

WEAR ANALYSIS OF TOTAL HIP REPLACEMENTS UNDER SUBJECT-SPECIFIC WALKING AND RUNNING CONDITIONS USING FINITE ELEMENT SIMULATIONS

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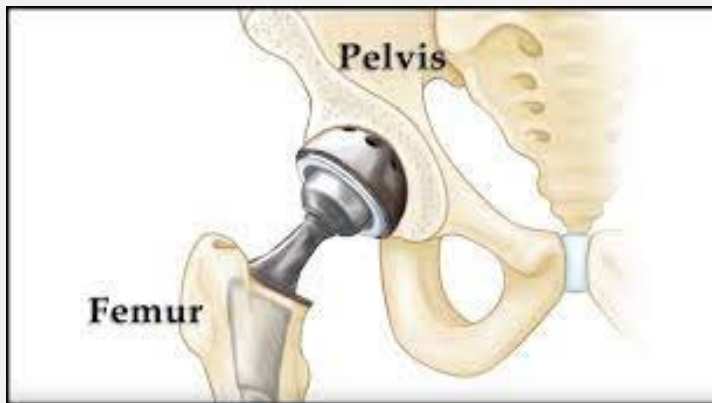
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BACKGROUND: TOTAL HIP JOINT REPLACEMENT AND WEAR PREDICTION

Total Hip Joint Replacement

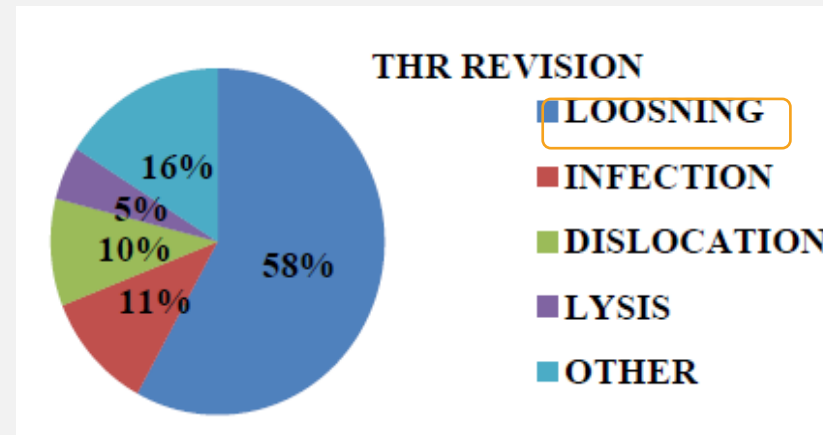
- Composed of an acetabular cup and femoral head with various material combinations



<https://orthoinfo.aaos.org>

Implant's Failure

- For the cup liner made of polyethylene-based materials, loosening is the major implant failure



Causes of failure of hip joint replacements [2]

Wear and Wear Particles

- Osteolysis (bone loss) and loosening due to polyethylene wear particles
- Excessive wear (threshold of 0.1 mm/year) could trigger osteolysis [3]
- Wear prediction
 - Joint wear simulator
 - Numerical simulations

[2] Chethan KN, et al. Role of different orthopedic biomaterials on wear of hip joint prosthesis: A review. *Materials Today: Proceedings* 2018 (5) 20827-36.

[3] Bergvinsson H, et al. Highly cross-linked polyethylene still outperforms conventional polyethylene in THA: 10-year RSA results. *Acta Orthop* 2021 (92): 568–574.

THE QUESTION ASKED BY PATIENTS

- Is it safe for me to return activities including running?
- If it is safe, how much I can do without affecting my hip/knee implants?
- Our study aims to help answer these questions with quantitative evidence based on wear analysis.



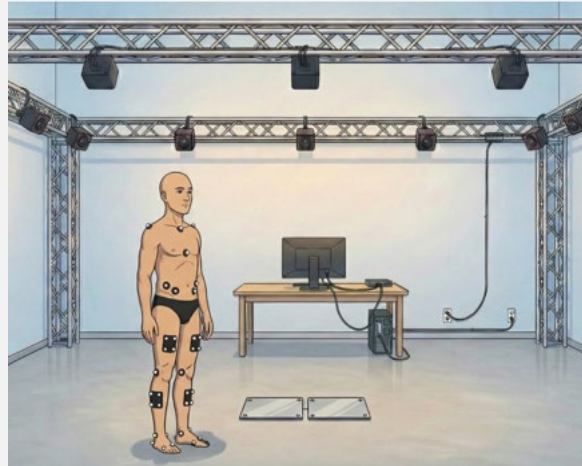
BIOMECHANICS: METHODOLOGY

Participants: 11 active

- 6 females and 5 males
- 12+ months post-operation
- Age 55.9 ± 9.8 years (younger)
- BMI 22.8 ± 2.8 (lower)



Motion Capture



Musculoskeletal Modelling (AnyBody)



- Joint motions
- Joint contact forces

Summary of key facts about joint replacement during the 2024 calendar year^[4]

Hips



recorded by the NJR since April 2003

2024

116,901

primary total and resurfacing replacement procedures

average ages:

67.2 69.5
60%

Data:



Acute trauma



Osteoarthritis

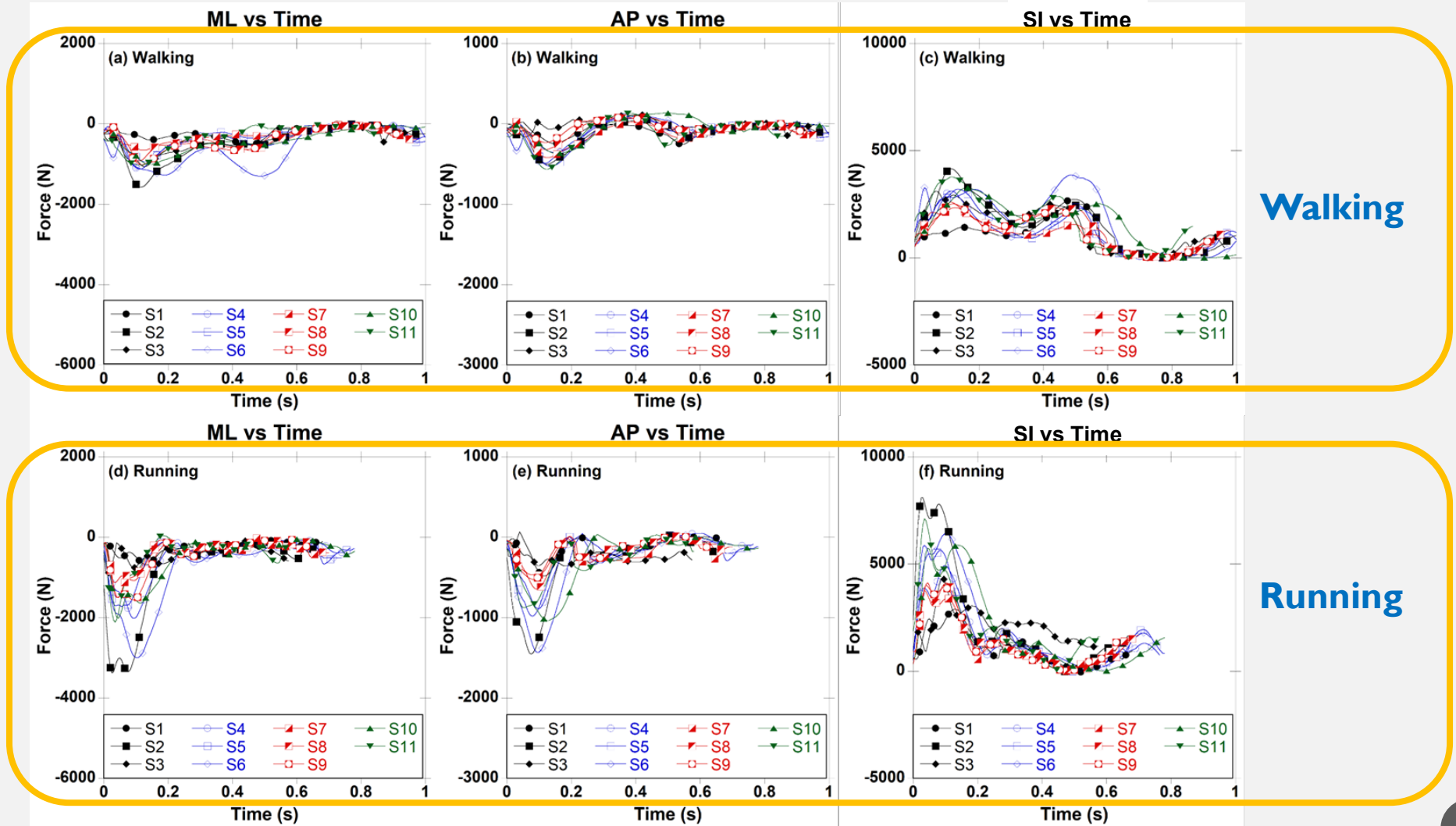
average BMI
28.9

[4] National Joint Registry (NJR) – 22nd Annual Report 2025

BIOMECHANICS: RESULTS OF FORCES

Joint forces in 3D directions

- Medial-Lateral (ML)
- Anterior-Posterior (AP)
- Superior-Inferior (SI)
- Cyclic time normalised to 1 sec



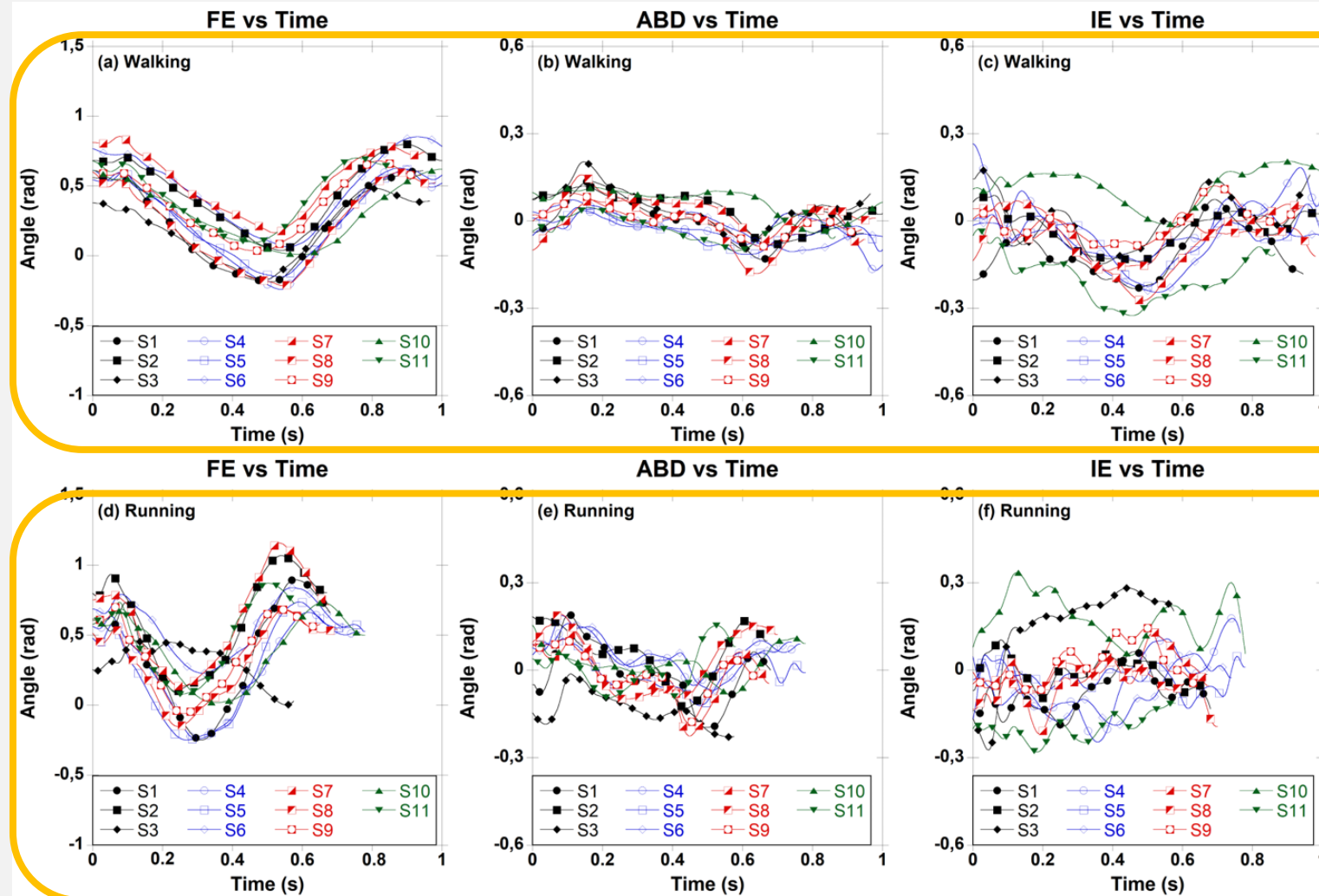
Walking

Running

BIOMECHANICS: RESULTS OF ANGLES

Angle displacements in 3D directions

- Flexion-Extension (FE)
- Adduction-Abduction (ABD)
- Internal-External Rotation (IE)
- Cyclic time normalised to 1 sec



Walking

Running

WEAR: METHODOLOGY OF FEA MODELLING

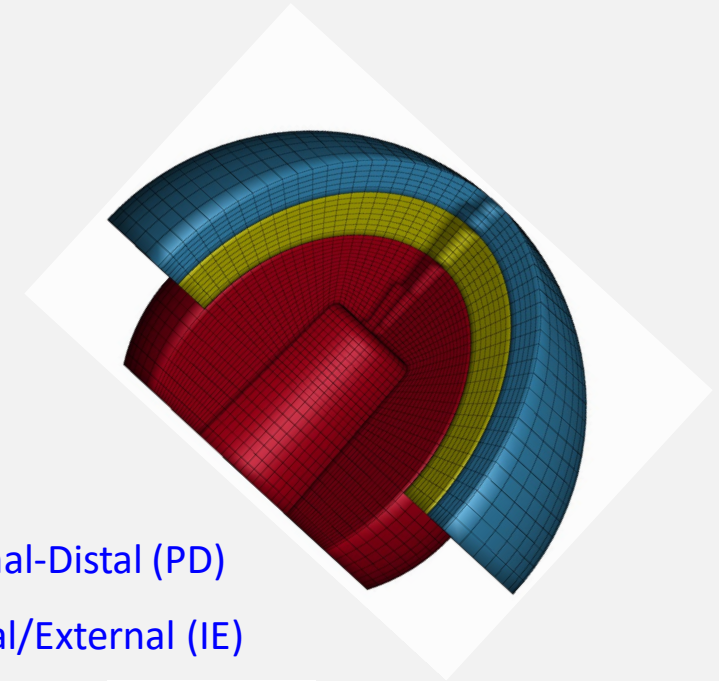
Geometry

Head radius	16 mm
Cup liner bearing surface radius	16.05 mm
Cup liner thickness	4 mm
Cup shell thickness	3 mm

Materials [5]

	XLPE (liner)	CoCr (Shell)
Young's modulus (GPa)	1	210
Poisson's ratio	0.4	0.3
Density (kg/m ³)	963	7800
Hardness (MPa)	45.6	1193

XLPE: Crosslinked polyethylene
CoCr: Cobalt Chromium alloy



Z-axis

Proximal-Distal (PD)

Internal/External (IE)

Y-axis

Medial-Lateral (ML)

Flexion/Extension (FE)

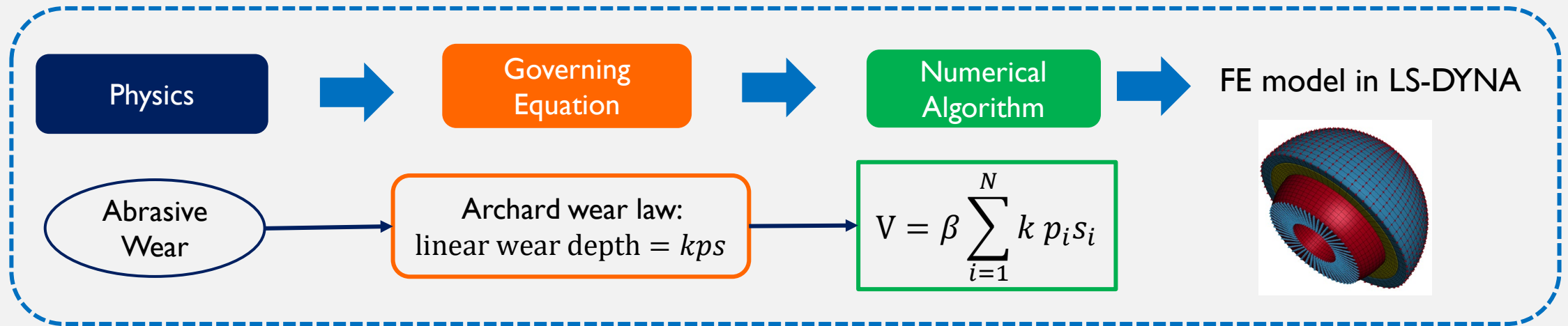


X-axis

Anterior-Posterior (AP)

Abduction/Adduction (ABD)

WEAR: METHODOLOGY OF WEAR LAW

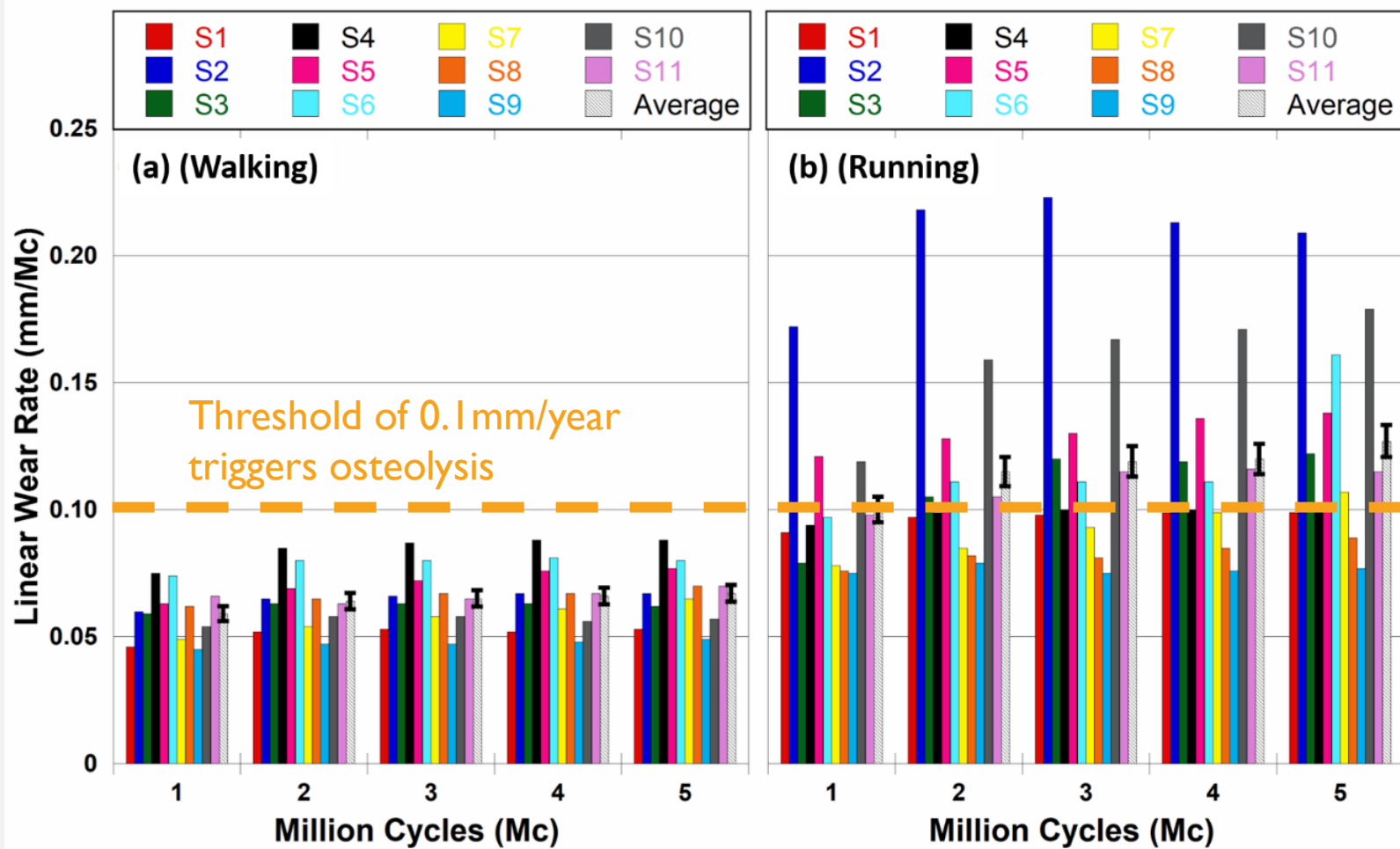


- V - incremental wear volume
- β - number of activity cycles in each updating increment of the worn surface, $\beta = 0.25 Mc$
- k - wear coefficient, $k = 5.32 \times 10^{-10} \text{ mm}^3 / (N \cdot \text{mm})$ [6]
- p_i - contact pressure at the mesh node i
- s_i - sliding distance at the mesh node i
- N - total number of element nodes

Limitations: factors not considered in the current wear model

- Creep deformation
- Lubrication
- Surface roughness

WEAR: RESULTS OF LINEAR RATE



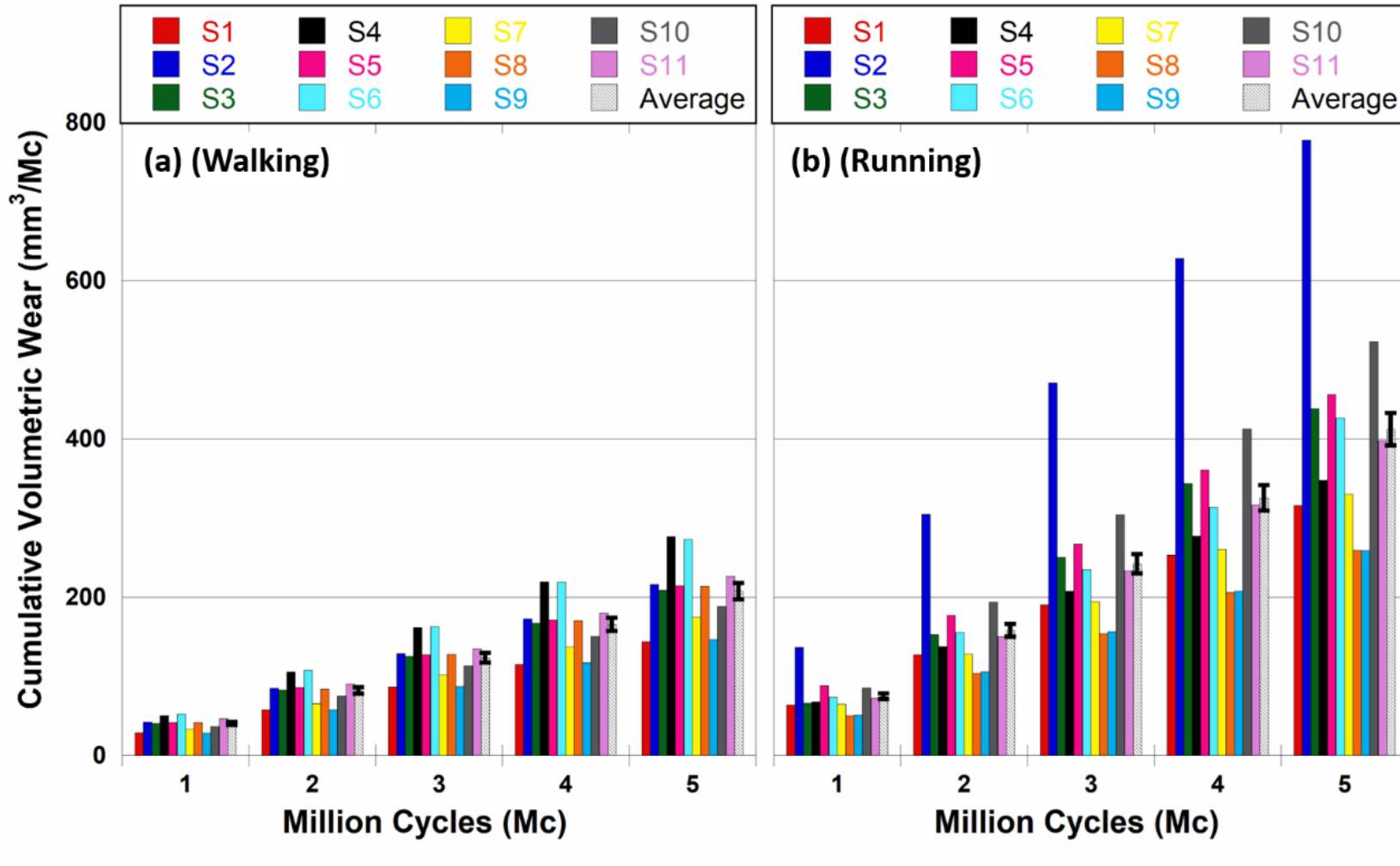
Average wear rate in this study

- 0.06 mm/Mc in walking
- 0.12 mm/Mc in running

Clinical reported wear rate ranged from 0.02 (HXLPE) to 0.17 (Conventional PE) mm/Mc [7].

[7] Hopper et al. Otto Aufranc Award: Crosslinking Reduces THA Wear, Osteolysis, and Revision Rates at 15-year Followup Compared With Noncrosslinked Polyethylene. Clinical Orthopaedics and Related Research 2018 (476):279-290.

WEAR: RESULTS OF CUMULATIVE VOLUME

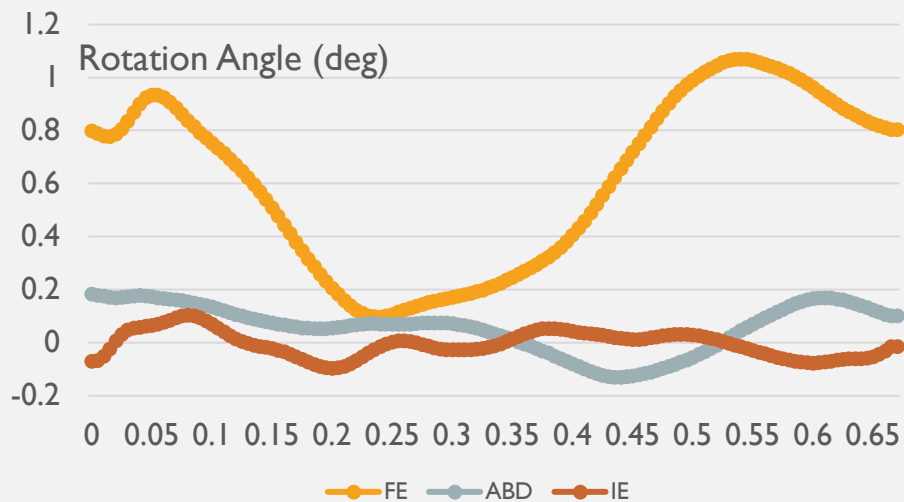
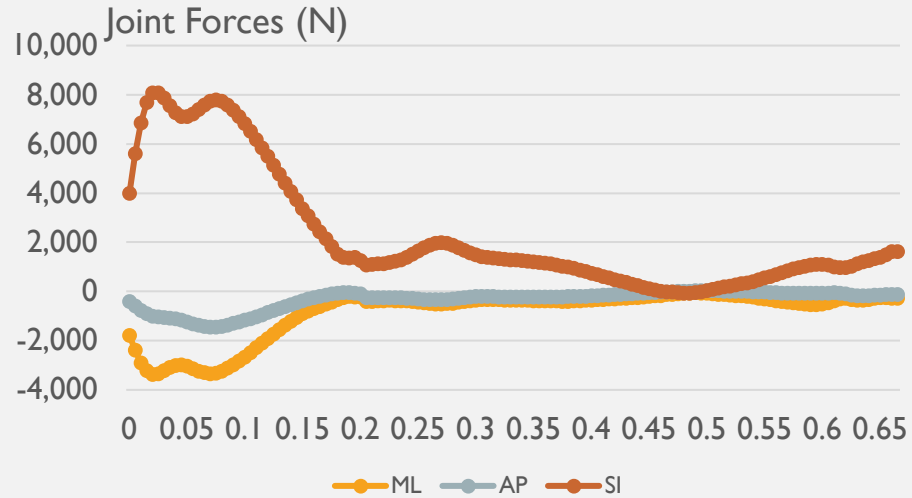


- Mean volumetric wear rate in current study
 - 42 mm³/Mc under walking
 - 82 mm³/Mc under running
- Why the difference between subjects?
 - BMI?
 - Joint loading?
 - Rotation pattern?

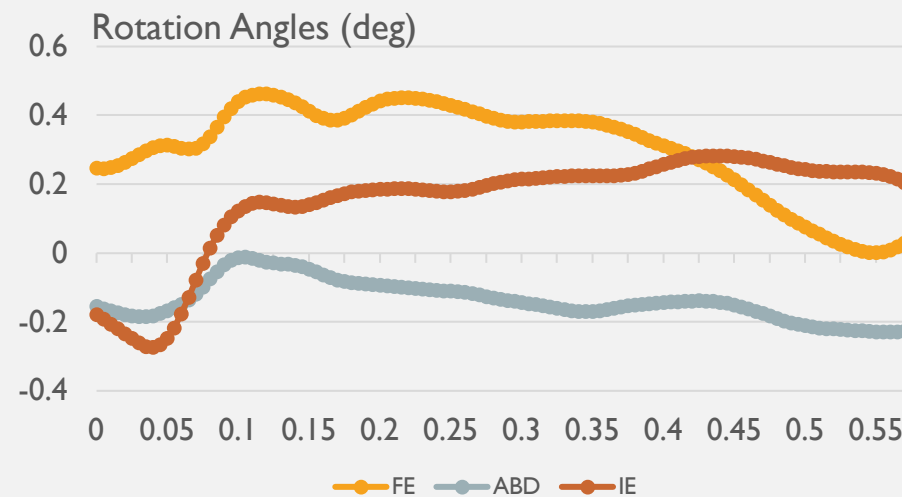
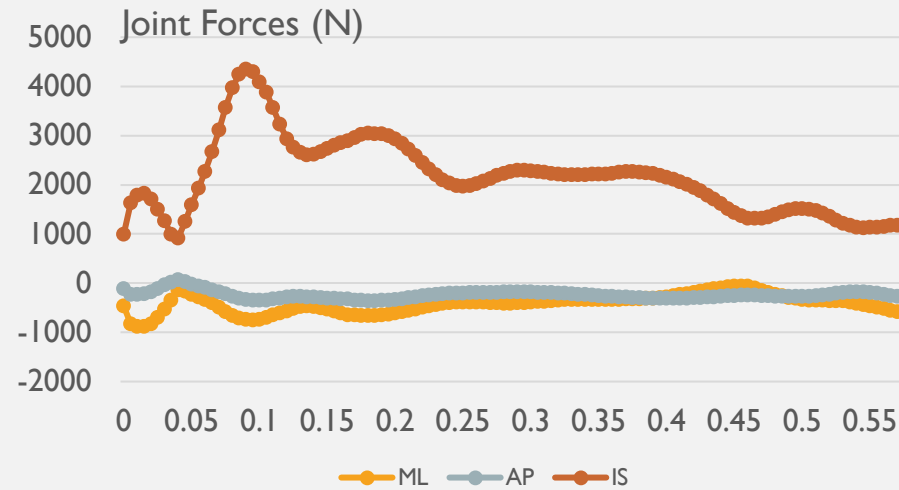
Let's look at Sub #2 and Sub #3

WEAR: RESULTS OF CUMULATIVE VOLUME

Subject 2: BMI 21.0



Subject 3: BMI 21.9



CONCLUSION AND FUTURE WORK

Conclusions

- Across 11 subjects and up to 5 million cycles, running produced approximately two-fold wear than walking
- Dynamic joint loading and rotation angles during running vary significantly between individuals that substantially affect wear
- Use of subject-specific, activity-dependent FE frameworks for implant wear assessment is important

Future Work

- Wear model development including creep and lubrication
- Further investigation of specific subjects to understand the underlying wear mechanism
- More materials (ceramic-on-ceramic) and designs (hip resurfacing)
- Knee joint replacements wear analysis

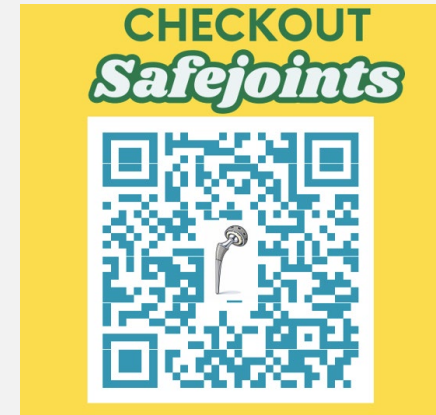
Thank you!

We welcome collaborations and discussions on

- Hip and knee joint wear analysis
- Wear testing protocols
- Patient-specific and high-demand activities

Acknowledgement

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<https://safejoints.netlify.app/>

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