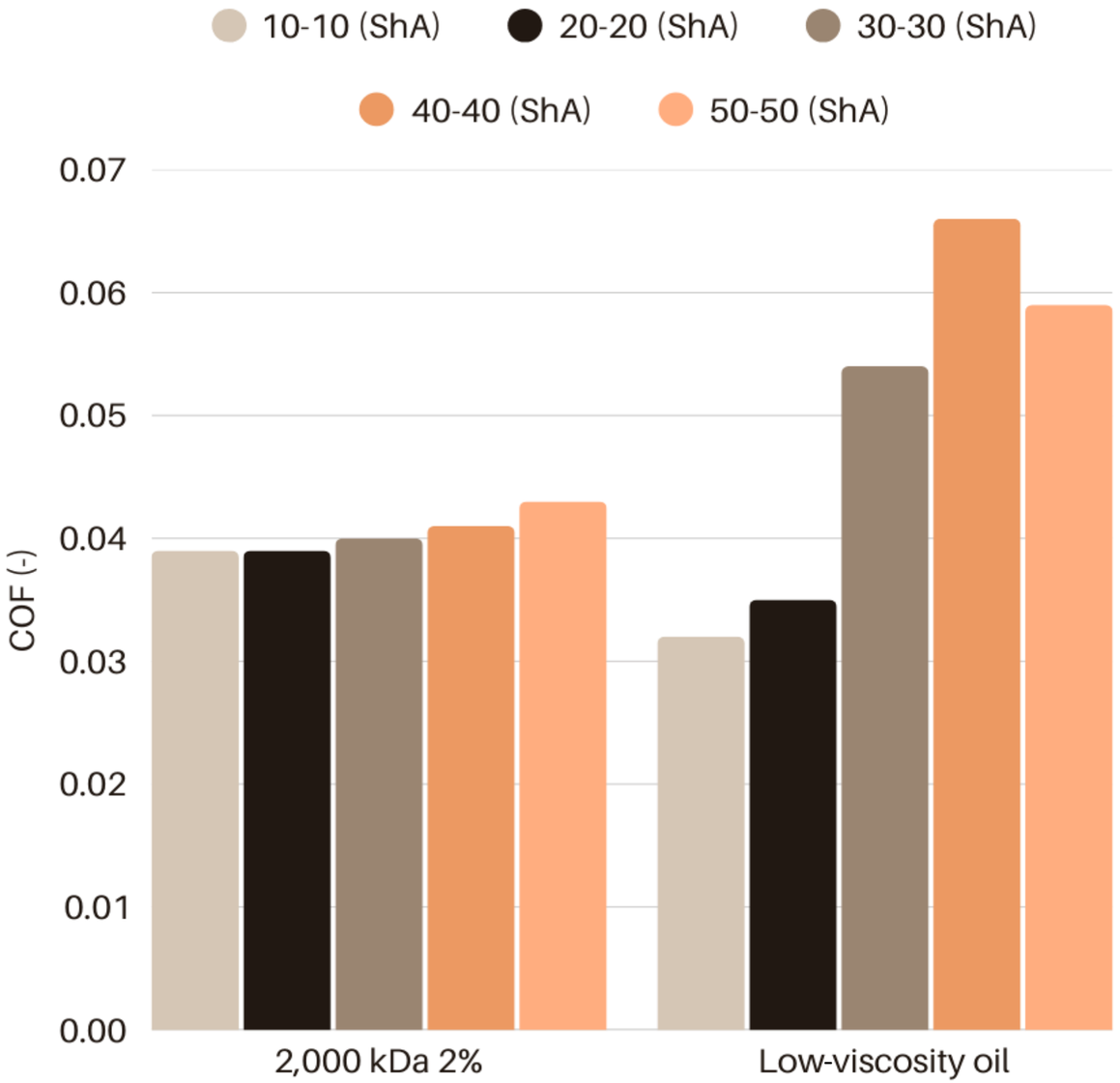
Plate: PDMS 10, 20, 30, 40, 50 ShA



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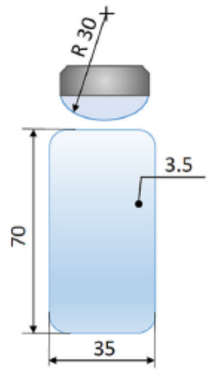
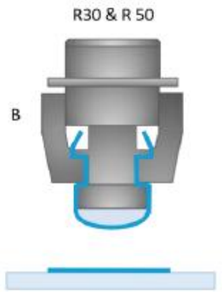
Results II

Hyaluronic acid properties estimation





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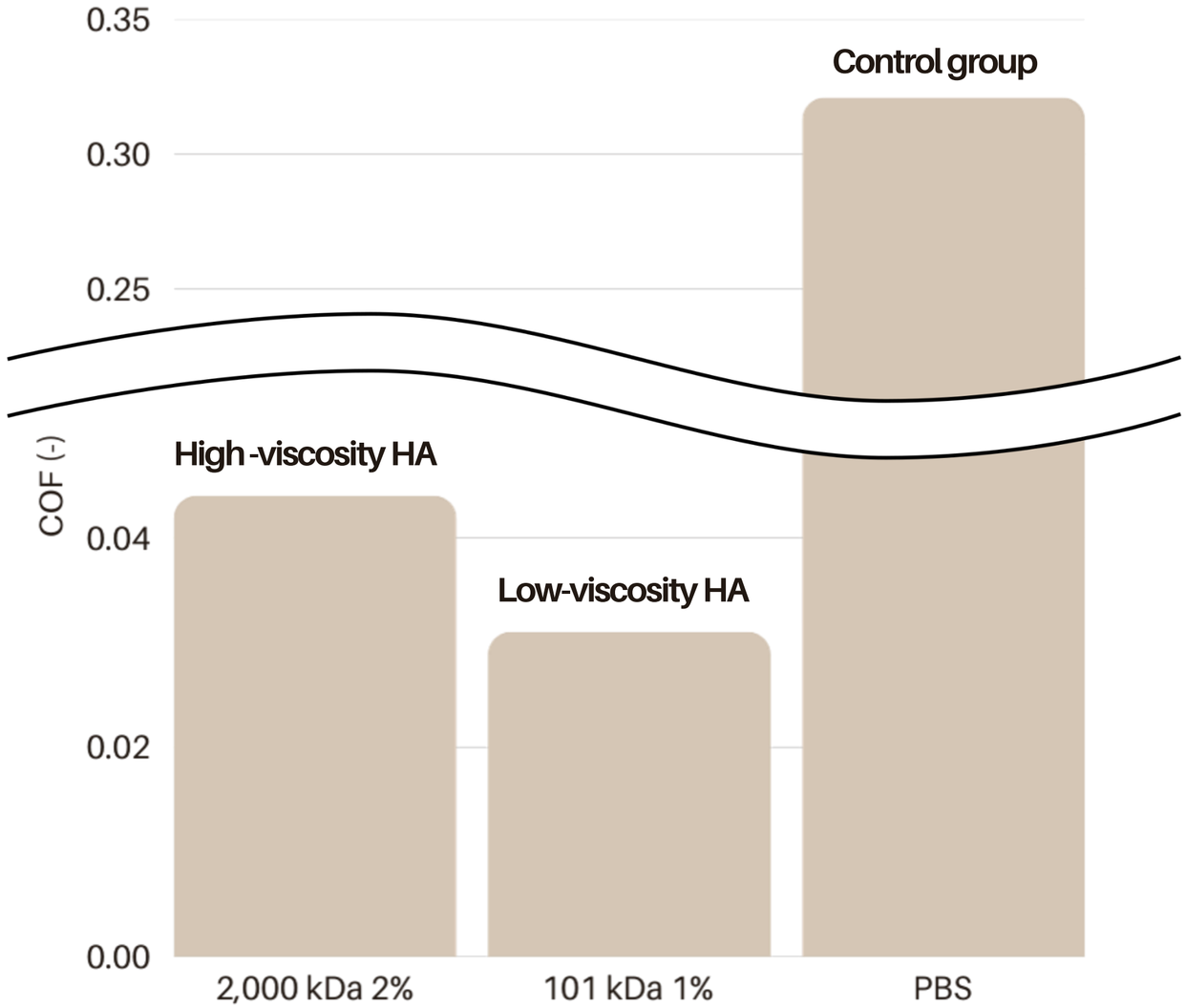

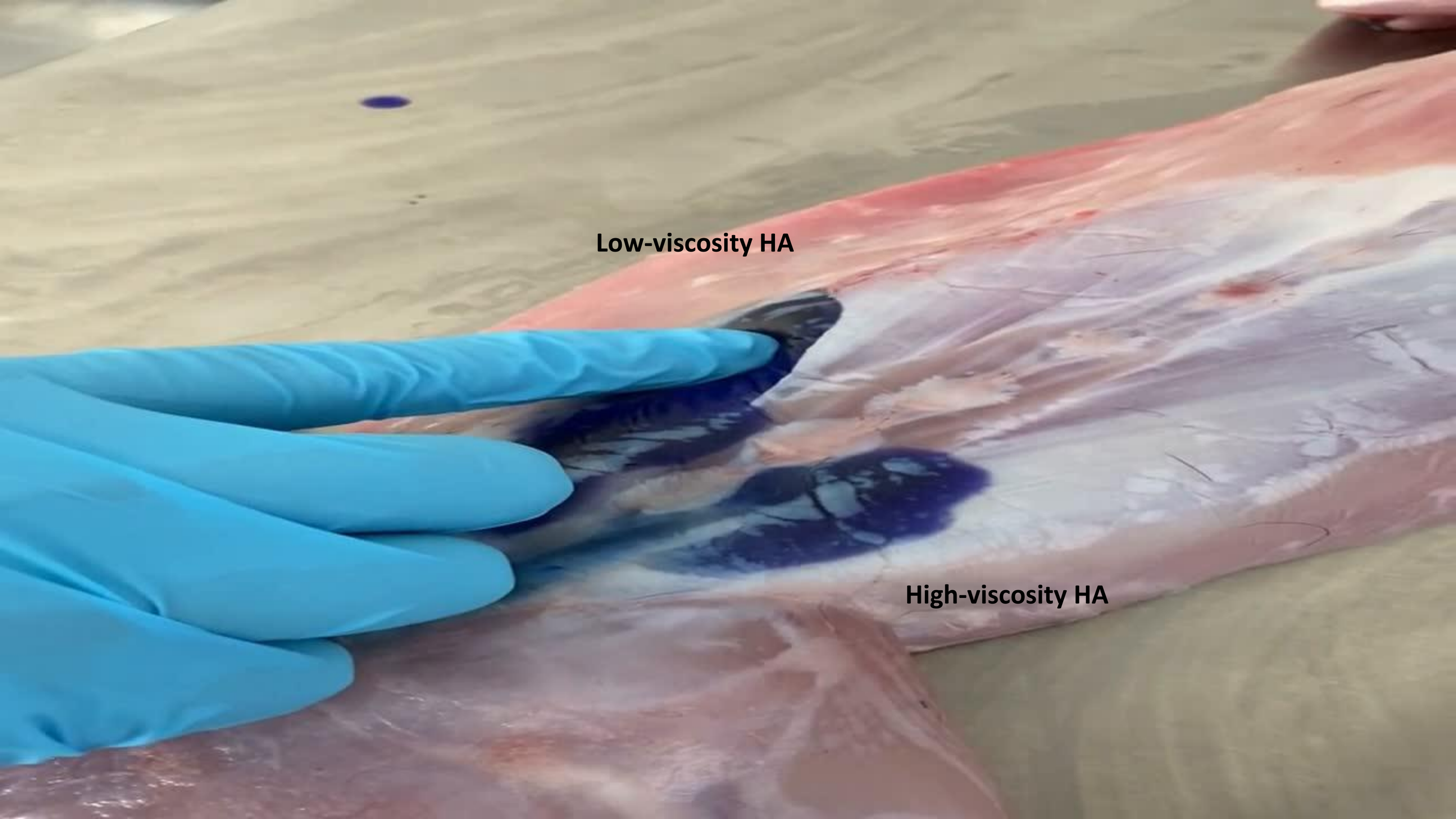
Low-viscosity HA
High-viscosity HA

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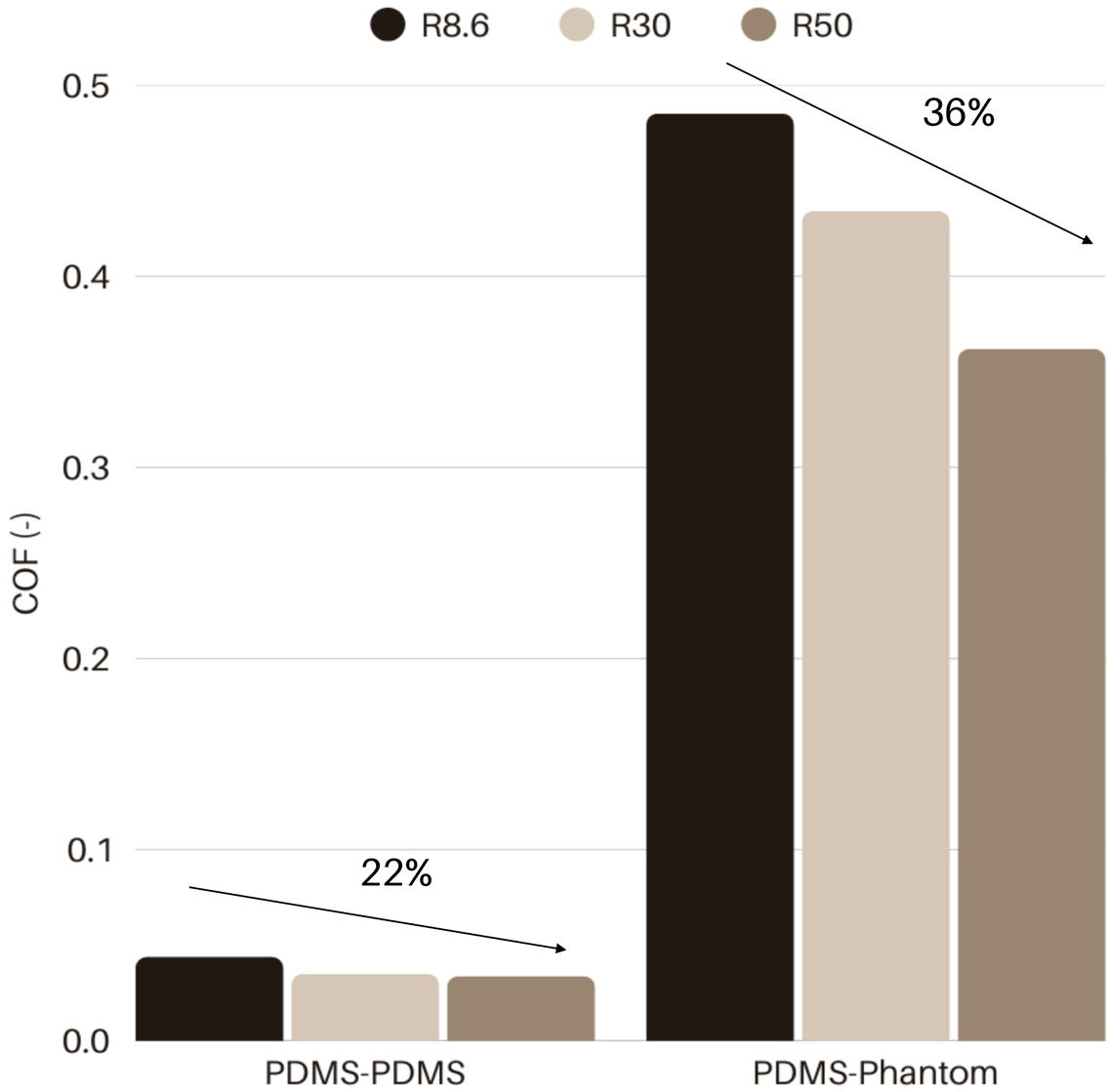
Results III

The effect of pin geometry

The most rigid model
PDMS-PDMS

The most compliant model
PDMS-Phantom



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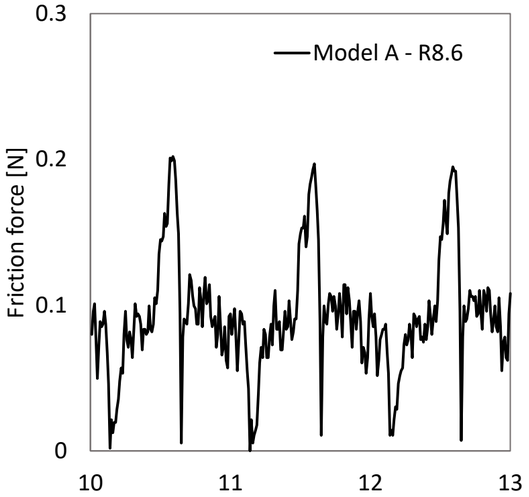
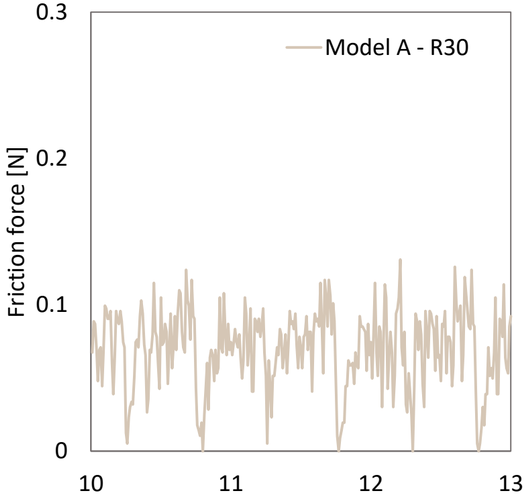
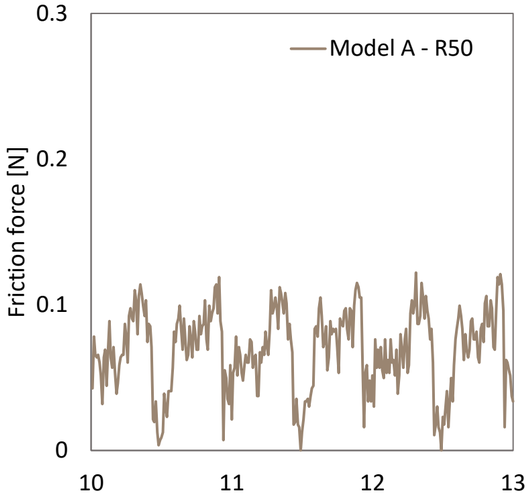
The effect of pin geometry

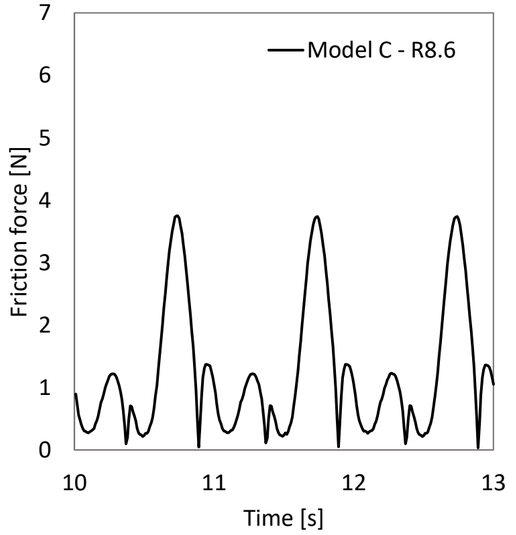
The most rigid model
PDMS-PDMS

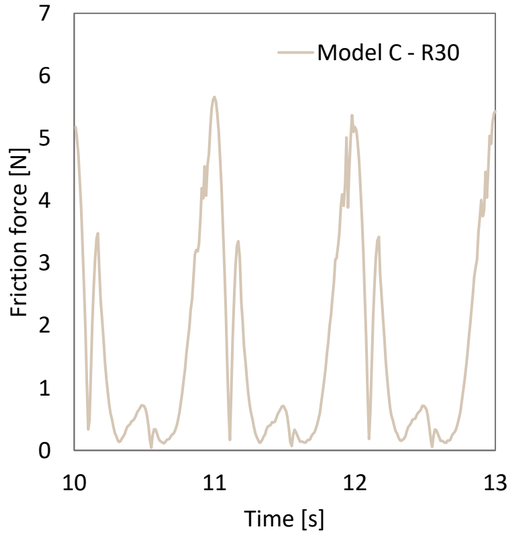


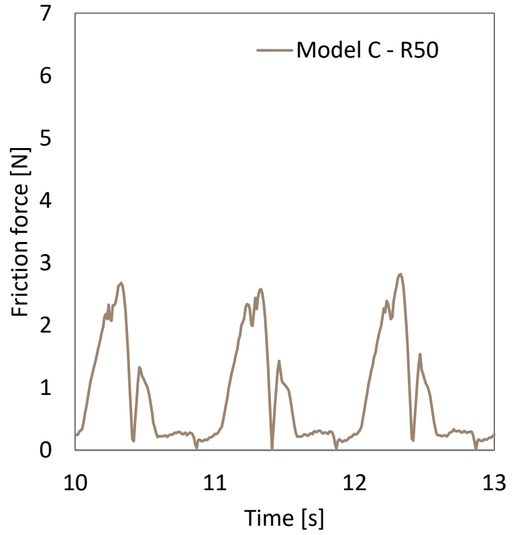




The most compliant model
PDMS-Phantom







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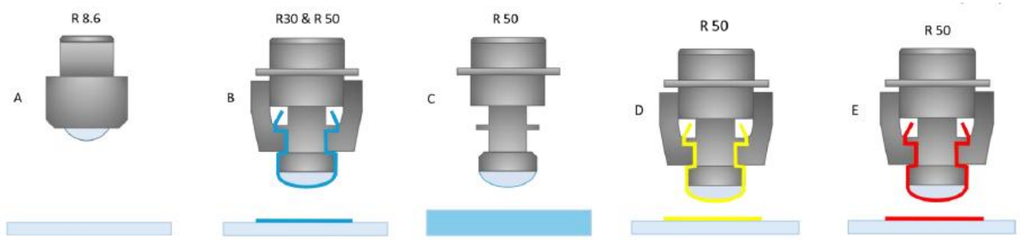
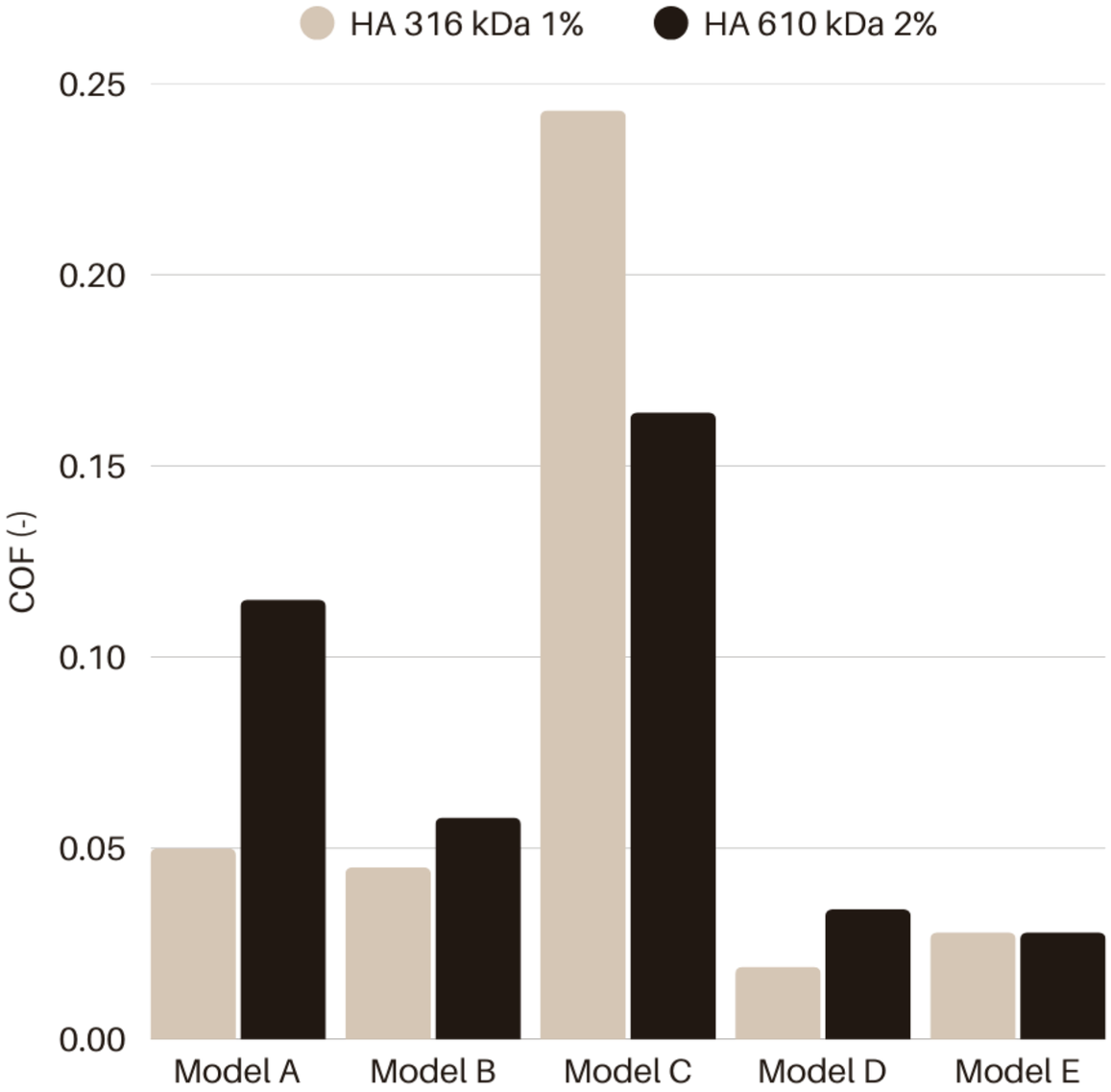
Results III

Testing of friction in fascia models



common model | 2-layered model | the softest model | hydrophilic model | rabbit fascia model



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Results III

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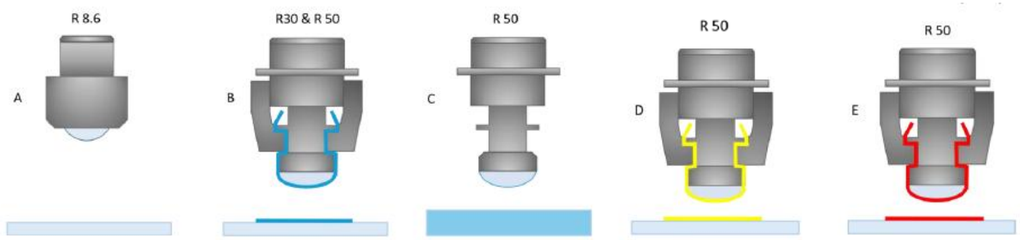

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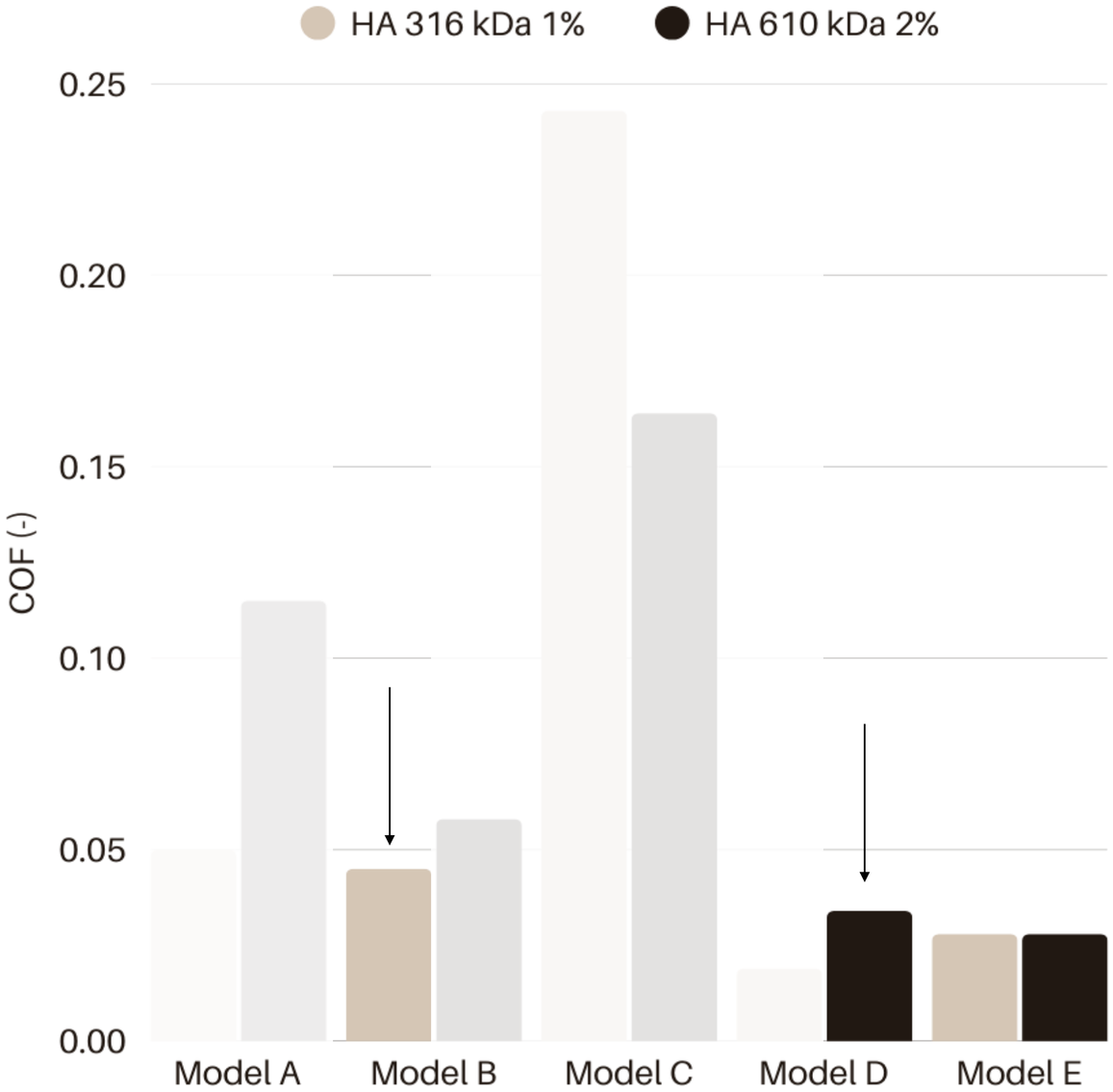

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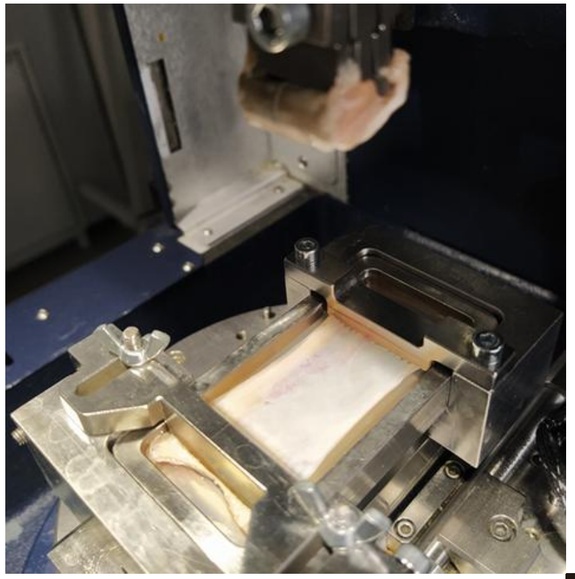
Results IV

The effect of fascia prestressing



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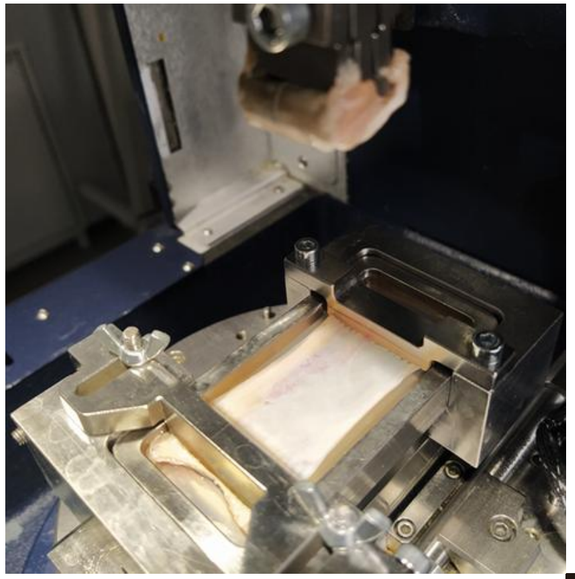
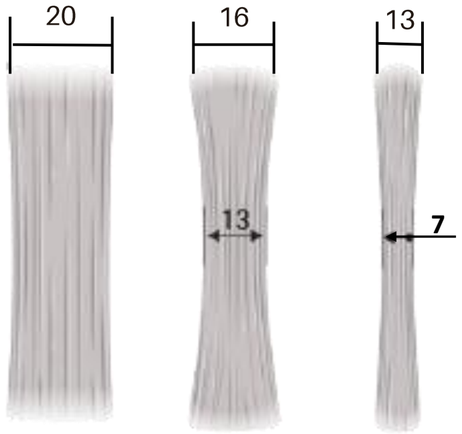
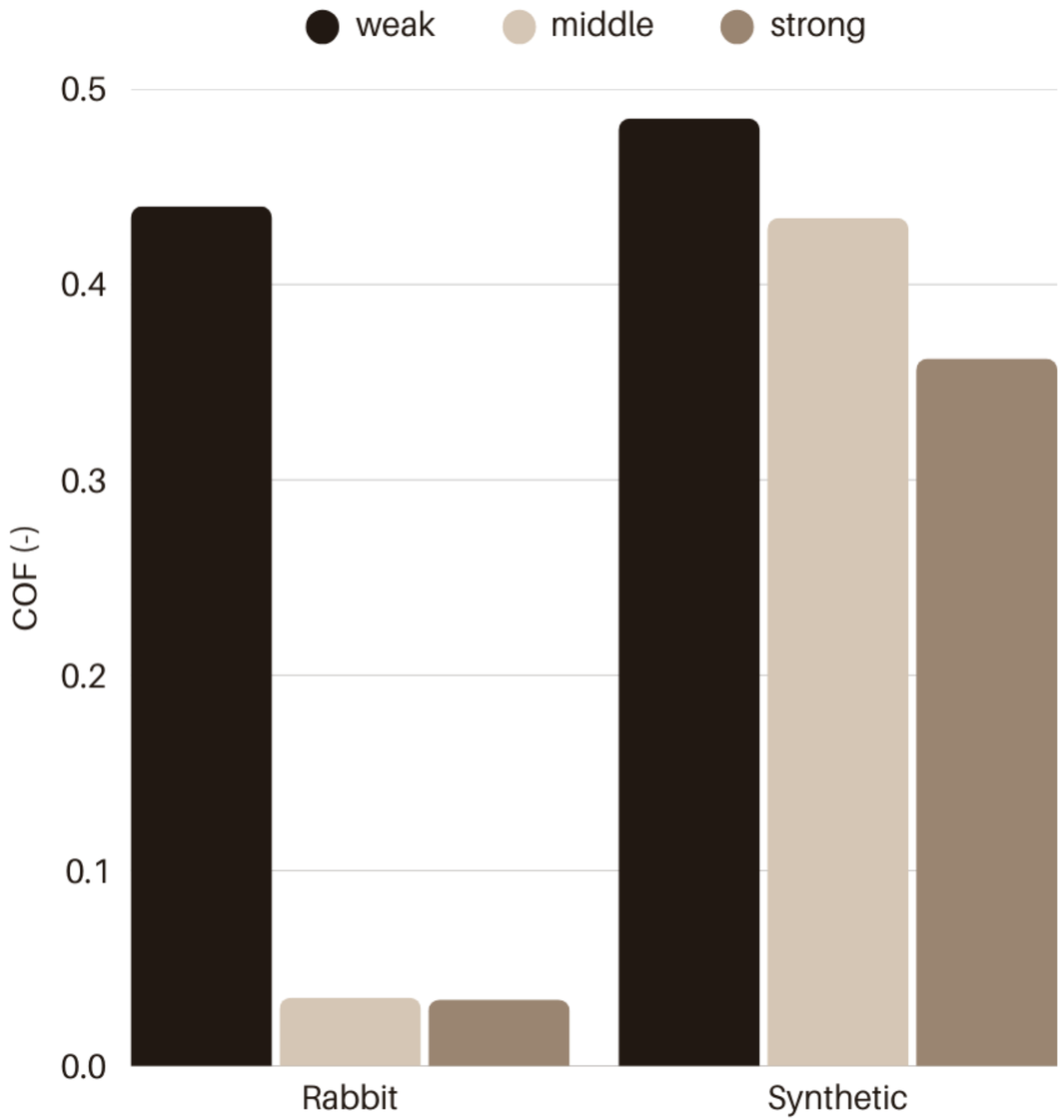
Results IV

The effect of fascia prestressing







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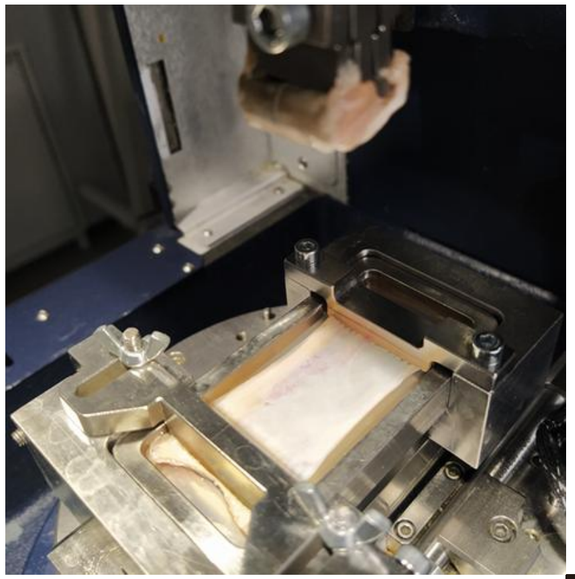

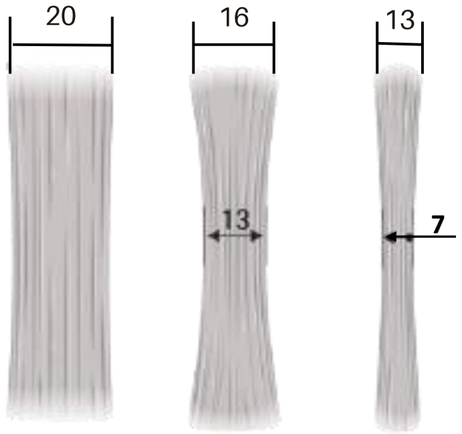

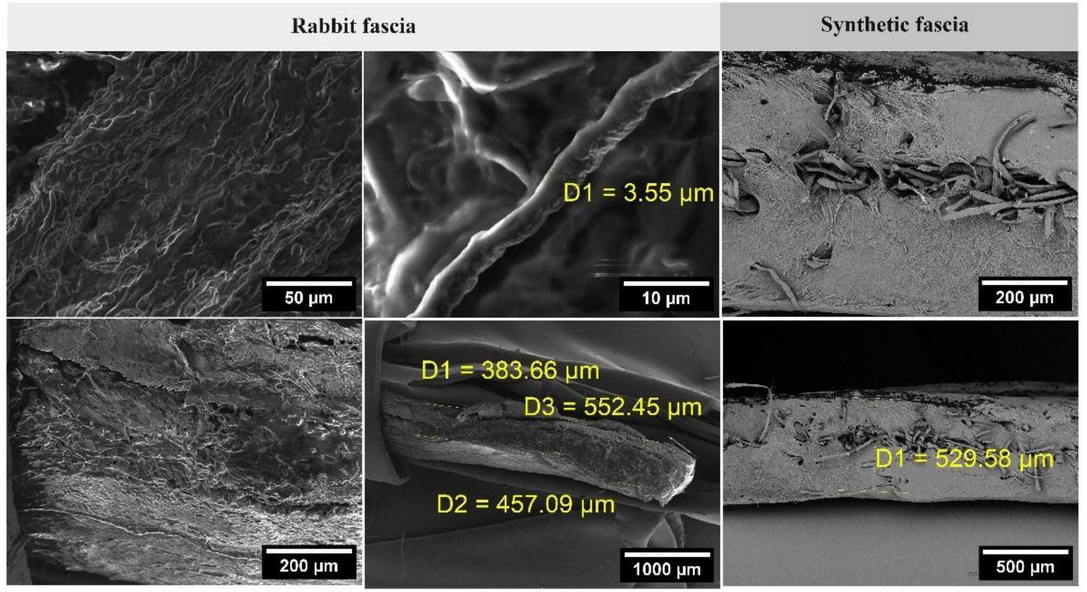

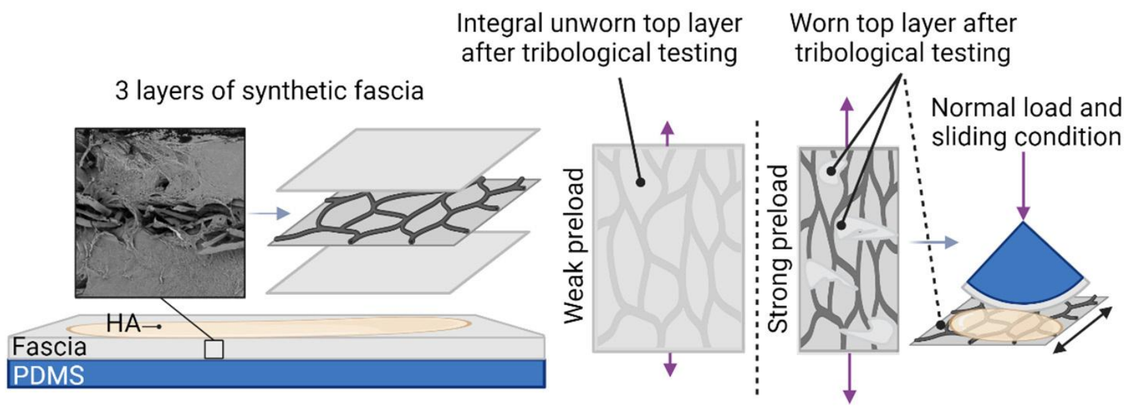

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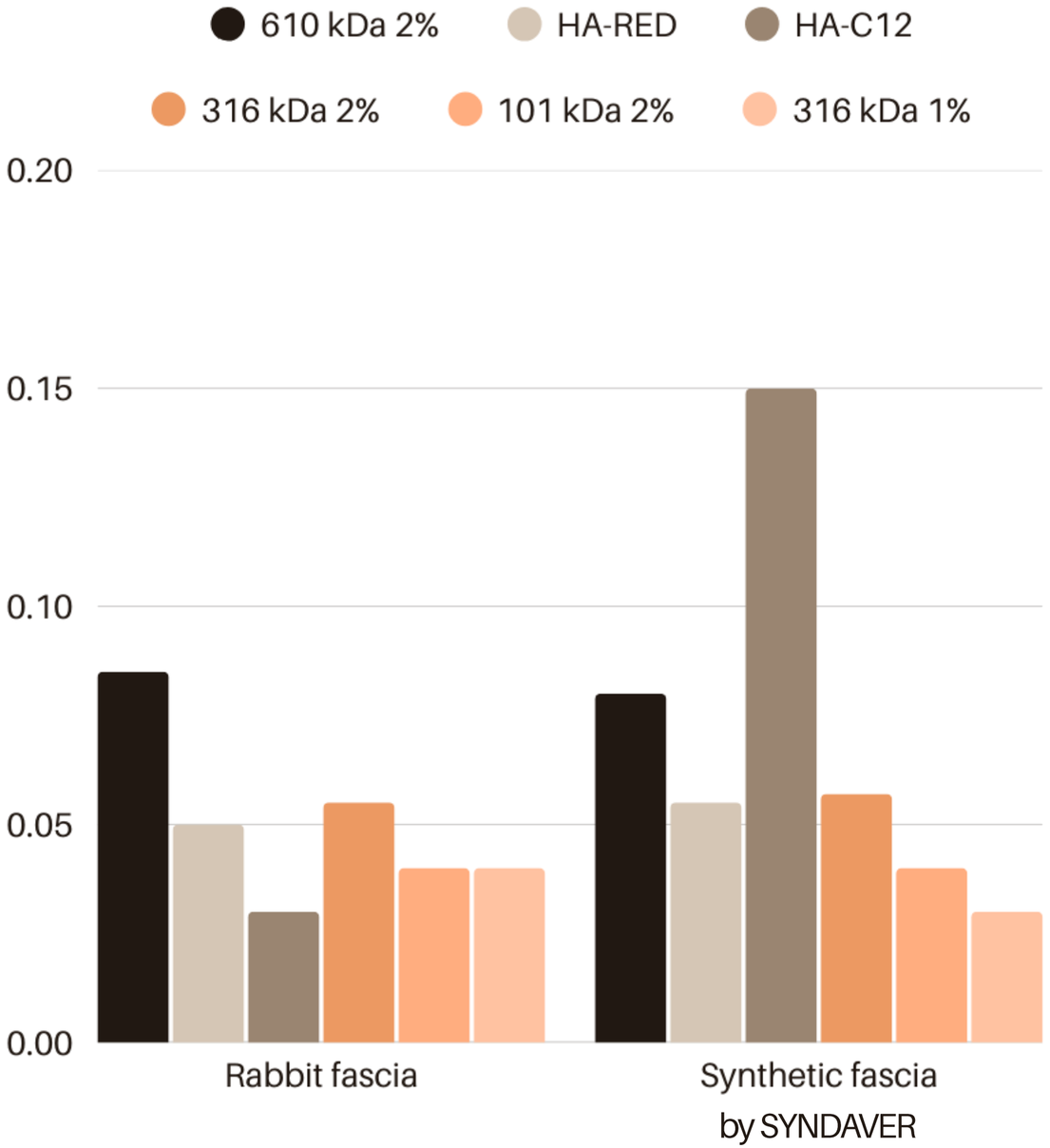
Results IV

Native forms vs HA derivatives



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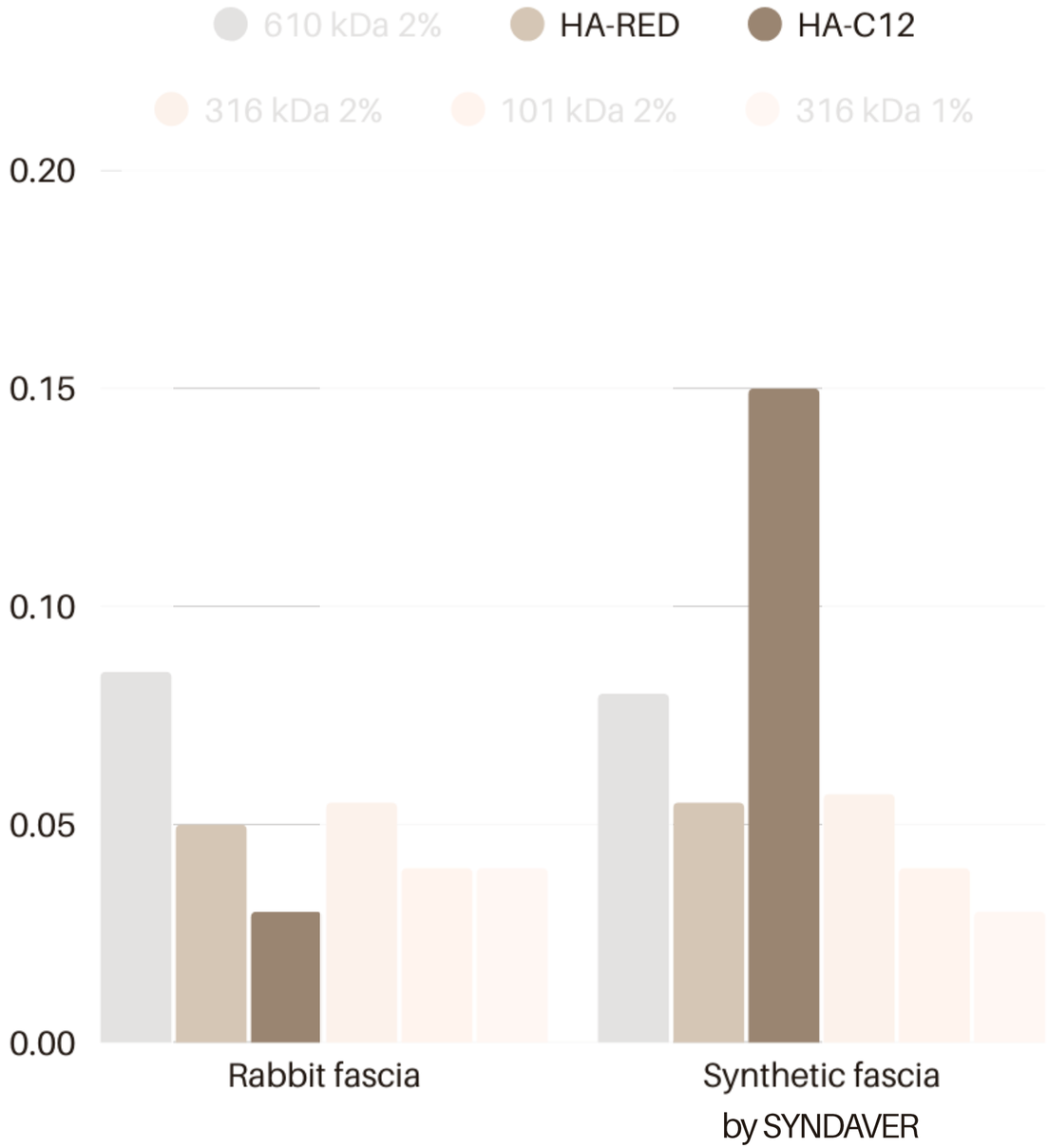
Results IV

Native forms vs HA derivatives



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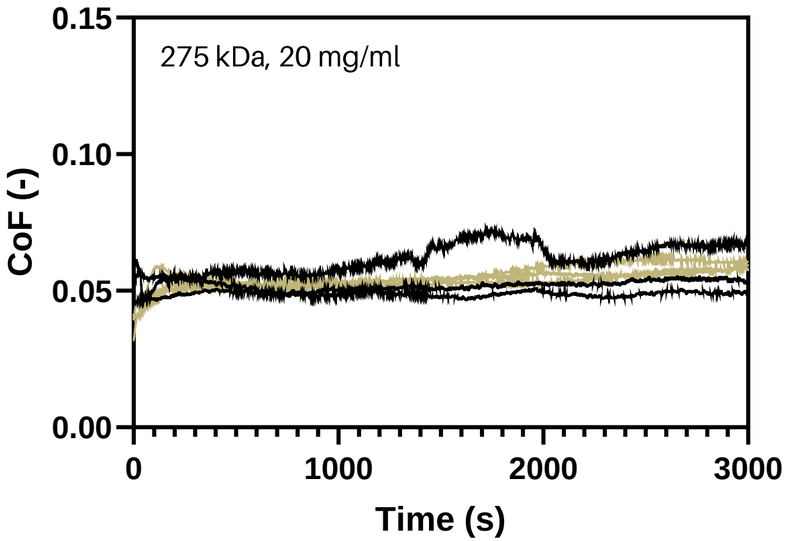
Results IV

Native forms vs HA derivatives

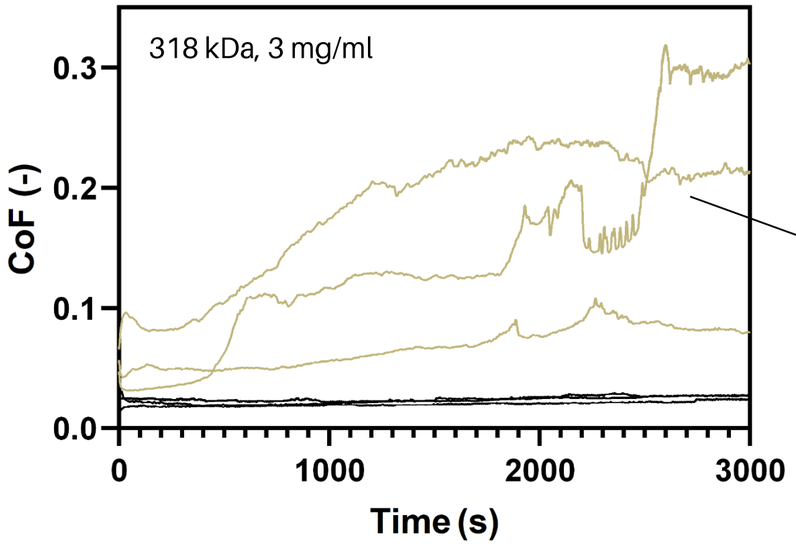
610 kDa 2% HA-RED HA-C12

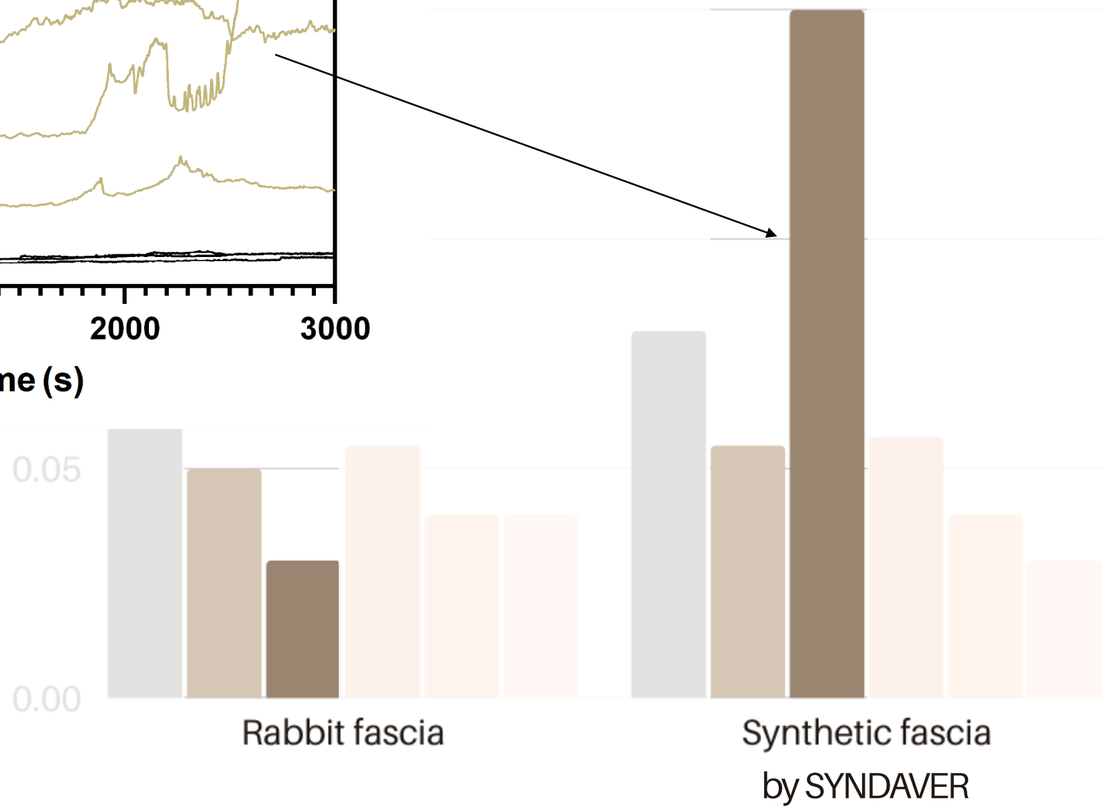
316 kDa 2% 101 kDa 2% 316 kDa 1%

HA-RED



HA-C12





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Scientific outcomes

- Tribological models enable controlled testing without biological tissue
- Material stiffness affects friction more than contact area
- Lower MW HA provides superior lubrication
- Collagen structure of the fascia improves HA lubrication
- Chemical derivation matters but...

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Conclusion

The optimal HA for fascial viscosupplementation should be:

- Low to medium MW (101–316 kDa)
- Moderate concentration (10 mg/ml)
- Stable long-term performance
- Compatible with collagen-rich tissues
- Biocompatible with prolonged retention

Fascigel

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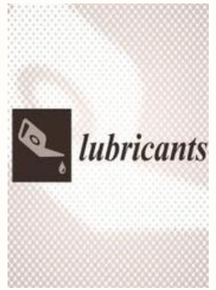
Conclusion

STREĎANSKÁ, A., D. NEČAS, M. VRBKA, I. KŘUPKA, M. HARTL, E. TOROPITSYN, J. HUSBY. Development of Tribological Model of Human Fascia: The Influence of Material Hardness and Motion Speed. Biotribology, Volume 30, 2022, ISSN 2352-5738.
[CiteScore – 3.9]. (Author's contribution 53%)

NEŠPOROVÁ, K., J. MATONOHOVÁ, J. HUSBY, E. TOROPITSYN, L. DIVOKÁ STUPECKÁ, A. HUSBY, T. SUCHÁNKOVÁ KLEPLOVÁ, **A. STREĎANSKÁ**, M. ŠIMEK, D. NEČAS, M. VRBKA, R. SCHLEIP, V. VELEBNÝ. Injecting hyaluronan in the thoracolumbar fascia: A model study. International Journal of Biological Macromolecules, Volume 253, Part 3, 2023. ISSN 0141-8130.
[IF = 7,7]. (Author's contribution 20%)

STREĎANSKÁ, A., D. NEČAS, M. VRBKA, J. SUCHÁNEK, J. MATONOHOVÁ, E. TOROPITSYN, M. HARTL, I. KŘUPKA, K. NEŠPOROVÁ. Understanding frictional behavior in fascia tissues through tribological modeling and material substitution, Journal of the Mechanical Behavior of Biomedical Materials, Volume 155, 2024, 106566, ISSN 1751-6161.
[IF = 3,3]. (Author's contribution 47%)

STREĎANSKÁ, A., M. ŠIMEK, J. MATONOHOVÁ, D. NEČAS, M. VRBKA, J. SUCHÁNEK, V. PAVLIŇÁKOVÁ, L. VOJTOVÁ, M. HARTL, I. KŘUPKA, K. NEŠPOROVÁ. Optimizing Hyaluronan-Based Lubricants for Treating Thoracolumbar Fascia Pathologies: Insights from Tribological and Pharmacokinetic Studies, Lubricants 2025, 13, 184.
[IF = 3,1]. (Author's contribution 35%)



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Conclusion

Conferences

5th International Conferece of BioTribology (ICOBT) 2021 - online - live and on-demand

- poster - Best Poster Award - 1st prize

Nordic Tribology Symposium (NordTrib) 2022 - Aalesund, Norway

- oral presentation

International Tribology Conference (ITC) 2023 - Fukuoka, Japan

- oral presentation

Internships

09/2021	(1 month) **Contipro a.s.**, Dolní Dobrouč, Czechia
05/2023	(1 month) **University of Groningen**, Groningen, Netherlands
05-09/2024	(5 months) **Kyushu University**, Fukuoka, Japan

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Thank You Very Much

Email Address :
alexandra.stredanska@vut.cz