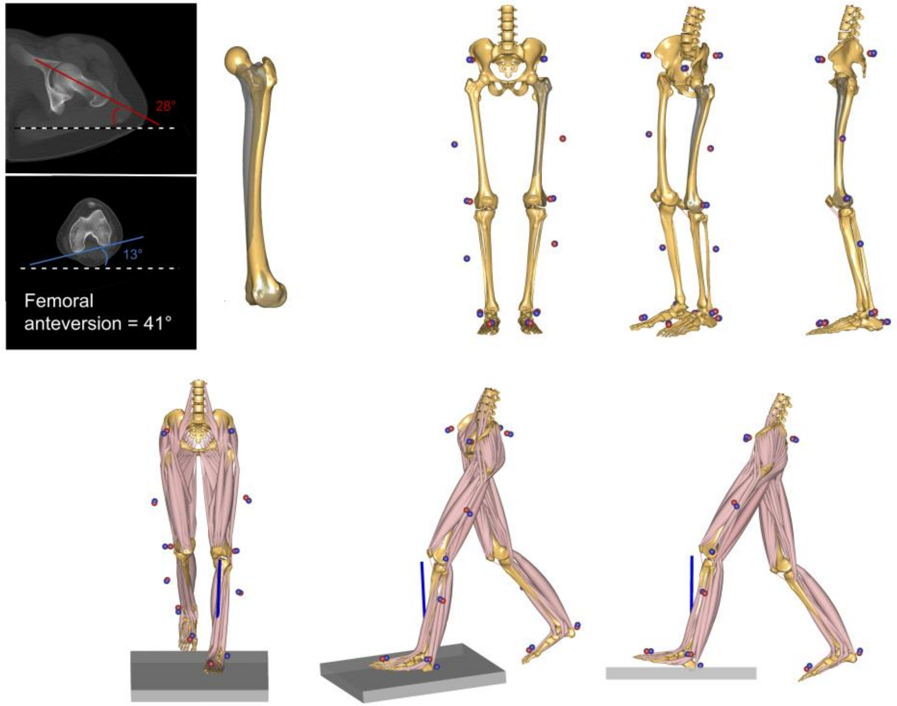
The webcast will begin shortly…

Increased femoral anteversion in children – can musculoskeletal modeling better inform clinical decision-making?

September 14th , 2023



Outline

- Introduction to the AnyBody Modeling System
- Presentation by Dr. Nathalie Alexander and Dr. Enrico De Pieri
- Upcoming events
- Question and answer session

Presenter:
Dr. Nathalie Alexander
Head of the Laboratory of Motion Analysis

The Children's Hospital of Eastern Switzerland in St. Gallen.

Presenter:
Dr. Enrico De Pieri
Senior Research Engineer at Zimmer Biomet

Former Research Associate at the University Children's Hospital Basel.

Host:
Kristoffer Iversen
Technical Sales Executive

AnyBody Technology

Control Panel

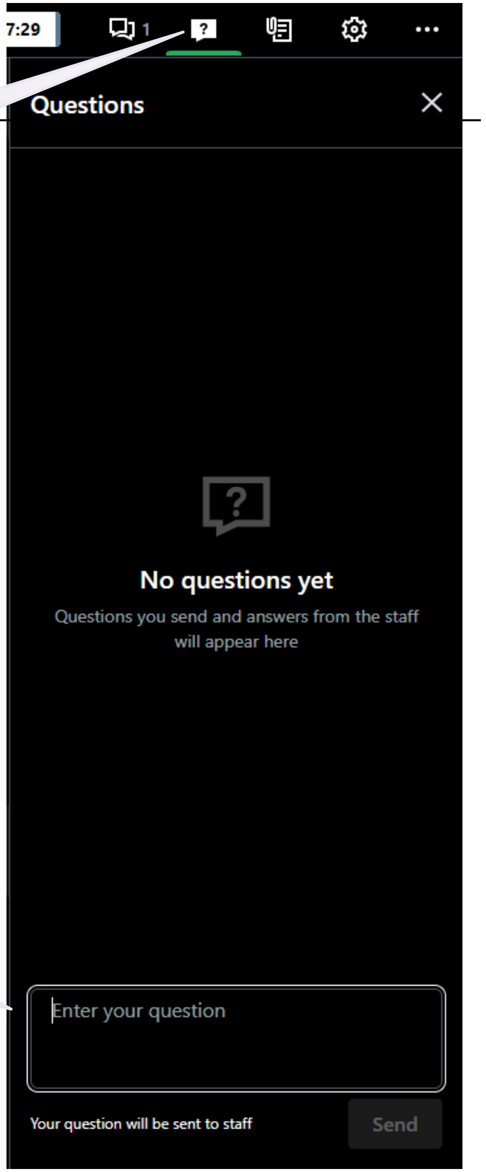
The Control Panel appears on the right side of your screen.

Submit questions and comments via the Questions panel.

Questions will be addressed at the end of the presentation. If your question is not addressed, we will do so by email.

Open the Question Panel

Ask a question during the presentation

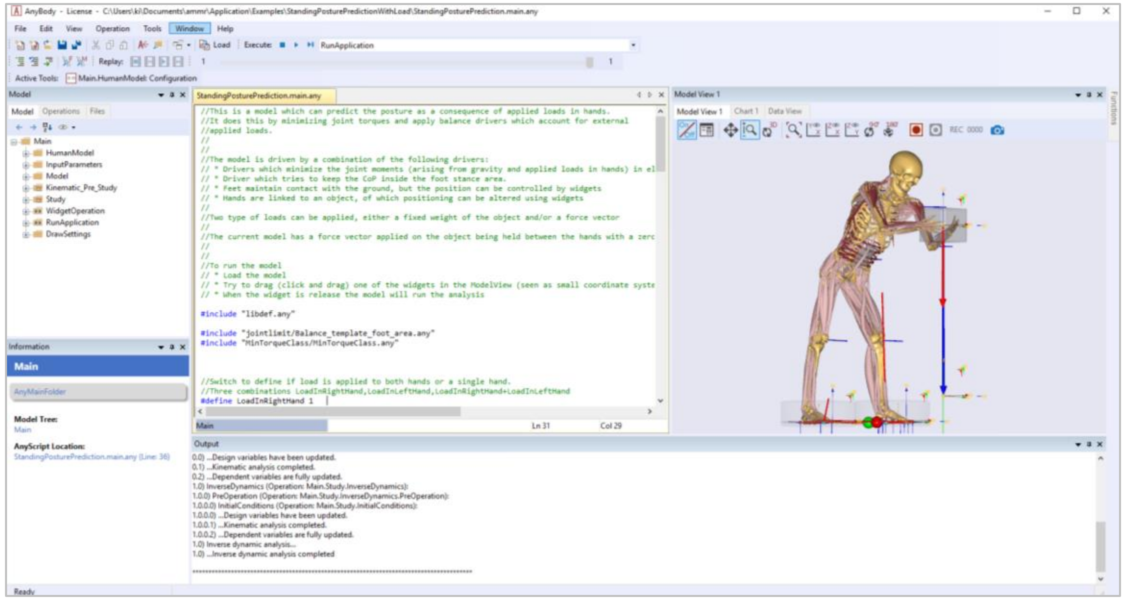


Musculoskeletal Simulation

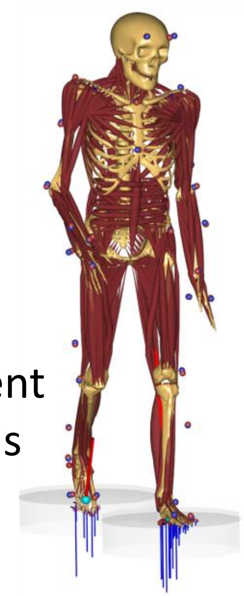
Motion Data
Kinematics and Forces

ANYBODY
Modeling System

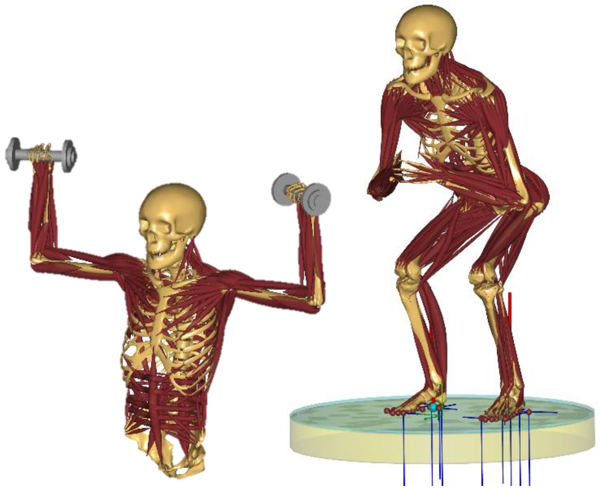
Body Loads
- Joint moments
- Muscle forces
- Joint reaction forces



Product optimization design

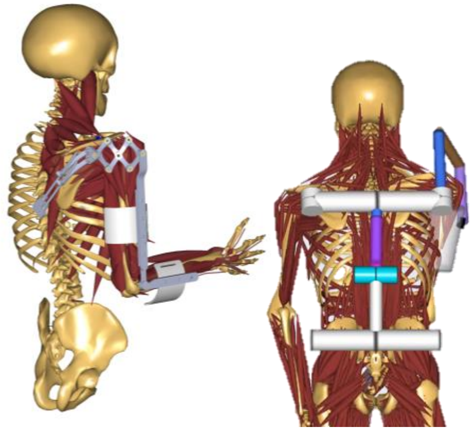


Movement
Analysis

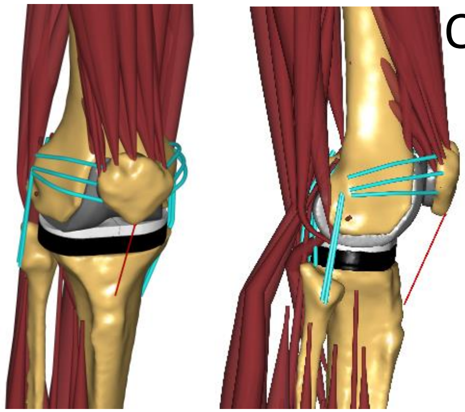


Sports

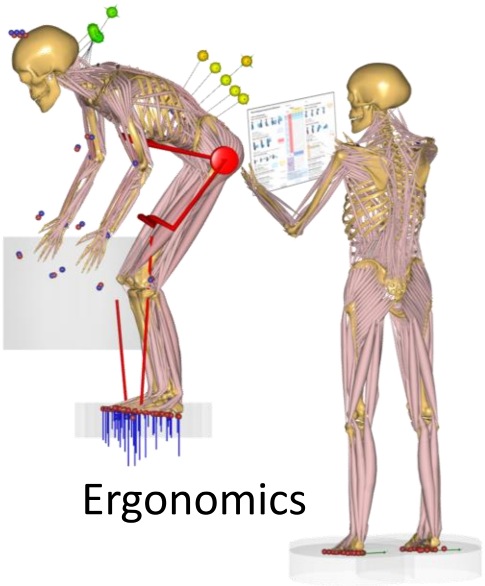
ANYBODY
Modeling System



Assistive
Devices



Orthopedics
and rehab



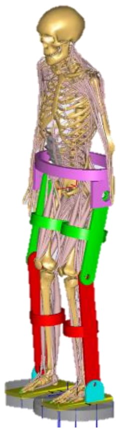
Ergonomics

AnyBody Modeling System

Motion and Forces

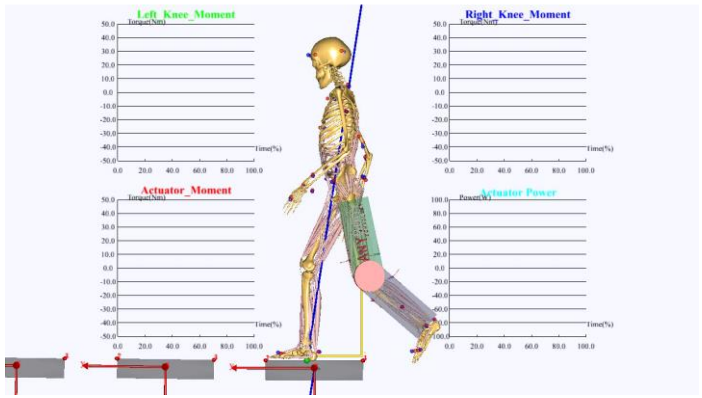
Body model

Environment model



Inverse dynamics
Muscle recruitment

Simulation



Internal body loads

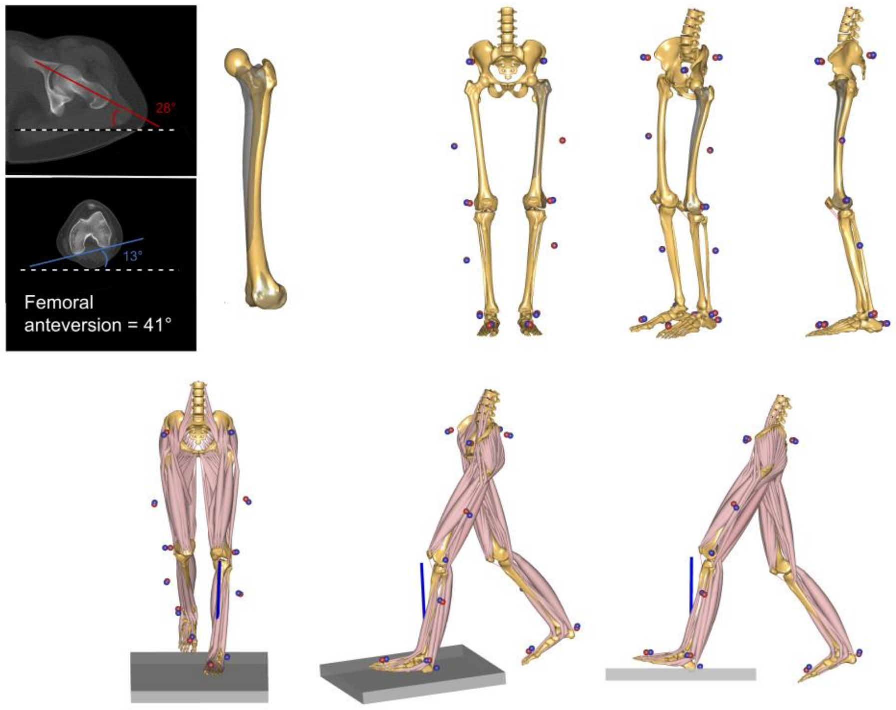
- Muscle forces
- Joint moments

Design Optimization

Post Processing (e.g., Finite element tools)

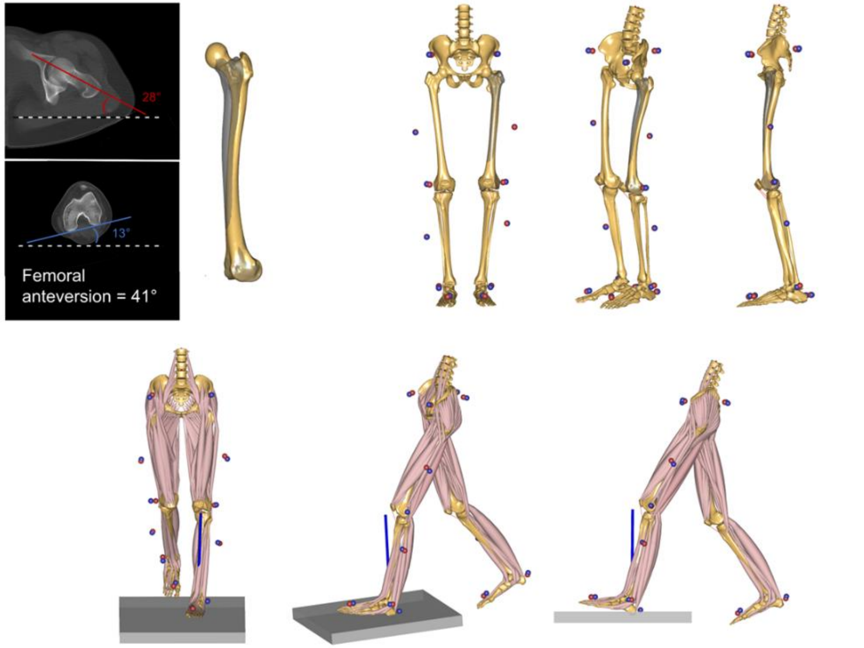
Increased femoral anteversion in children – can musculoskeletal modeling better inform clinical decision-making?

Presented by Dr. Nathalie Alexander and Dr. Enrico De Pieri



Increased femoral anteversion in children

Can musculoskeletal modelling better inform clinical decision-making?



Nathalie Alexander, Enrico De Pieri

Outline

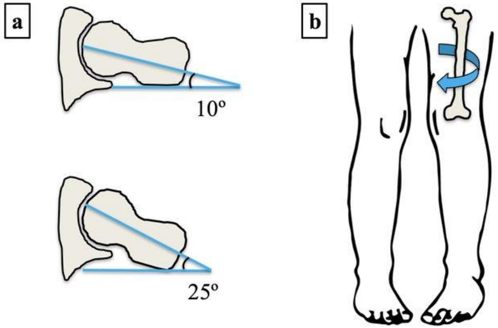
- Introduction
- Study #1: Altered joint loading
- Study #2: Altered muscle functionality

  → muscle moment contributions to net joint moment
- Study #3: Surgical intervention
- Conclusion and outlook

Introduction

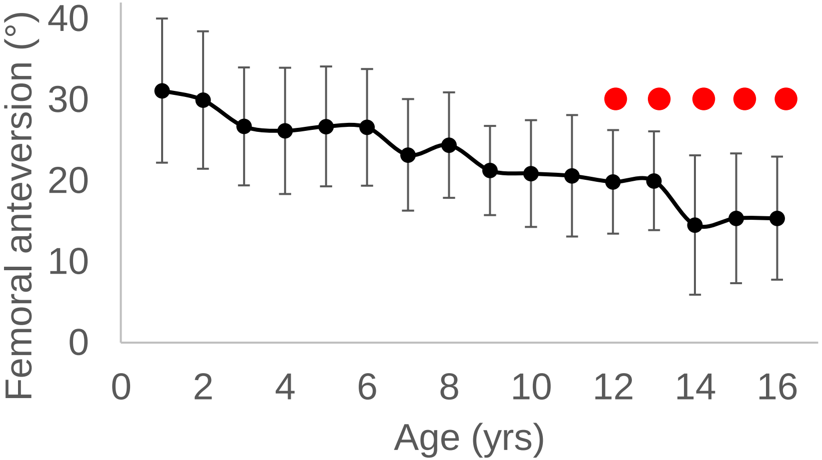
Femoral anteversion =

twist between the proximal & distal parts of the femur
(Kaiser et al., 2016)



Goyal et al., 2019

Femoral torsion decreases with age (Crane, 1959; Fabry et al., 1973)



(based on Fabry et al., 1973)

Introduction

„Kneeing-in“

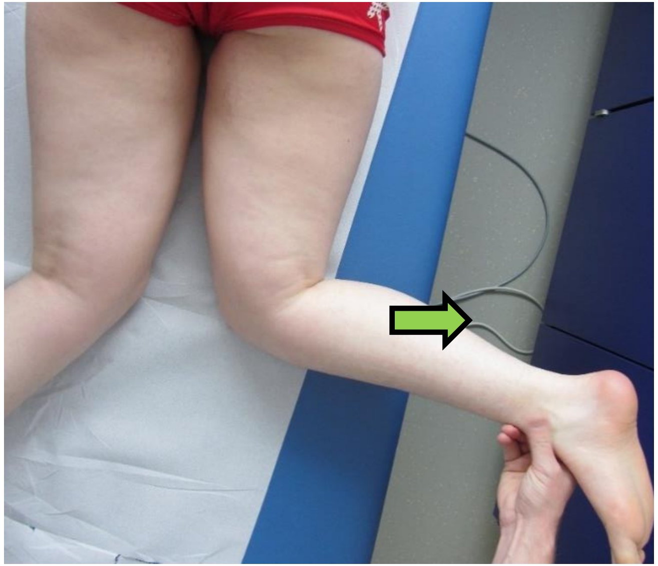
„Toeing-in“

Crane L. Femoral torsion and ist relation to toeing-in and toing-out JBJS 1959

Clinical examination

External rotation ↓

Internal rotation ↑

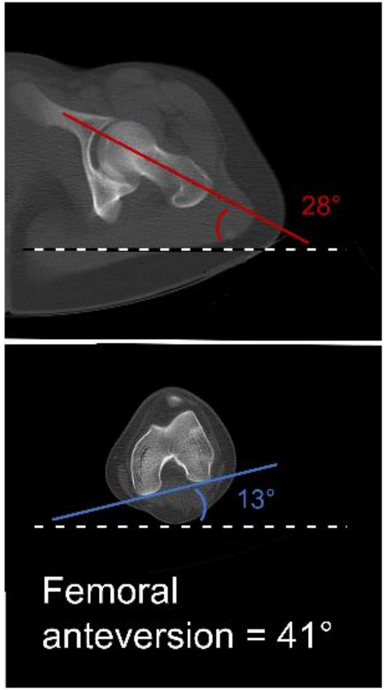


Trochanteric Prominence Angle Test

Davids J. et al, 2002, Journal of Pediatric Orthopedics
Dreher T. et al., 2019, Orthopäde

Imaging

Femoral torsion is commonly assessed using computer tomography (CT) or magnetic resonance imaging (MRI) [1-3]

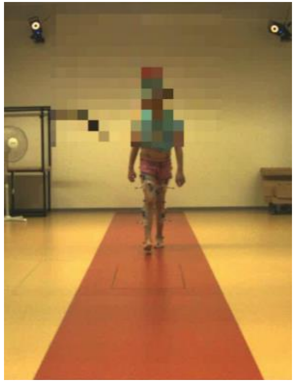


[1] Radler et al., 2010, Gait Posture, 32(3):405-410
[2] Cordier and Katthagen, 2000, Orthopade 29(9), 795-801
[3] Hefti, 2000, Orthopade 29(9), 814-820

Introduction

Increased femoral anteversion is associated with:

- Decreased function[1,2]
- Pain[2-6]
- Altered gait patterns[2, 7-10]



[1] Leblebici et al., 2019, Gait & Posture, 70:336-340
[2] Mackay et al., 2021, Gait & Posture, 86:144-149
[3] Powers, 2003, J Orthop Sports Phys Ther, 33(11):639-646
[4] Eckhoff et al., 1997, CORR, 339: 152-155
[5] Erkocak et al., 2016, Knee Surgery, Sports Traumatology, Arthroscopy, 24:3011-20
[6] Stambough et al., 2018, Journal of Pediatric Orthopaedics. 38:503-9
[7] Bruderer-Hofstetter et al., 2015, J. Orthop. Res. 33 (2):155–162
[8] Passmore et al., 2018, Gait Posture 63:228–235
[9] Alexander et al., 2019, J. Biomechanics 86:167–174
[10] Alexander et al., 2022, Front. Bioeng. Biotechnol.

Function

Asymptomatic patients with increased femoral anteversion

- Lower-extremity function form score ↑
- Falling frequency ↑

Falling frequency during activities (%).

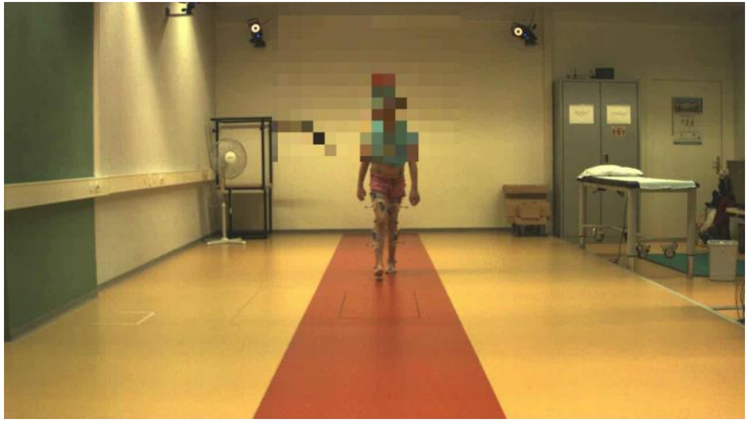
	IFA (n = 65)	Control (n = 32)
Standing	2.80	0.00
Walking	14.28	7.14
Walking faster	21.42	7.14
Running	60.00	14.28
Climbing stairs	12.85	10.71
Walking on uneven ground	21.42	35.71

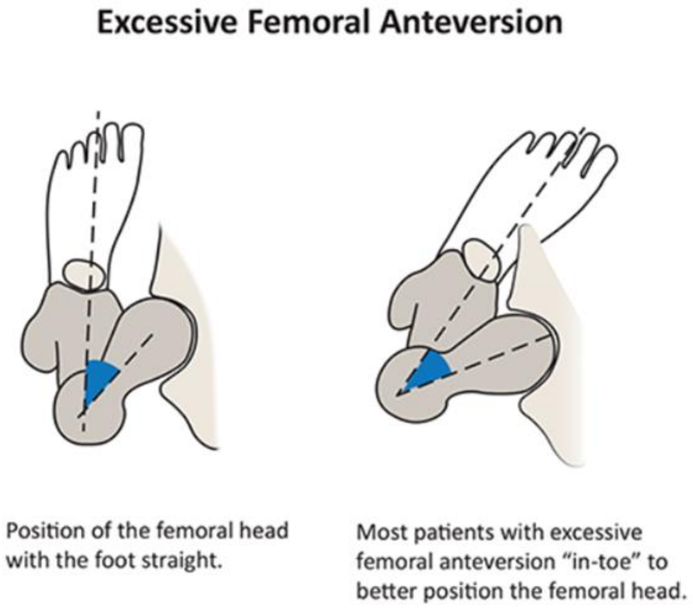
Abbreviation: IFA, increased femoral anteversion.

2x 3x 4x

Leblebici et al., 2019, Gait & Posture, 70:336-340

Gait deviations

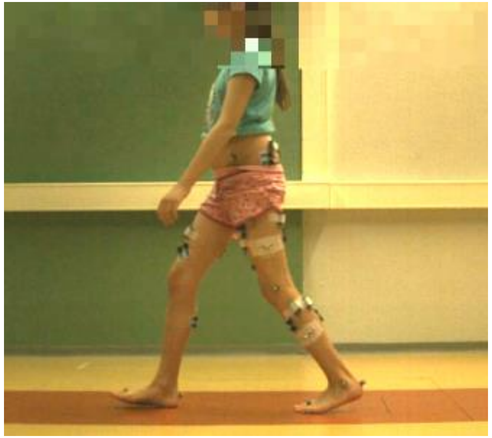




Gait deviations

- ↑ anterior pelvic tilt
- ↑ hip flexion
- ↑ hip internal rotation
- foot progression angle 'in-toeing'[1-5]
- ↑ knee flexion (terminal stance) [2-5]

[1] Bruderer-Hofstetter et al., 2015, J. Orthop. Res. 33 (2):155–162
[2] Passmore et al., 2018, Gait Posture 63:228–235
[3] Alexander et al., 2019, J. Biomechanics 86:167–174
[4] Mackay et al., 2021, Gait Posture 86:144–149
[5] Alexander et al., 2022, Front. Bioeng. Biotechnol.



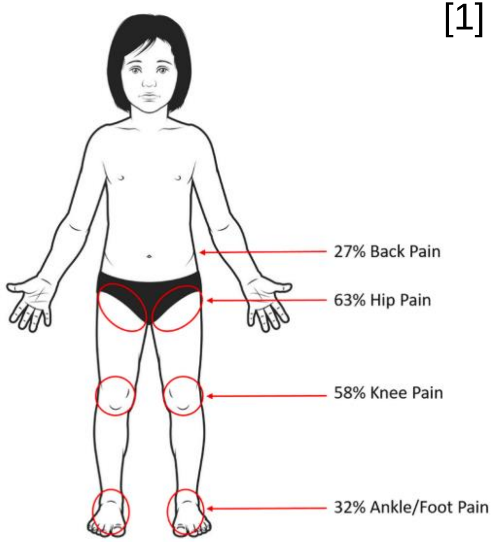
Introduction

Increased femoral anteversion is associated with:

- patellofemoral / anterior knee pain[2-5]
- hip pain and labral damage[6]
- patellofemoral instability[7]
- severity of hip osteoarthritis[8]

Gait & Posture 86 (2021) 144–149

[1]



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[5] Stambough et al., 2018, Journal of Pediatric Orthopaedics. 38:503-9
[6] Tönnis & Heinecke, 1999, J Bone Joint Surg Am 81(12), 1747-1770
[7] Dejour & Le Coultre, 2007, Sports Med Arthrosc Rev 15(1), 39-46
[8] Parker et al., 2021, Arthroscopy, Sports Medicine, and Rehabilitation 3(6), e2047-e2058

Study #1

frontiers | Frontiers in Bioengineering and Biotechnology

ORIGINAL RESEARCH
published: 06 June 2022
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Check for updates

Increased Femoral Anteversion Does Not Lead to Increased Joint Forces During Gait in a Cohort of Adolescent Patients

Nathalie Alexander[1,2], *Reinald Brunner*[3,4,5], *Johannes Cip*[6], *Elke Viehweger*[3,4,5] and *Enrico De Pieri*[3,5]*

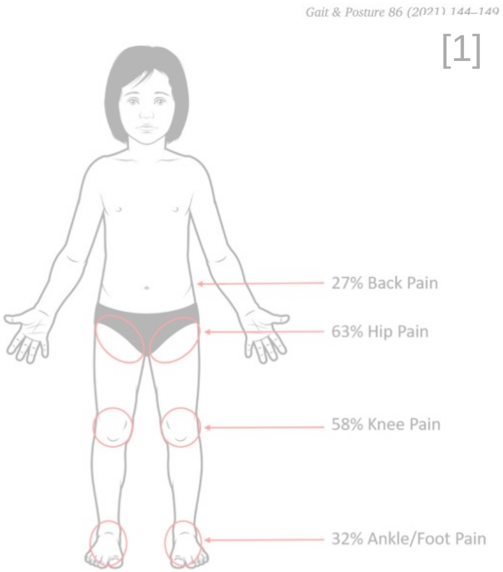
[1]Laboratory for Motion Analysis, Department of Paediatric Orthopaedics, Children's Hospital of Eastern Switzerland, St. Gallen, Switzerland, [2]Department of Orthopaedics and Traumatology, Cantonal Hospital St. Gallen, St. Gallen, Switzerland, [3]Laboratory for Movement Analysis, University of Basel Children's Hospital, Basel, Switzerland, [4]Department of Paediatric Orthopaedics, University of Basel Children's Hospital, Basel, Switzerland, [5]Dpartment of Biomedical Engineering, University of Basel, Basel, Switzerland, [6]Department of Paediatric Orthopaedics, Children's Hospital of Eastern Switzerland, St. Gallen, Switzerland

Introduction

Increased femoral anteversion is associated with:

- patellofemoral / anterior knee pain[2-5]
- hip pain and labral damage[6]
- patellofemoral instability[7]
- severity of hip osteoarthritis[8]

Altered joint loading?

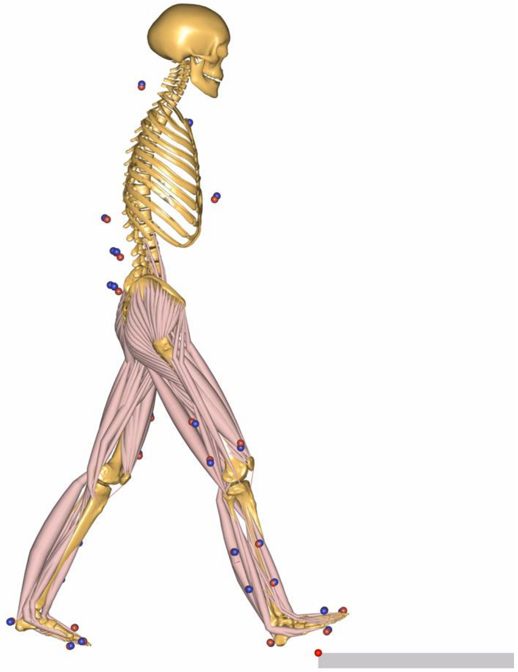


[1] Mackay et al., 2021, Gait & Posture, 86:144-149
[2] Powers, 2003, J Orthop Sports Phys Ther, 33(11):639-646
[3] Eckhoff et al., 1997, CORR, 339: 152-155
[4] Erkocak et al., 2016, Knee Surgery, Sports Traumatology, Arthroscopy, 24:3011-20
[5] Stambough et al., 2018, Journal of Pediatric Orthopaedics. 38:503-9
[6] Tönnis & Heinecke, 1999, J Bone Joint Surg Am 81(12), 1747-1770
[7] Dejour & Le Coultre, 2007, Sports Med Arthrosc Rev 15(1), 39-46
[8] Parker et al., 2021, Arthroscopy, Sports Medicine, and Rehabilitation 3(6), e2047-e2058

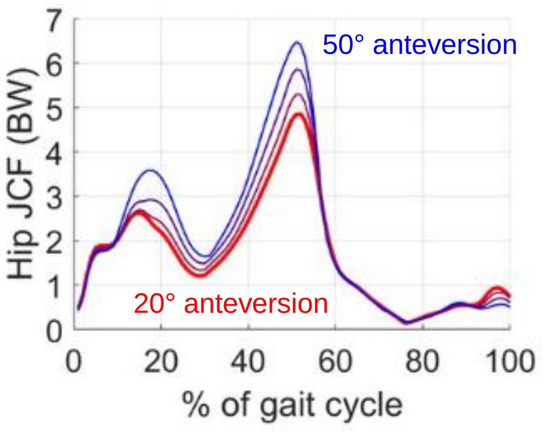
Introduction

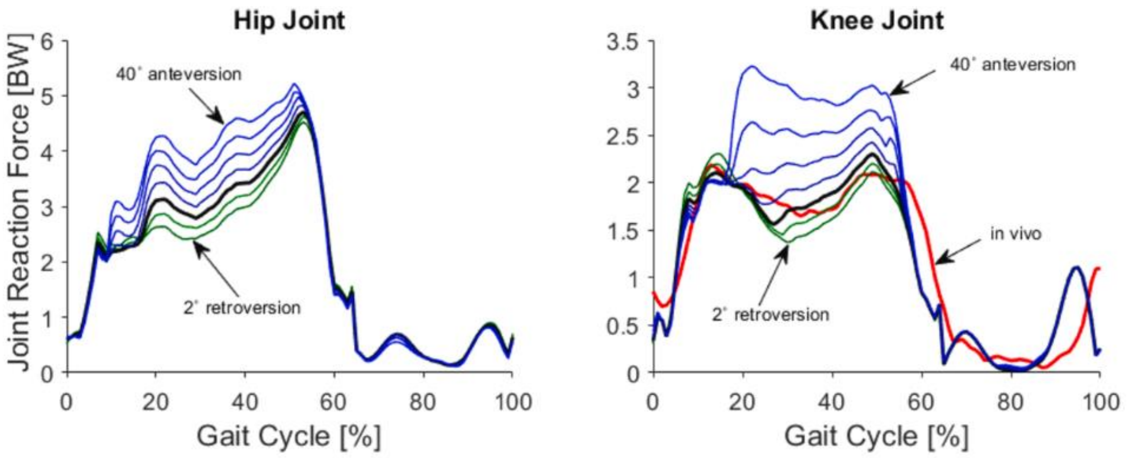
Musculoskeletal modelling

- Estimate joint loading



Biomechanical considerations





Kainz et al., 2020, PLoS One. 15:e0235966.

Modenese et al., 2021, Gait & Posture, 88:318-21

Introduction

Joint loading:

- ↑ femoral torsion → ↑ anterior & medial hip contact forces[1]

- personalized torsion model: [2]
  ↑ mediolateral patellofemoral joint contact forces
  ↑ hip contact forces

Joint loads ←→ kinematic gait patterns?

[1] De Pieri et al., 2021, Front. Bioeng. Biotechnol 9:551

[2] Passmore et al., 2018, Gait Posture 63, 228-235

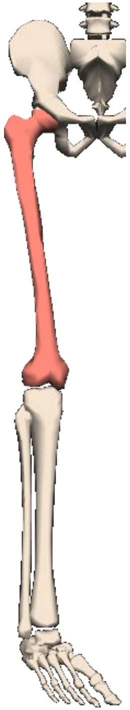
Aim

First aim:
Analysis of joint contact forces in patients with increased femoral anteversion compared to controls

Second aim:
Effect of kinematic gait patterns:
- Hip rotation
- Foot progression
- Knee flexion

Methods

	Patients (n = 42)
Femoral anteversion	39.6° (6.9°)
Gender	26 ♀ / 16 ♂
Age	12.8 (1.9) yrs
Height	1.56 (0.10) m
Mass	44.9 (9.5) kg



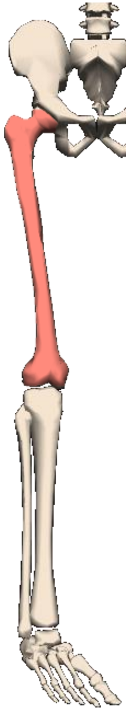
increased
femoral torsion: > 30°

physiological
tibial torsion: 33° ± 8°
(Waidelich et al., 1992)

torsion verfied by CT scans; no neurological disorder; no foot deformity

Methods

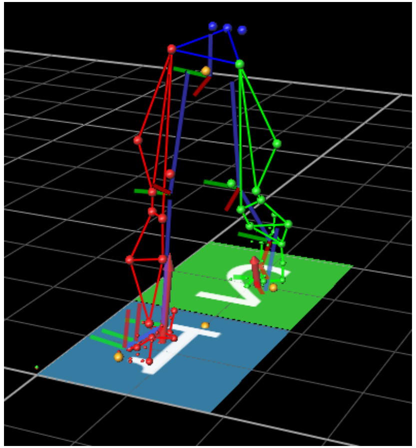
	Patients (n = 42)	**Controls** (n = 9)
Femoral anteversion	39.6° (6.9°)	18.7° (4.1°)
Gender	26 ♀ / 16 ♂	5 ♀ / 4 ♂
Age	12.8 (1.9) yrs	12.0 (3.0) yrs
Height	1.56 (0.10) m	1.53 (0.18) m
Mass	44.9 (9.5) kg	41.8 (12.3) kg



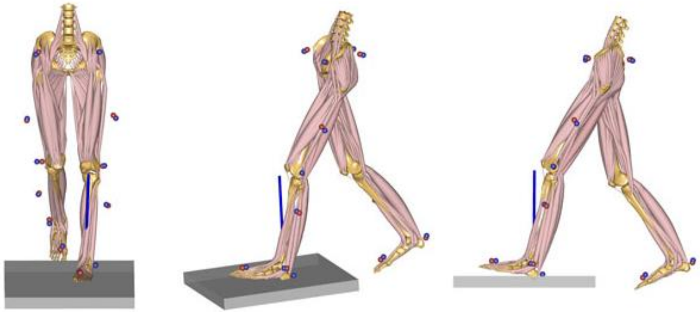
torsion verfied by CT scans; no neurological disorder; no foot deformity

Methods

- 3D gait analysis
  - Kinematic data (marker trajectories) markers placed according to PiG
  - Kinetic data (ground reaction forces)



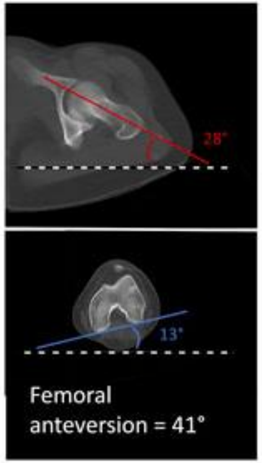
- AnyBody Modeling System (v. 7.3)



Methods

AnyBody Webcast 2021

Subject-specific modelling

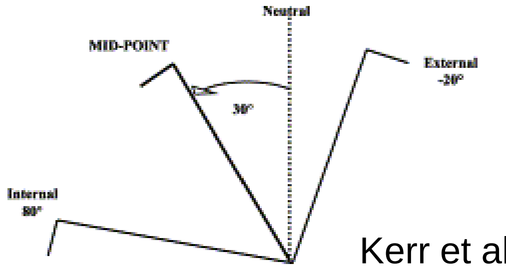


Methods

Parameters

<u>Morphological</u>

- Femoral anteversion
- Midpoint of hip rotation (Midpoint $_{HipRot\ ROM}$)



Kerr et al., 2003

<u>Gait</u>

- 3D hip contact forces
- 3D knee contact forces

Methods

Kinematic gait patterns - mean in terminal stance

Foot progression angle

$FootProg_{tSt}$

Hip rotation

$HipRot_{tSt}$

Knee flexion

$KneeFlex_{tSt}$

Methods

α = 0.05

Waveforms

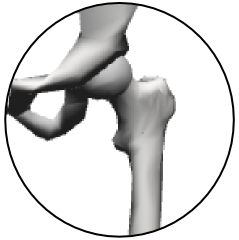
- 3D hip contact forces
- 3D knee contact forces

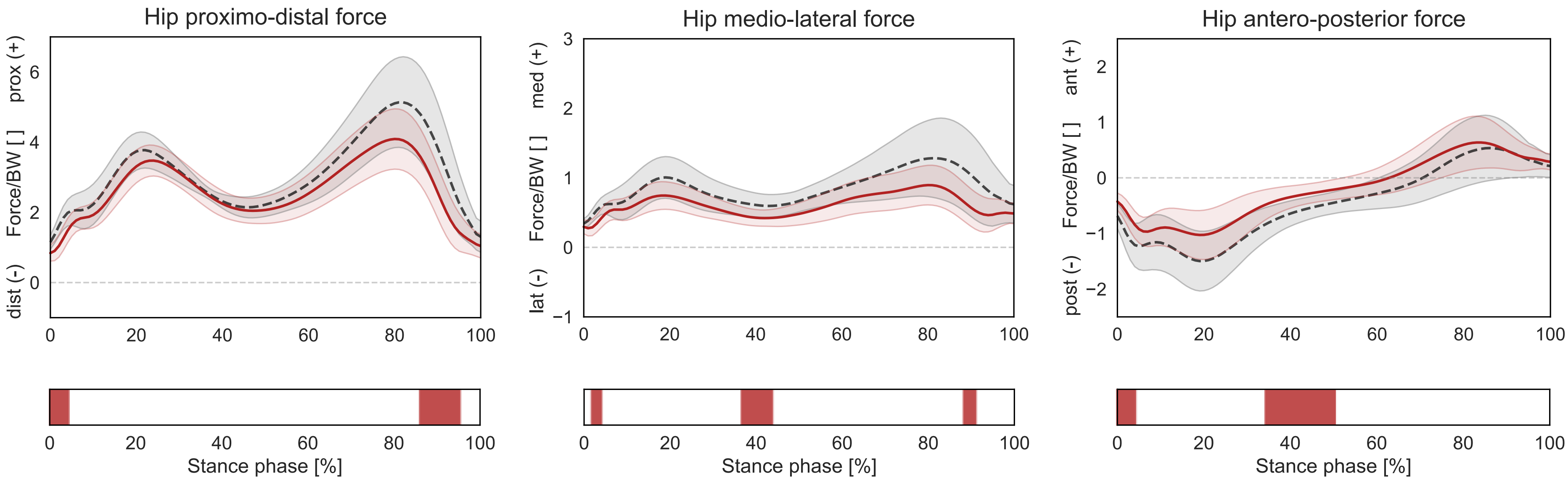
Regression anaysis

- Morphological parameters
- Gait patterns

Results

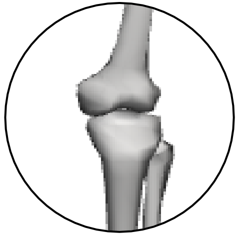
Patients vs. controls

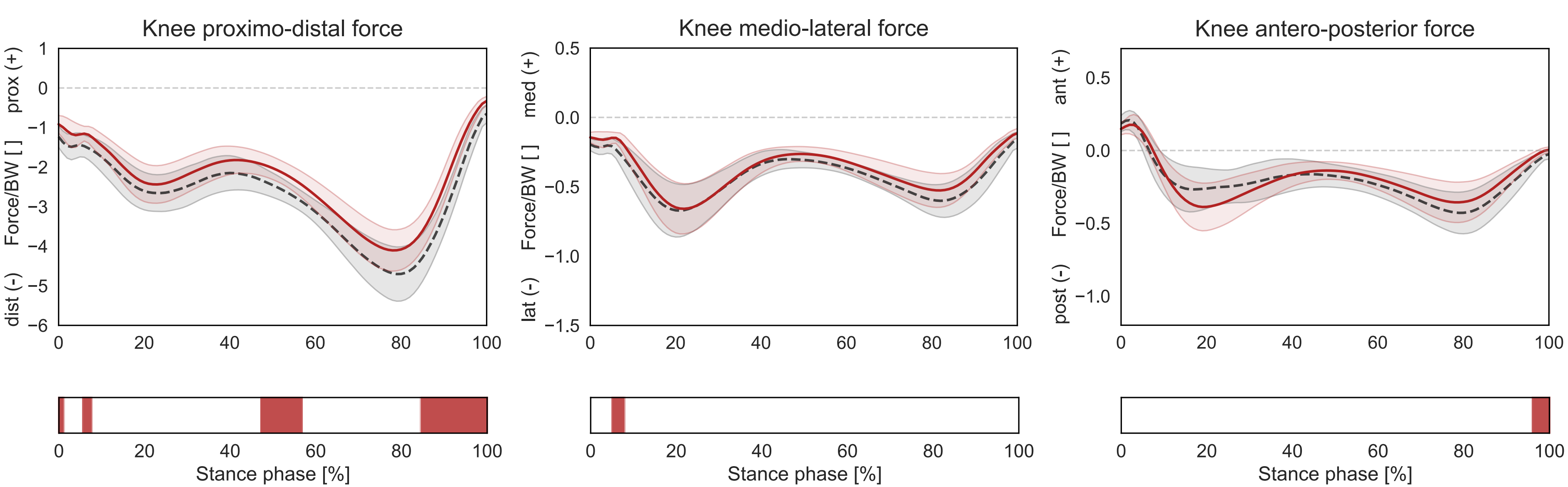




Results

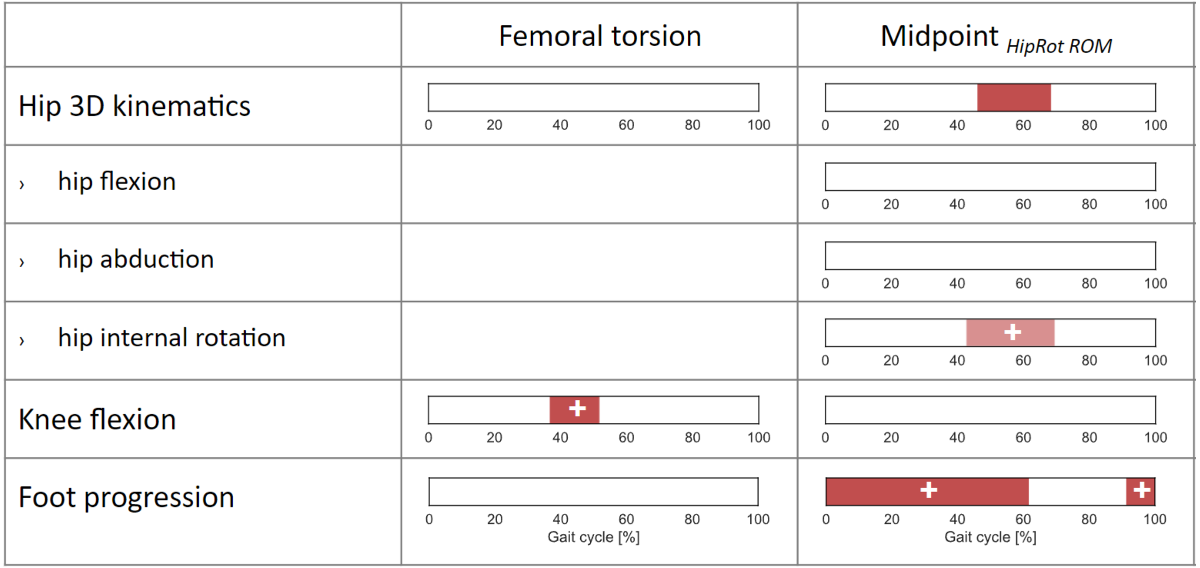
Patients vs. controls





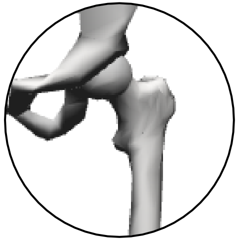
Results

Regression analysis of **morphological parameters**



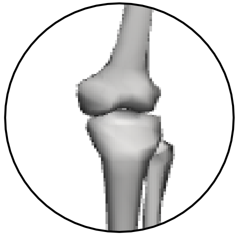
- No correlations with hip and knee joint forces

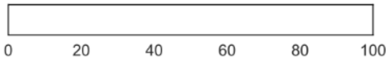
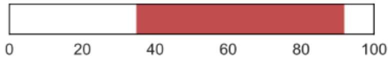
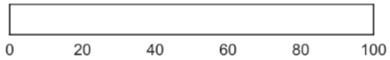
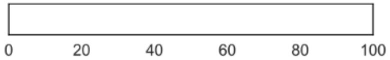
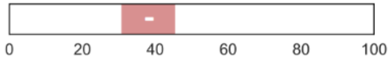
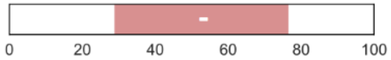
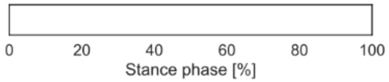
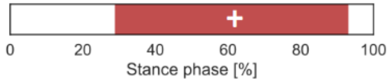
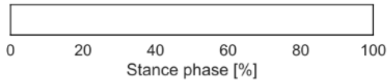
Results



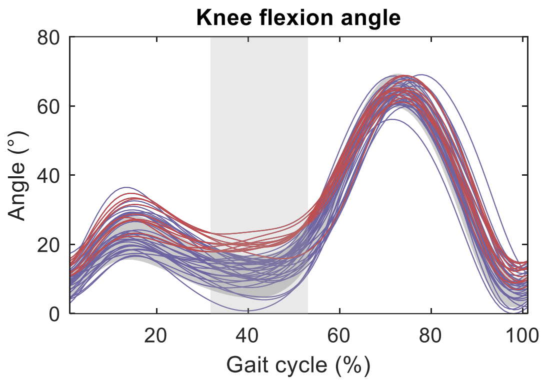
	Hip Rotation $_{tSt}$	Knee Flexion $_{tSt}$	Foot Progression $_{tSt}$
Hip 3D contact forces	0 20 40 60 80 100	0 20 40 60 80 100	0 20 40 60 80 100
› hip proximo-distal force		+ 0 20 40 60 80 100	
› hip medio-lateral force		+ 0 20 40 60 80 100	
› hip antero-posterior force		0 20 40 60 80 100	

Results



	Hip Rotation $_{tSt}$	Knee Flexion $_{tSt}$	Foot Progression $_{tSt}$
Knee 3D contact forces			
› knee proximo-distal force			
› knee medio-lateral force			
› knee antero-posterior force			
Quadriceps forces on patella			

Joint forces



Subgroup analysis
based on KneeFlex_{tSt}

Controls
Patients – increased KneeFlex_{tSt} (n=10)
Patients – normal KneeFlex_{tSt} (n = 32)

- increased KneeFlex_{tSt} vs. normal KneeFlex_{tSt}
  ↑ femoral anteversion: +7.3°
  ↑ posterior knee joint force
  ↑ quadriceps force on the patella

- limited differences between patients and controls
- relevant in terms of anterior knee pain?

Discussion

In contrast to modelling torsion irrespective of gait alterations [1,2]:

patients show **lower knee and hip joint forces**

[1] Kainz et al., 2020, PLoS One. 15:e0235966.
[2] Modenese et al., 2021, Gait & Posture, 88:318-21

Discussion

Morphological parameters

- No correlation between femoral torsion and hip rotation [1-3]

- Midpoint $_{HipRot\ ROM}$ = better indicator for transversal gait deviations than femoral anteversion [4]

[1] Radler et al., 2010, Gait Posture, 32(3):405-410
[2] Schranz et al., 2021, Clin Biomech, 84:105333
[3] Mackay et al., 2021, Gait Posture 86:144–149
[4] Kerr et al., 2003, Gait Posture, 17(1):88-91.

Discussion

Effect of gait patterns

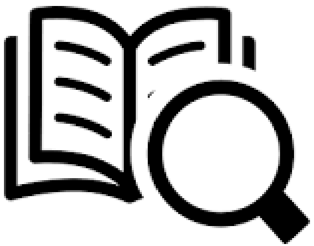
HipRot$_{tSt}$ and FootProg$_{tSt}$

- did not affect joint loading

↑ KneeFlex$_{tSt}$ gait pattern leads to:

- → more medial and proximal HCFs
- → more lateral and posterior KCFs
- → ↑ quadriceps force on the patella

Discussion



Increasing knee flexion →

- increasing patellofemoral compression forces [1,2]
- increased quadriceps force contributes to larger tibiofemoral and patellofemoral joint loadings [3]

[1] Modenese et al., 2013, J Biomech, 46(6):1193-1200
[2] Alexander et al., 2016, Gait Posture, 45:137-142
[3] Steele et al., 2012, Gait Posture 35(4), 556-560

Take Home

Patients: ↓ knee & hip joint loading

Clinical hip rotation better indicator for transversal gait patterns

<u>Gait pattern knee flexion</u>:

- ↑ joint loads
- ↑ femoral anteversion
- Subgroup: limited differences patients vs. controls
  → limited clinical relevance?
- Related to anterior knee pain ?

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ORIGINAL RESEARCH
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Increased Femoral Anteversion Does Not Lead to Increased Joint Forces During Gait in a Cohort of Adolescent Patients

*Nathalie Alexander[1,2], Reinald Brunner[3,4,5], Johannes Cip[6], Elke Viehweger[3,4,5] and Enrico De Pieri[3,5]**

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Study #2

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Gait & Posture 100 (2023) 179–187

Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/gaitpost

ELSEVIER

The functional role of hip muscles during gait in patients with increased femoral anteversion

Enrico De Pieri [a,b], Johannes Cip [c], Reinald Brunner [a,b,d], Claudia Weidensteiner [b,e], Nathalie Alexander [f,g,*]

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[b] Department of Biomedical Engineering, University of Basel, Basel, Switzerland
[c] Department of Paediatric Orthopaedics, Children's Hospital of Eastern Switzerland, St. Gallen, Switzerland
[d] Department of Paediatric Orthopaedics, University of Basel Children's Hospital, Basel, Switzerland
[e] Division of Radiological Physics, Department of Radiology, University Hospital Basel, Basel, Switzerland
[f] Laboratory for Motion Analysis, Department of Paediatric Orthopaedics, Children's Hospital of Eastern Switzerland, St. Gallen, Switzerland
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Disclosure & Acknowledgement

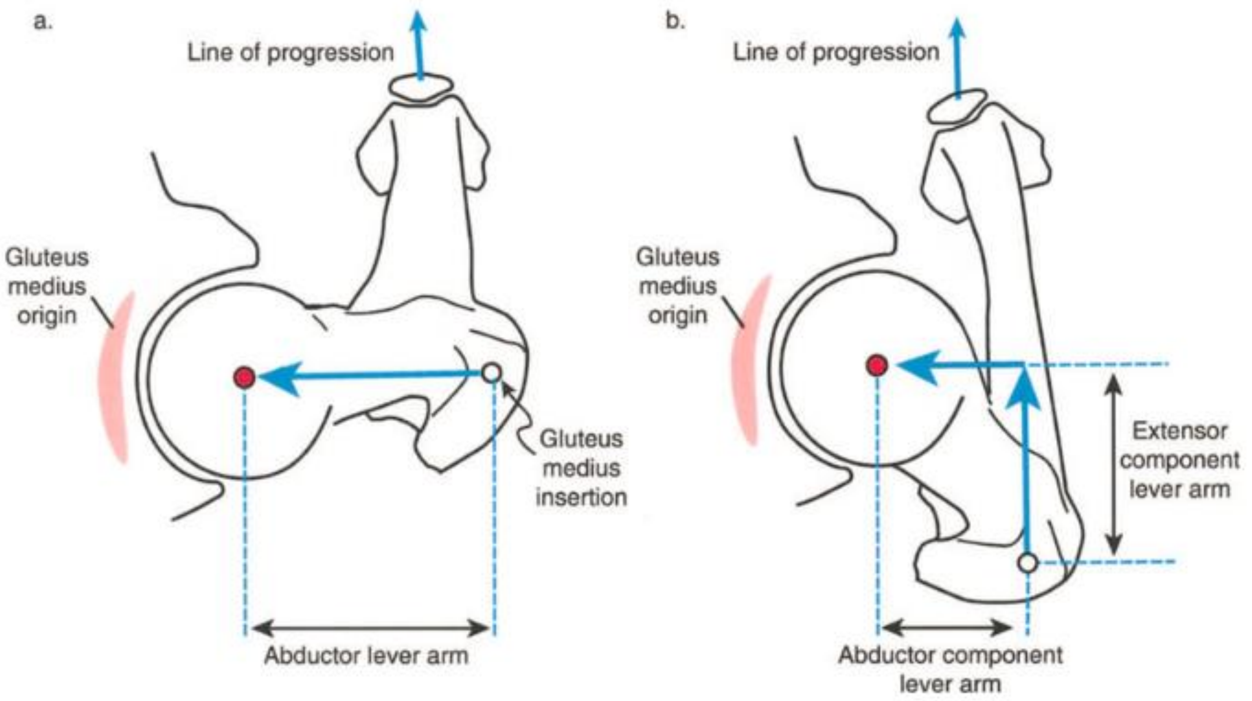
Financial support:

Research Fund for Excellent Junior Researchers
special program Clinical Research

Biomechanical considerations

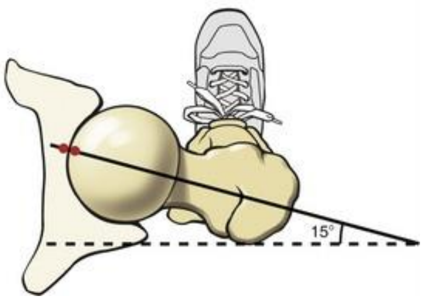
normal

increased femoral anteversion

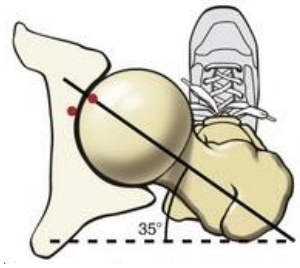


Paley, 2002, Dynamic Deformities and Lever Arm Considerations. In: Principles of Deformity Correction.

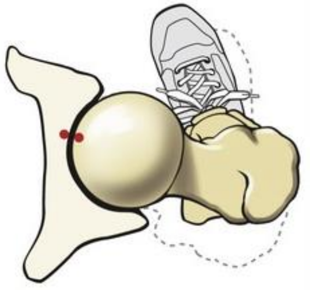
Biomechanical considerations



Normal anteversion

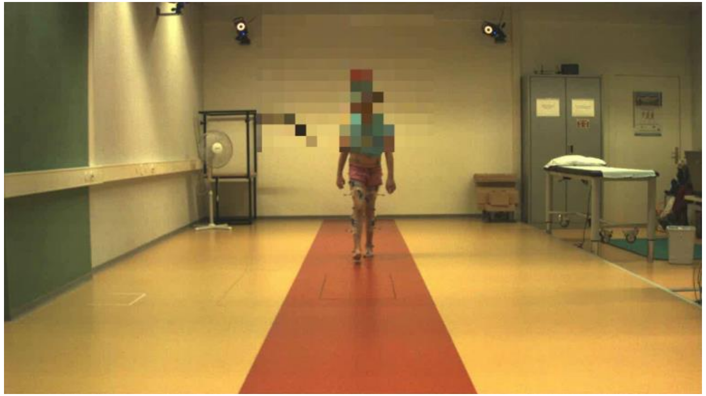


Increased anteversion



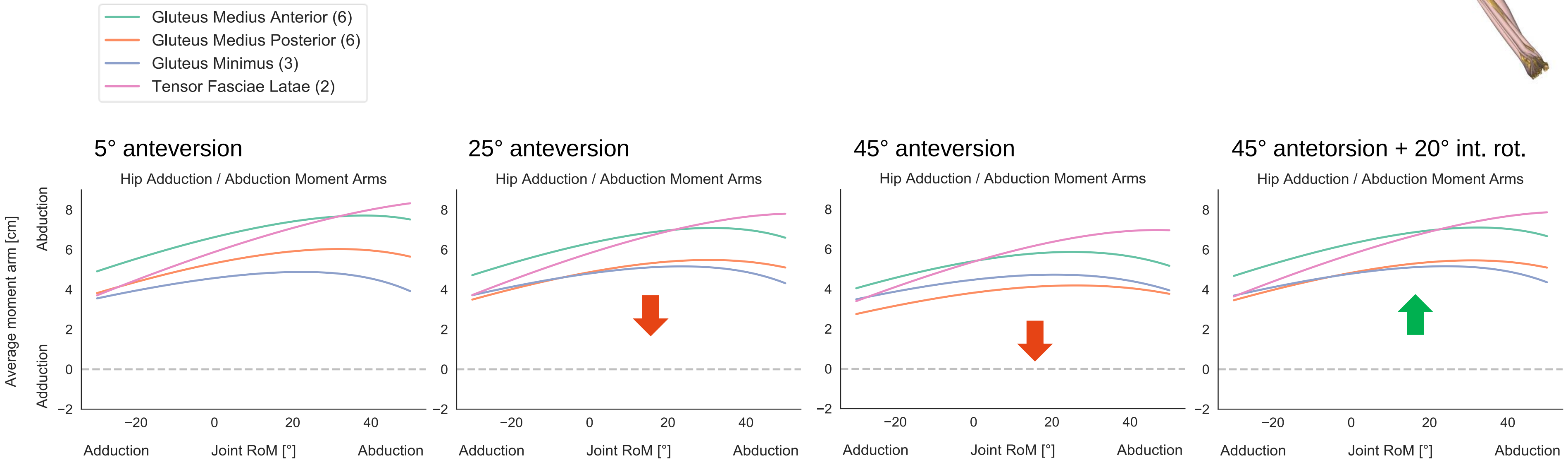
Increased anteversion with in-toeing

https://clinicalgate.com/hip-5/



Biomechanical considerations

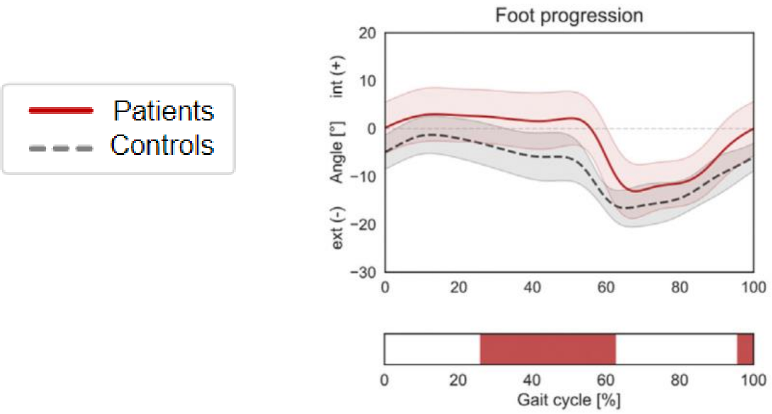
- Hip abductors’ lever arms decrease for higher femoral anteversion
- Abductive capacity restored with 20° hip internal rotation

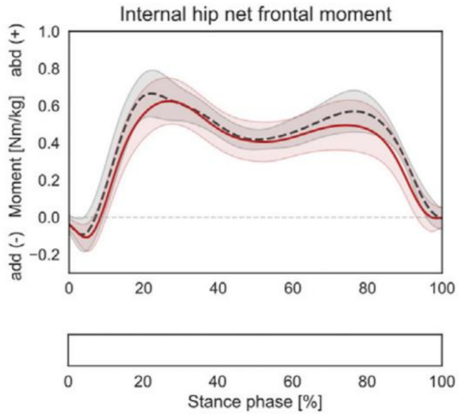


De Pieri et al., 2021, Front. Bioeng. Biotechnol. 9:551

Introduction

Patients vs. in-toeing controls





Patients do not present a net hip abductive deficit during gait

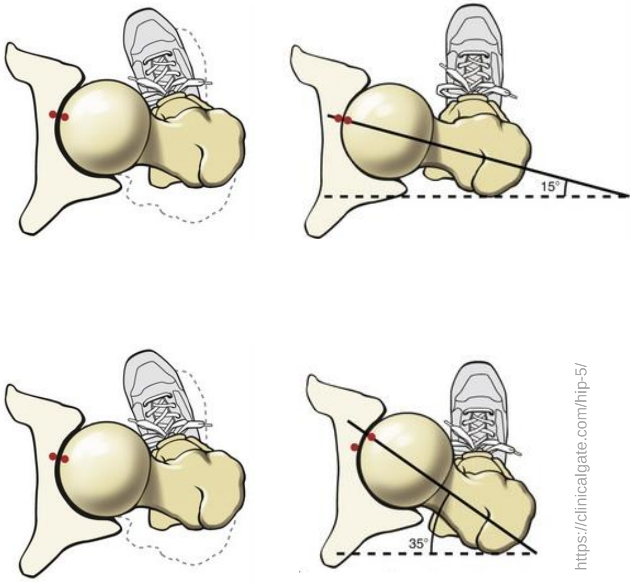
Demands placed on individual muscles?

Aim

Analyse muscle contributions to hip joint moments and muscle forces in patients compared to:

- controls
- hypothetical patients

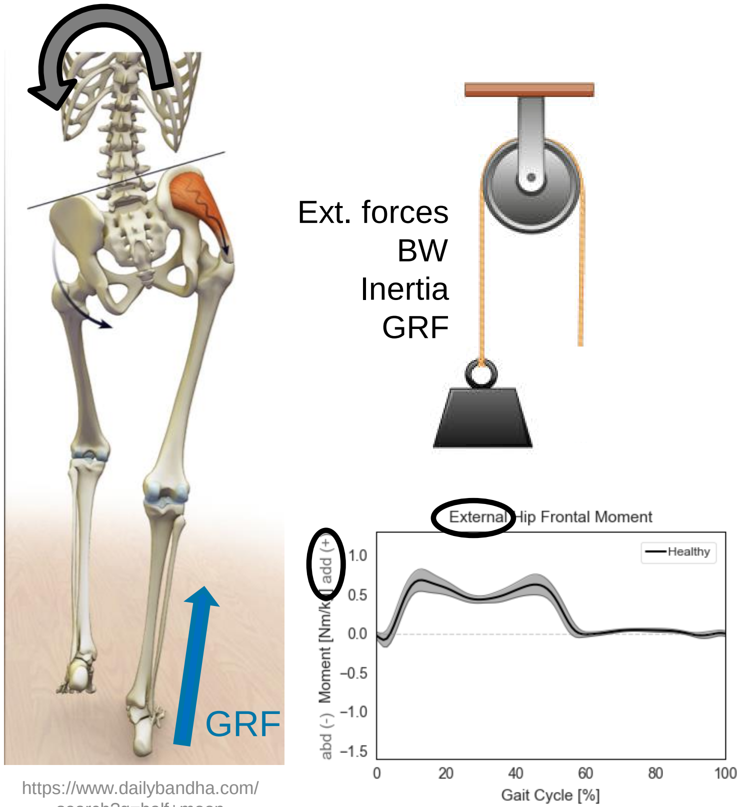
  (controls' gait pattern + increased anteversion)



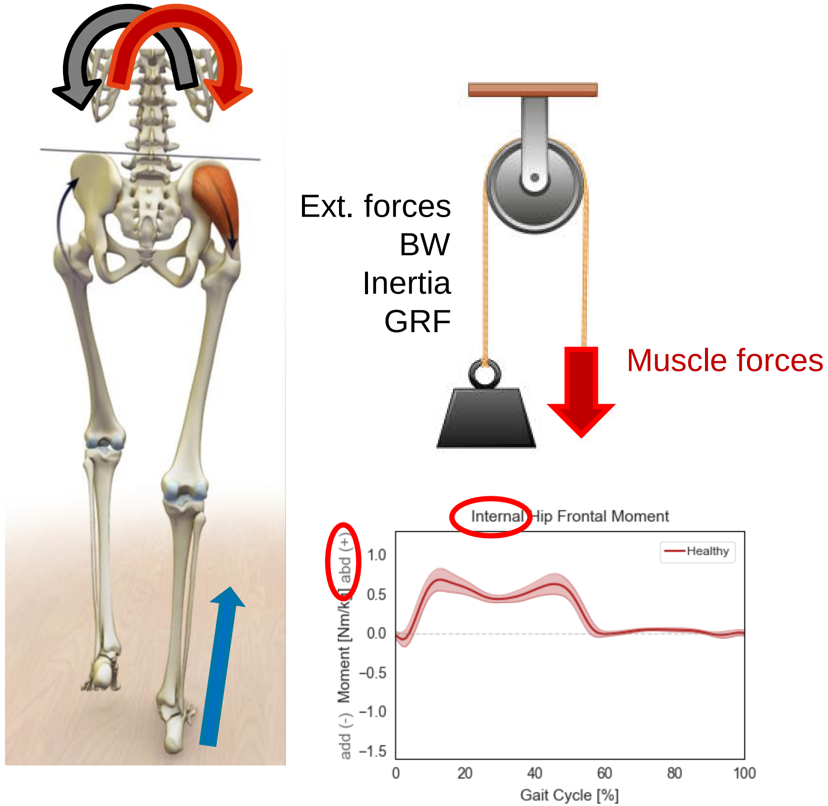
https://clinicalgate.com/hip-5/

Muscle moment contributions to net joint moment

Net joint moments



https://www.dailybandha.com/
search?q=half+moon



Derrick et al., 2020, J. Biomech. 99:109533

Net joint moments

$$M_{ankle}^{sagittal} = \sum_{m_a = ankle\ muscles} M_{m_a}^{sagittal}$$

For an unconstrained DOF

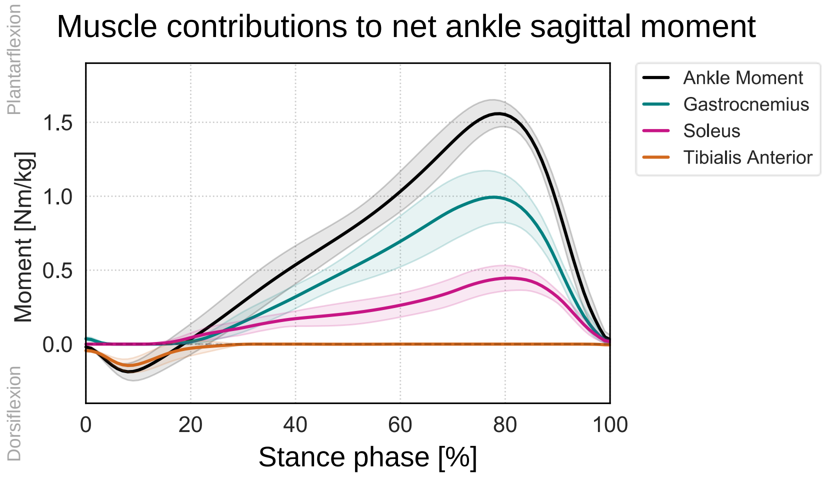
net joint moment = sum of moments generated by the muscles

FullBody.main.any | RightLegSelectedOutput.any | LeftLegSelectedOutput.any | LegMoments.any

```
AnyForceMomentMeasure2
AnklePlantarFlexionNetMomentMuscle = {
  AnyRefFrame &ref = ..Seg.Shank.AnkleJoint;
  IncludeSegments = {&..Seg.Foot, &..Seg.Talus};
  IncludeForces = arrcat(
    ObjSearch("..Mus.*", "AnyMuscle"),
    ObjSearch("..TrunkMuscles.PsoasMajor.*",
    "AnyMuscle"),
    ObjSearchRecursive("..JointMuscles", "*",
    "AnyMuscle")
  );
  AnyVec3 Mlocal=M*ref.Axes;
  AnyVar MPlantarFlexion=-Mlocal[2];
};
```

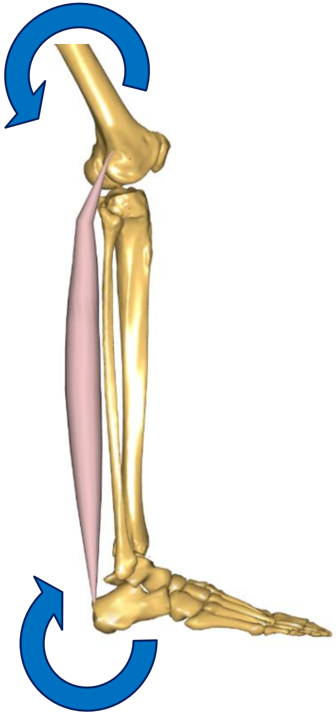
Muscle moments

$$M_{ankle}^{sagittal} = \sum_{m_a = ankle\ muscles} M_{m_a}^{sagittal}$$




```
AnyForceMomentMeasure2
Soleus_AnkleMoment = {
  AnyRefFrame &ref = ..Seg.Shank.AnkleJoint;
  IncludeSegments = {&..Seg.Foot, &..Seg.Talus};
  IncludeForces = arrcat(
    ObjSearch("..Mus.Soleus*", "AnyMuscle")
  );
  AnyVec3 Mlocal=M*ref.Axes;
  AnyVar MPlantarFlexion=-Mlocal[2];
};
```

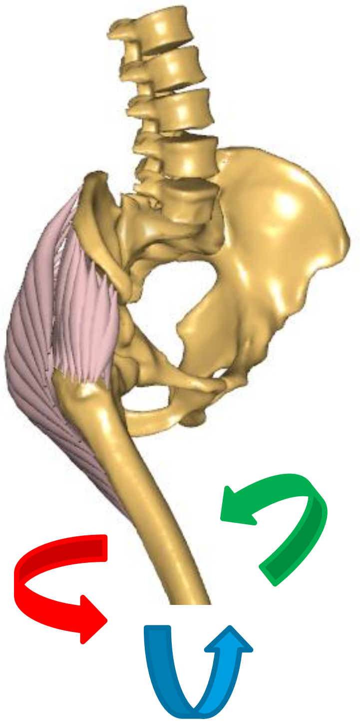
Muscle moments



```
AnyForceMomentMeasure2 Gastrocnemius_AnkleMoment = {
  AnyRefFrame &ref = ..Seg.Shank.AnkleJoint;
  IncludeSegments = {&..Seg.Foot, &..Seg.Talus};
  IncludeForces = arrcat(ObjSearch("..Mus. Gastrocnemius *", "AnyMuscle"));
  AnyVec3 Mlocal=M*ref.Axes;
  AnyVar MPlantarFlexion=-Mlocal[2];};

AnyForceMomentMeasure2 Gastrocnemius_KneeMoment = {
  AnyRefFrame &ref = ..Seg.Thigh.KneeJoint.RotNode;
  IncludeSegments = {&..Seg.Shank, &..Seg.Foot, &..Seg.Talus};
  IncludeForces = arrcat(ObjSearch("..Mus. Gastrocnemius *", "AnyMuscle"));
  AnyVec3 Mlocal=M*ref.Axes;
  AnyVar MKneeFlexion=-Mlocal[2];};
```

Muscle moments



```
AnyForceMomentMeasure2 GluteusMedius_HipMoment = {
  AnyRefFrame &ref = .. Seg.Pelvis.HipJoint.RotNode;
  IncludeSegments = {&..Seg.Thigh, &..Seg.Shank, &..Seg.Patella,
  &..Seg.Foot, &..Seg.Talus};
  IncludeForces = arrcat(ObjSearch("..Mus. GluteusMedius *", "AnyMuscle"));
  AnyVec3 Mlocal=M*ref.Axes;

  AnyVar MHipAbduction=Mlocal[0];
  AnyVar MHipFlexion=Mlocal[2];
  AnyVar MHipExternalRotation=Mlocal[1];
```

For more details

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ORIGINAL RESEARCH
published: 11 April 2022
doi: 10.3389/fbioe.2022.810560

Check for updates

Altered Muscle Contributions are Required to Support the Stance Limb During Voluntary Toe-Walking

Enrico De Pieri[1,2*], *Jacqueline Romkes*[1,2], *Christian Wyss*[1,2], *Reinald Brunner*[1,2,3†] and *Elke Viehweger*[1,2,3†]

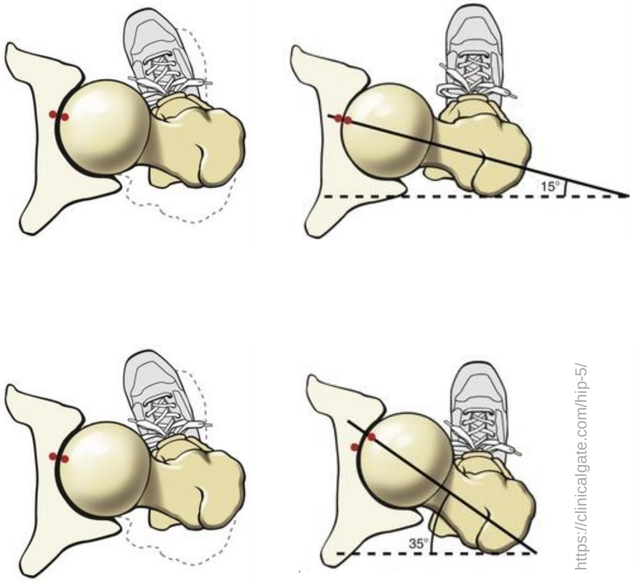
[1]Laboratory for Movement Analysis, University of Basel Children's Hospital, Basel, Switzerland, [2]Department of Biomedical Engineering, University of Basel, Basel, Switzerland, [3]Department of Paediatric Orthopaedics, University of Basel Children's Hospital, Basel, Switzerland

Aim

Analyse muscle contributions to hip joint moments and muscle forces in patients compared to:

- controls
- hypothetical patients

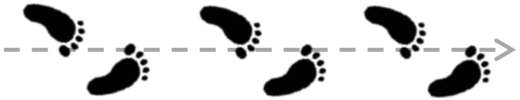
  (controls' gait pattern + increased anteversion)



Methods

Patients (n = 42)

Femoral anteversion
39.6° (6.9°)



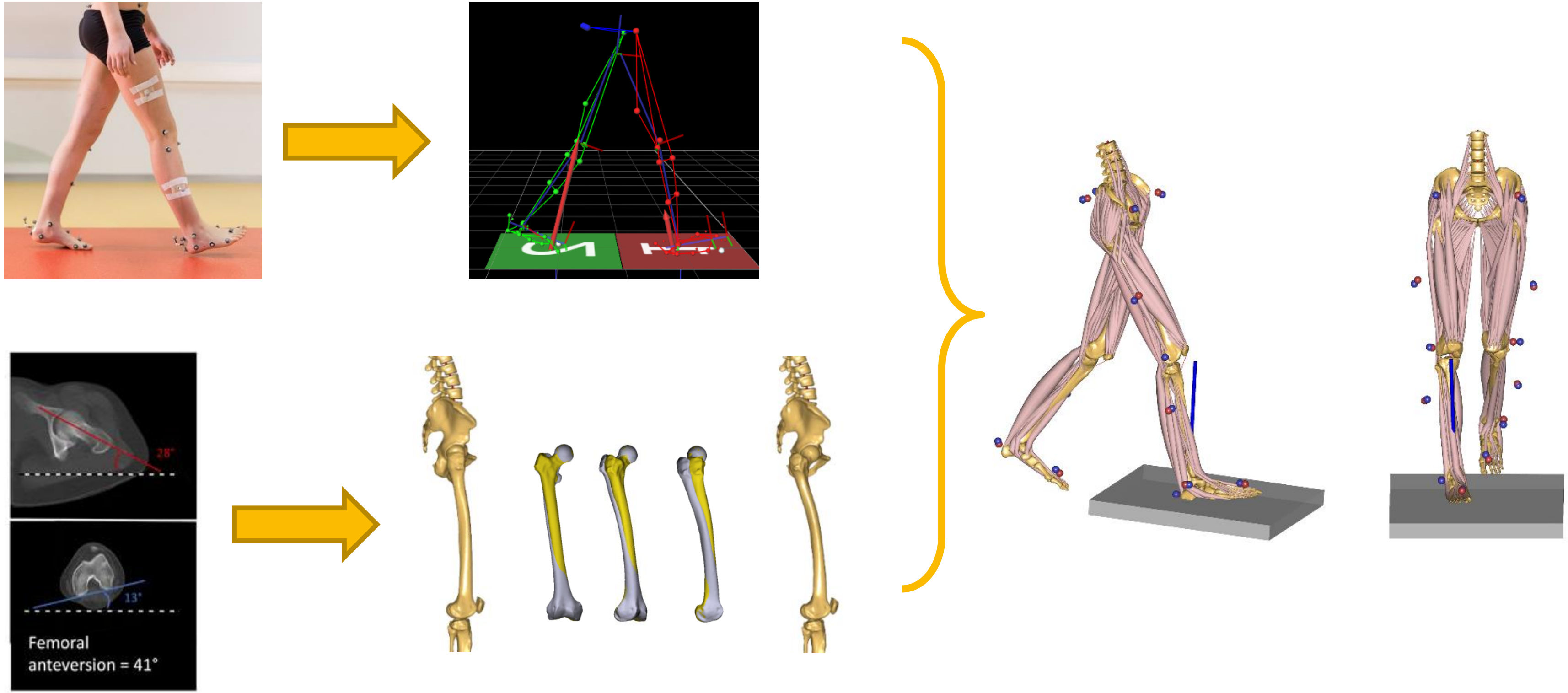
Controls (n = 9)

Femoral anteversion
18.7° (4.1°)

Hypothetical patients (n = 9)

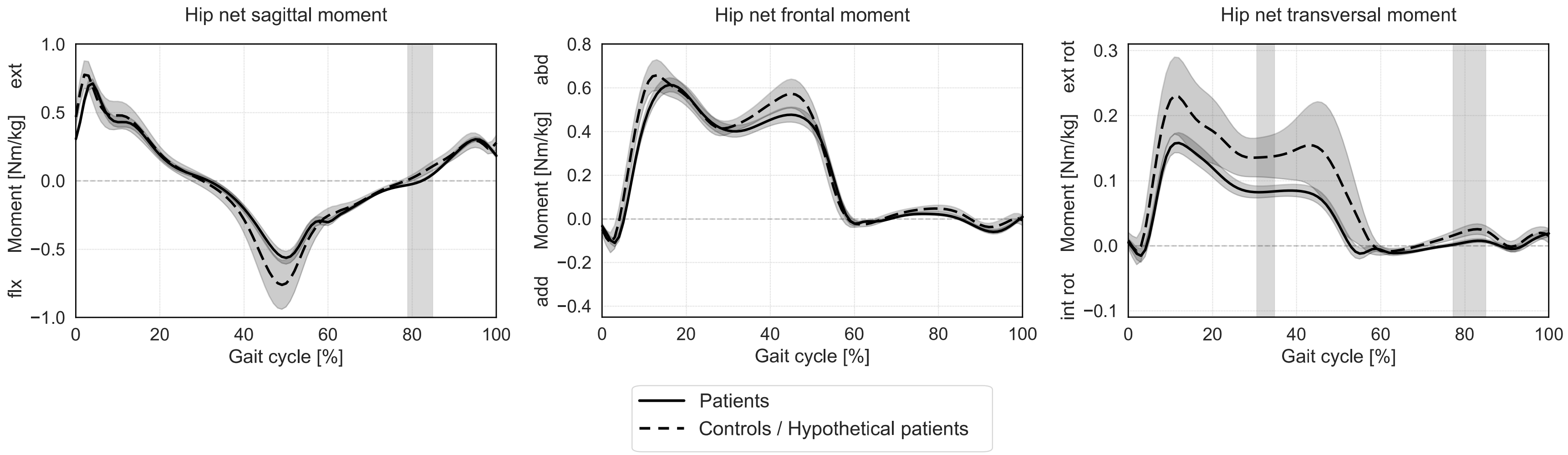
Femoral anteversion
40°

Methods



De Pieri et al., 2021, Front. Bioeng. Biotechnol 9:551

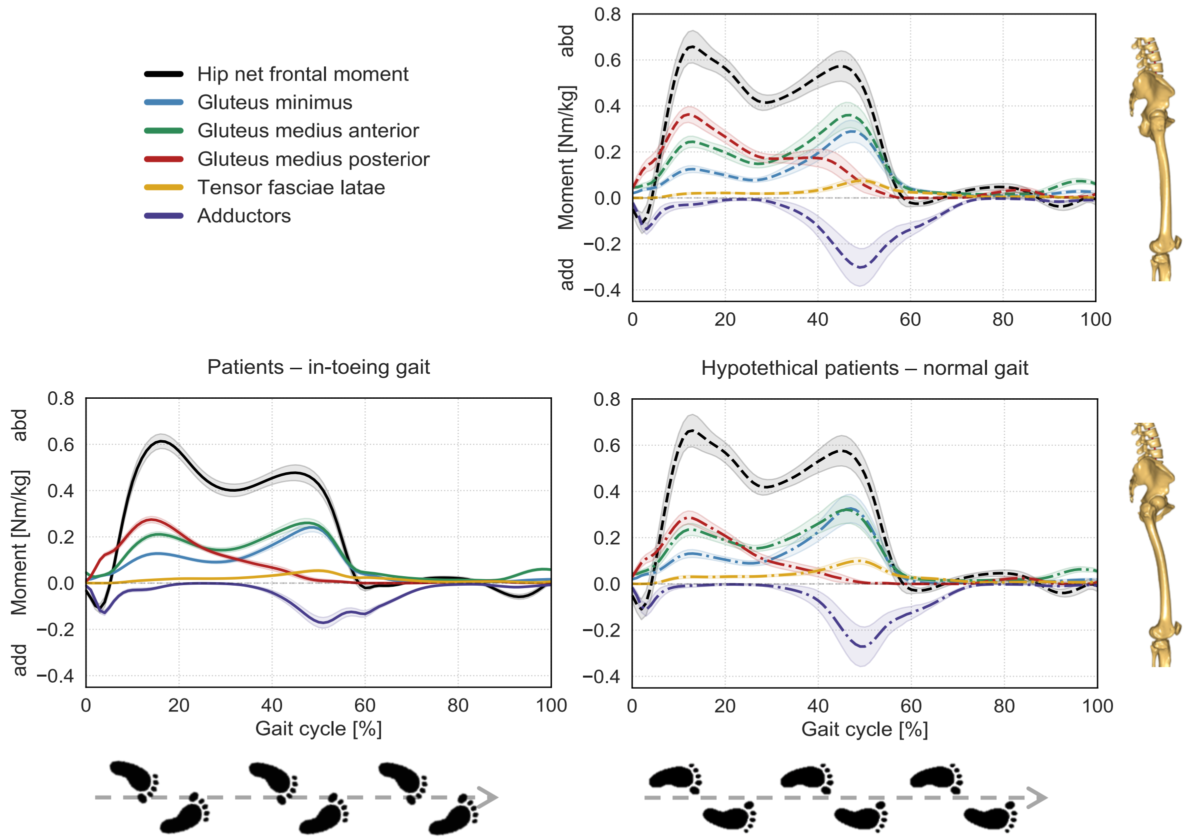
Results



Hip net sagittal moment
Hip net frontal moment
Hip net transversal moment
Moment [Nm/kg]
ext
flx
abd
add
ext rot
int rot
1.0
0.5
0.0
−0.5
−1.0
0.8
0.6
0.4
0.2
−0.2
−0.4
0.3
0.2
0.1
−0.1
0
20
40
60
80
100
Gait cycle [%]
Patients
Controls / Hypothetical patients

Results

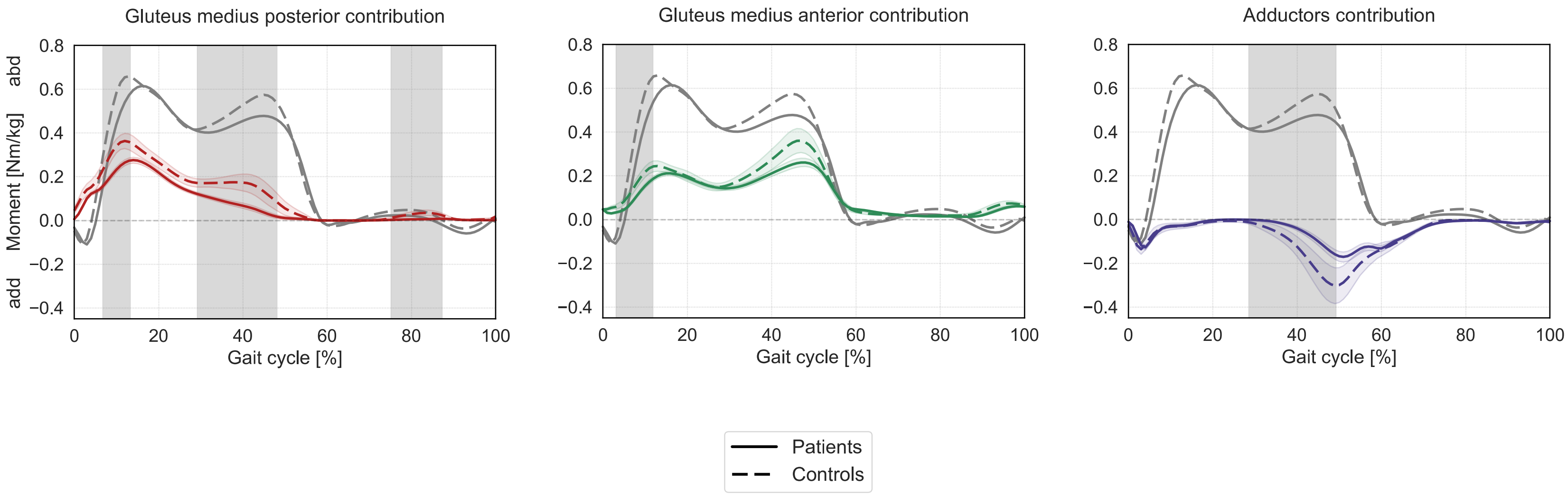
Muscle contributions to hip net frontal moment



Results I

Patients vs controls

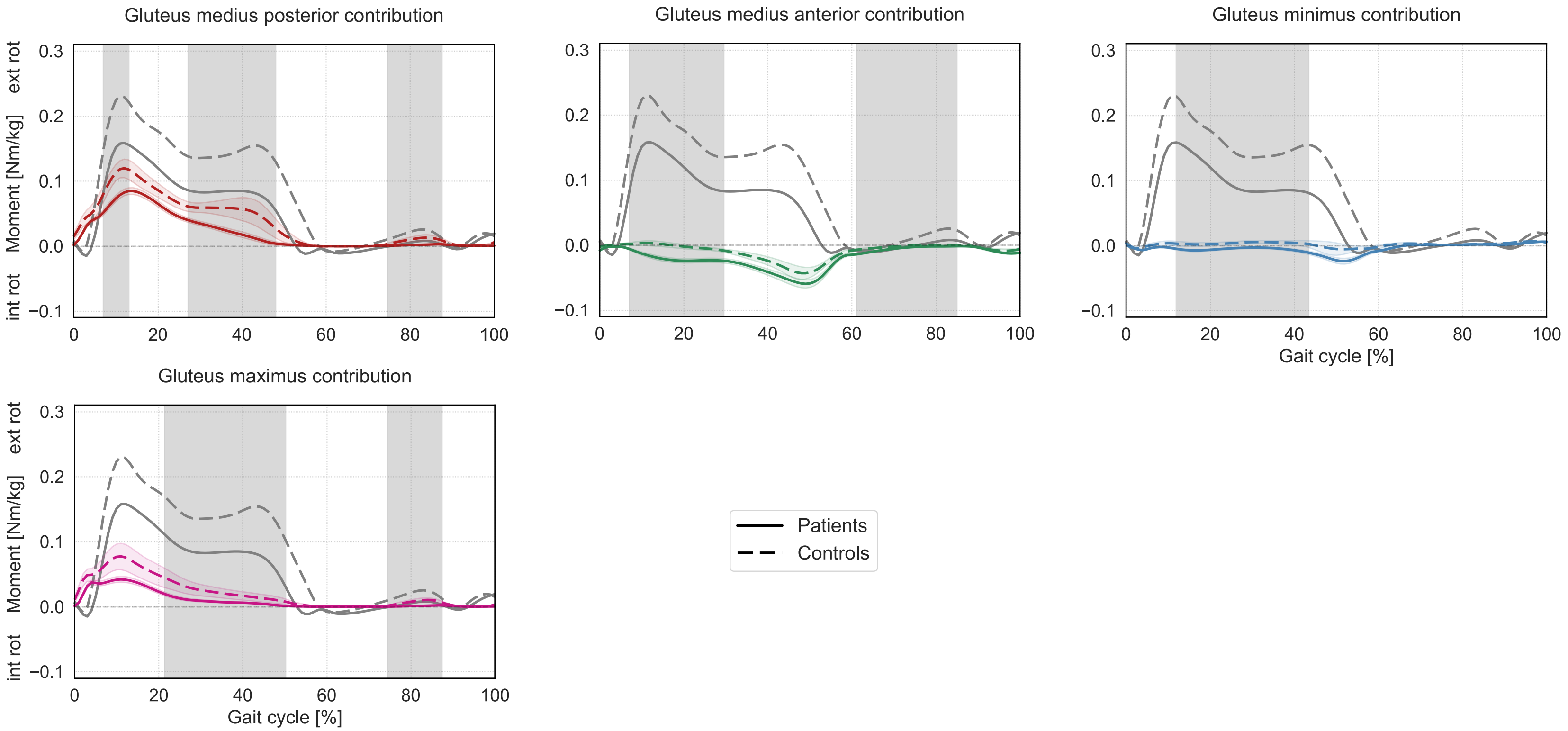
muscle contributions to hip net frontal moment



Results I

Patients vs controls

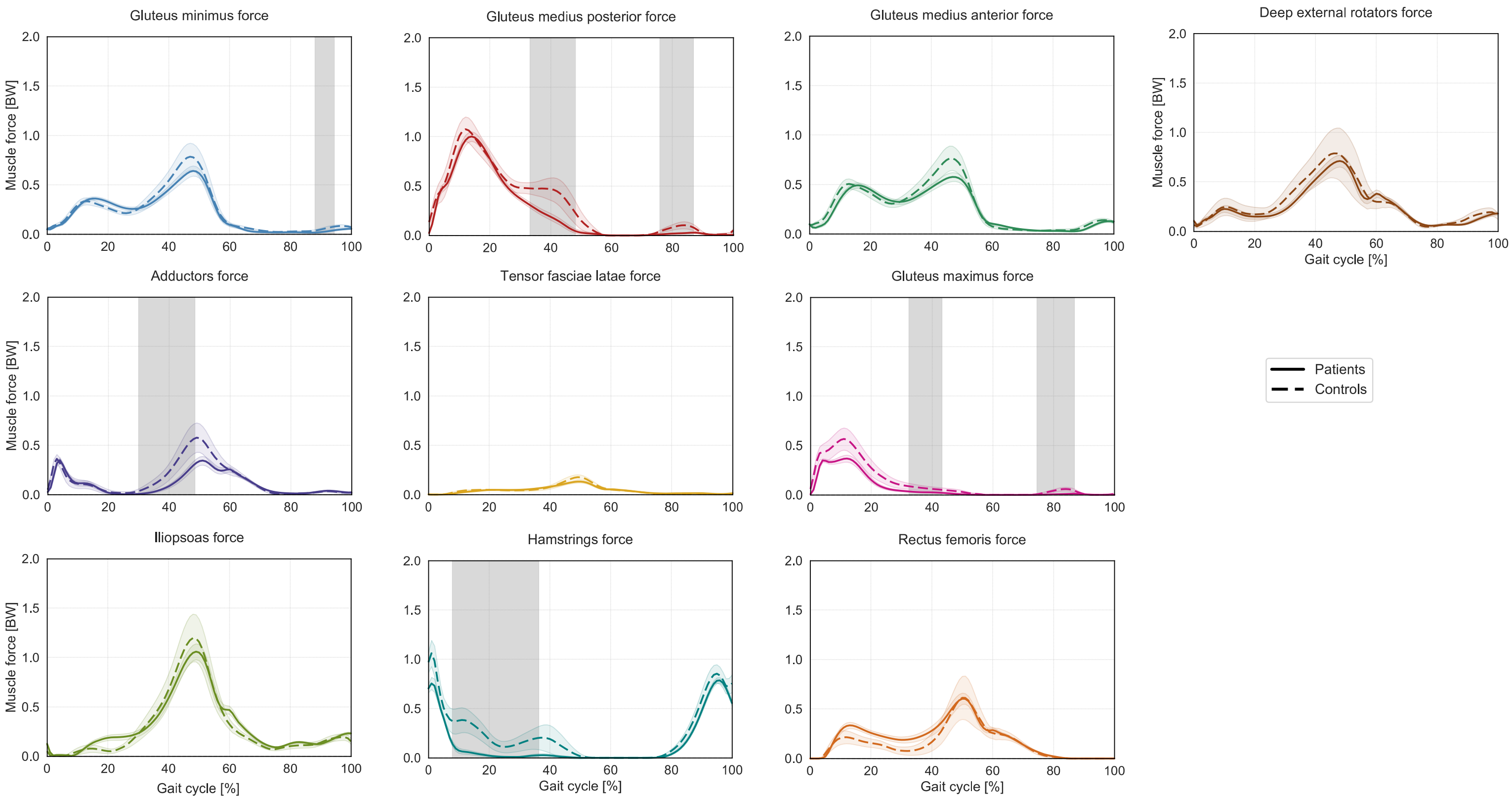
muscle contributions to hip net transversal moment



Results I

Patients vs controls

muscle forces



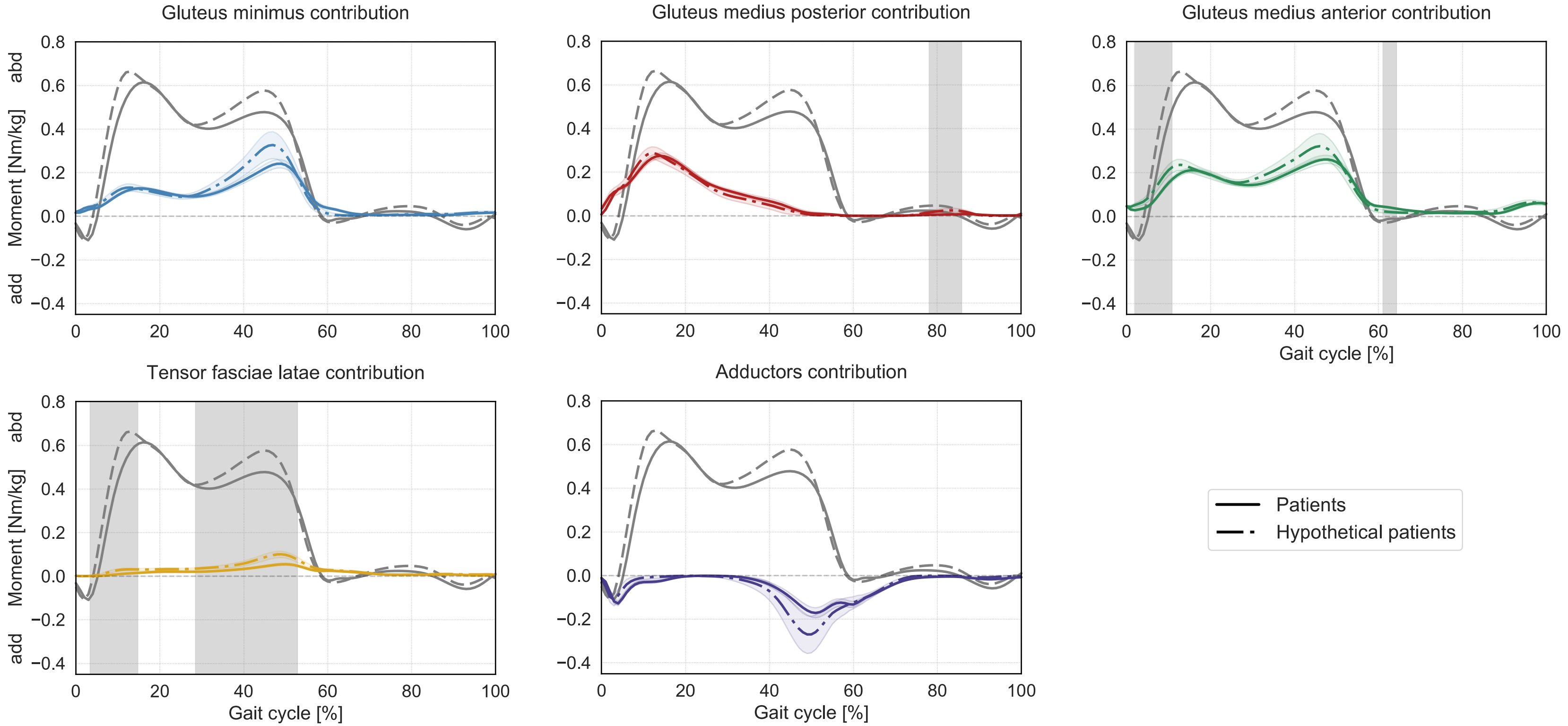
Discussion – patients vs controls

- Altered muscles' contributions, but net abduction moment comparable (no net functional deficit)
- Altered transversal plane net moment and muscle contributions
- Patients required lower muscle forces
  - Comparable fatigue onset time with healthy peers (Leblebici et al., 2021)
  - Reduced joint loads

Results II

Patients vs hypothetical patients

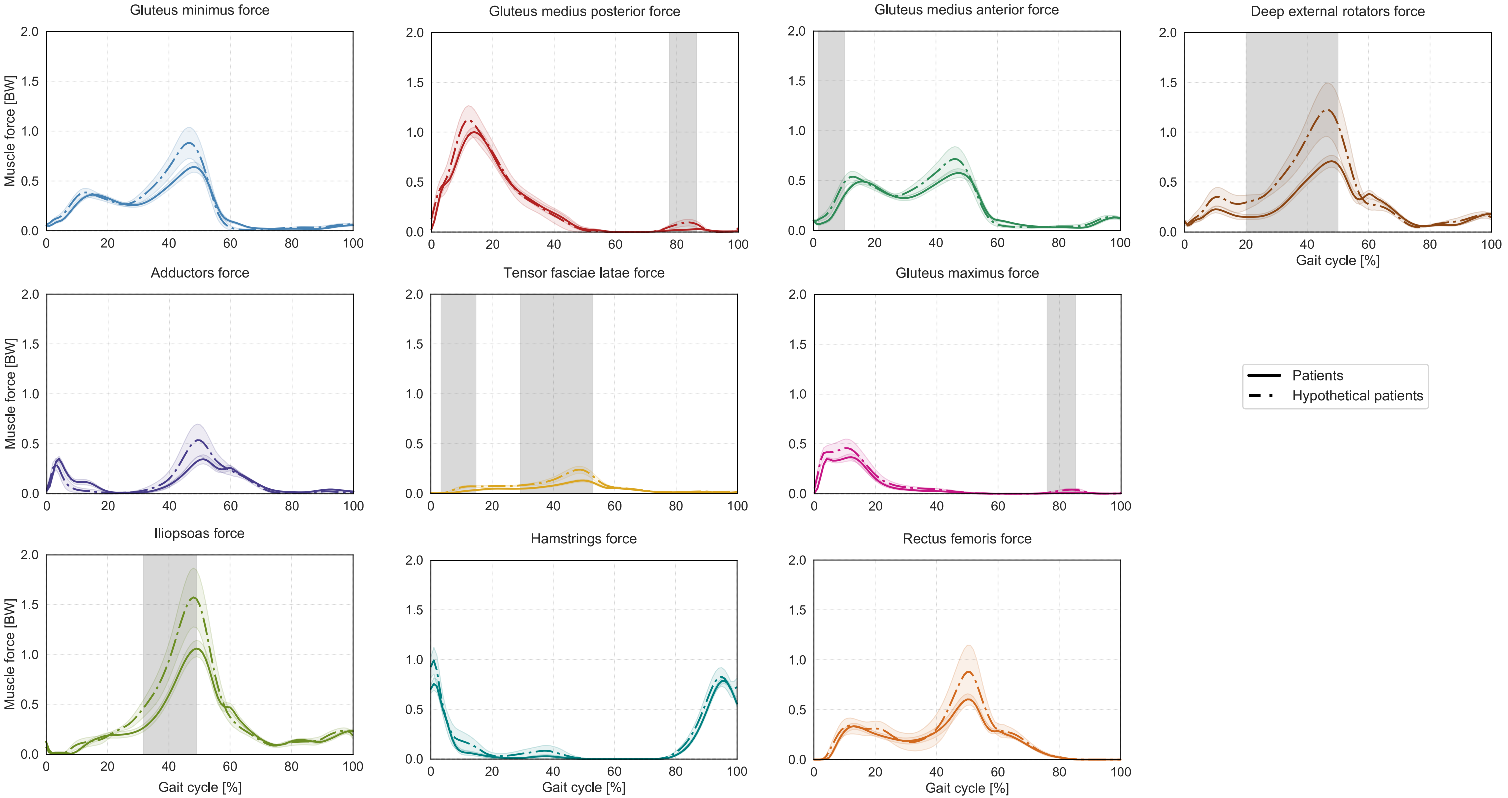
muscle contributions to hip net frontal moment



Results II

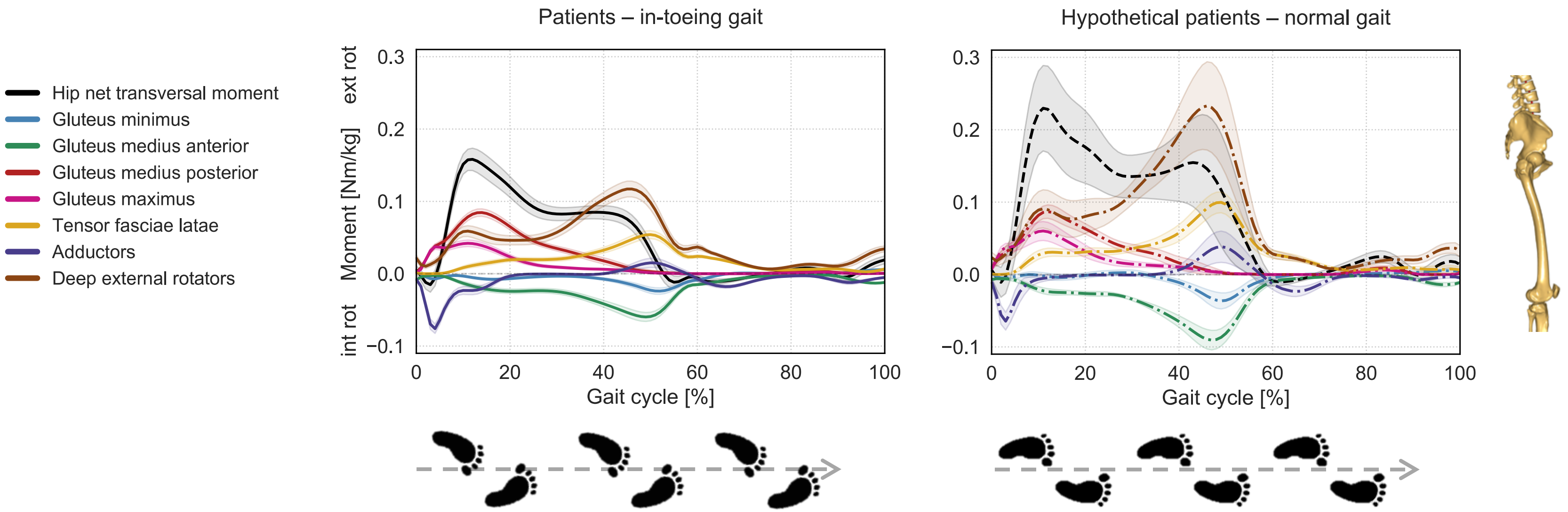
Patients vs hypothetical patients

muscle forces



Results II

Muscle contributions to hip net transversal moment

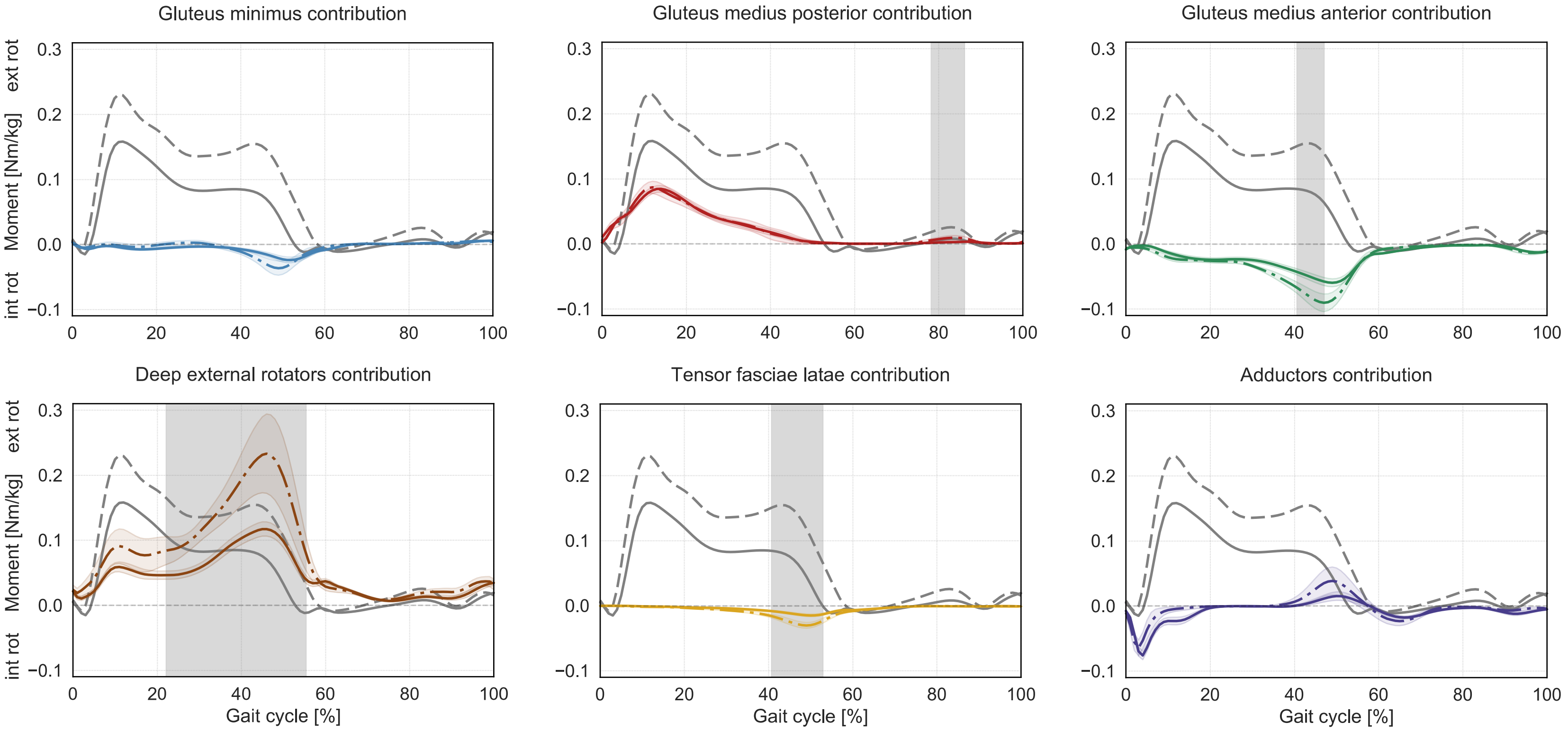


Results II

Patients vs hypothetical patients

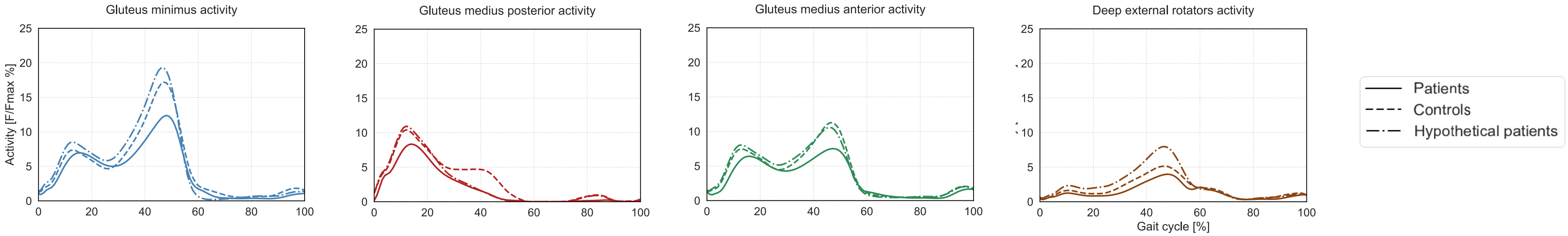
muscle contributions to hip net tranversal moment

Patients
Hypothetical patients



Discussion – straight vs in-toeing

- Comparable hip abductors’ moment contributions
- Muscle activation < 30% of the maximum strength



- Capable of walking straight?
- Targeted muscle strengthening beneficial?
- Functional deficits more visible in other activities
  - e.g. running (Byrnes et al., 2021)

Discussion – straight vs in-toeing

- Higher required muscle forces
  - Confirm abductive lever arm dysfunction
  - Higher joint loads (Kainz et al. 2020, Modenese et al., 2021)
- Simultaneous co-contraction of hip internal and external rotators in transversal plane
  - Pathomechanism not described in literature so far
  - Potential joint stiffness → discomfort
  - Higher metabolic cost of walking

Take Home

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Increased anteversion with in-toeing:

- ~ net abduction moment
- ↓ net external rotation moment
- ↓ muscle forces

Gait & Posture 100 (2023) 179–187

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The functional role of hip muscles during gait in patients with increased femoral anteversion

Enrico De Pieri[a,b], Johannes Cip[c], Reinald Brunner[a,b,d], Claudia Weidensteiner[b,e], Nathalie Alexander[f,g,*]

[a] Laboratory for Movement Analysis, University of Basel Children's Hospital, Basel, Switzerland
[b] Department of Biomedical Engineering, University of Basel, Basel, Switzerland
[c] Department of Paediatric Orthopaedics, Children's Hospital of Eastern Switzerland, St. Gallen, Switzerland
[d] Department of Paediatric Orthopaedics, University of Basel Children's Hospital, Basel, Switzerland
[e] Division of Radiological Physics, Department of Radiology, University Hospital Basel, Basel, Switzerland
[f] Laboratory for Motion Analysis, Department of Paediatric Orthopaedics, Children's Hospital of Eastern Switzerland, St. Gallen, Switzerland
[g] Department of Orthopaedics and Traumatology, Cantonal Hospital St. Gallen, Switzerland

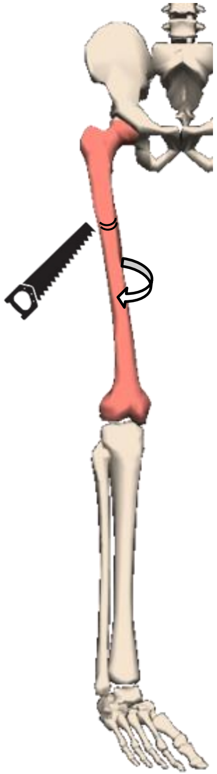
Increased anteversion without in-toeing:

- ~ muscle contributions to abduction moment
- ↑ muscle forces → lever-arm dysfunction
- transversal plane co-contraction

Study #3

Effect of **femoral derotational osteotomy**
in patients with idiopathic increased femoral anteversion
on joint loading and muscular demands

Femoral derotional osteotomy



- Increased femoral anteversion can be correct by a femoral derotional osteotomy (FDRO)
- FDRO is suggested as the only possible treatment
- depends on the severity of the patient's symptoms

Hefti, 2000, Orthopade 29(9): 814-20.
Fabry, 2010, Eur J Pediatr 169(5): 529-34.
Sass & Hassan, 2003, Am Fam Physician 68(3): 461-8.

Introduction

Effect of femoral derotional osteotomy (FDRO):

- Improvements in pain and activity scales[1,2]
- Improvements in gait patterns[2,3]
  - E.g. hip rotation and foot progression angle

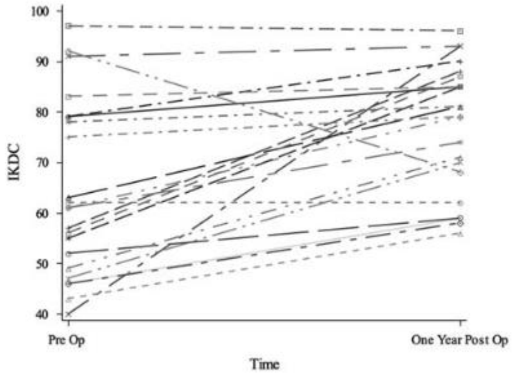


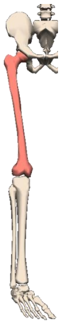
FIGURE 4. Ladder graph depicting the association between individual preoperative and 1-year postoperative International Knee Documentation Committee (IKDC)-9 scores. All but 2 subjects demonstrated improved function and pain at 1-year, while 1 patient had no change in his IKDC.

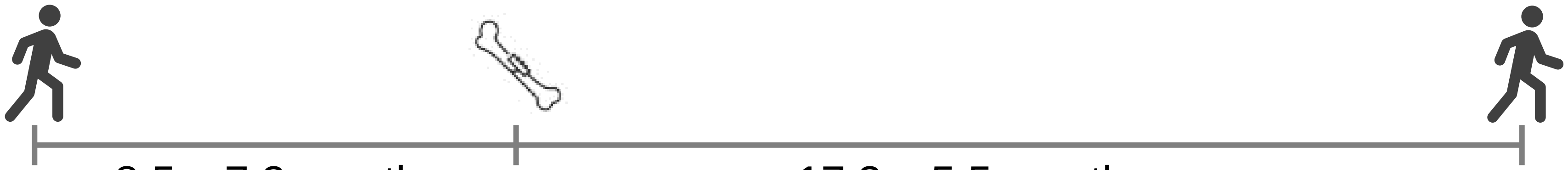
Effect on joint and muscle forces ?

[1] Stambough et al., 2018, J Pediatr Orthop, 38:503-509
[2] Hamid et al., 2022, J Pediatr Orthop,
[3] MacWilliams et al., 2016, Gait Posture, 49: 202-206

Methods

	Patients (n = 17, 25 limbs)	**Controls (TDC)** (n = 9, 9 limbs)
Femoral anteversion	49.0° (7.1°)	18.7° (4.1°)
Age	13.2 (2.2) yrs	12.0 (3.0) yrs





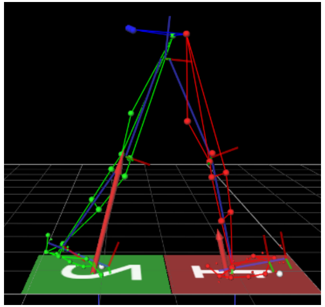
8.5 ± 7.2 months

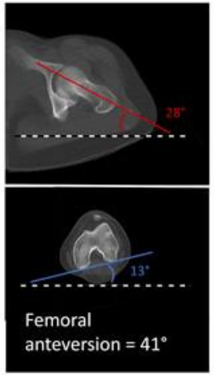
17.3 ± 5.5 months

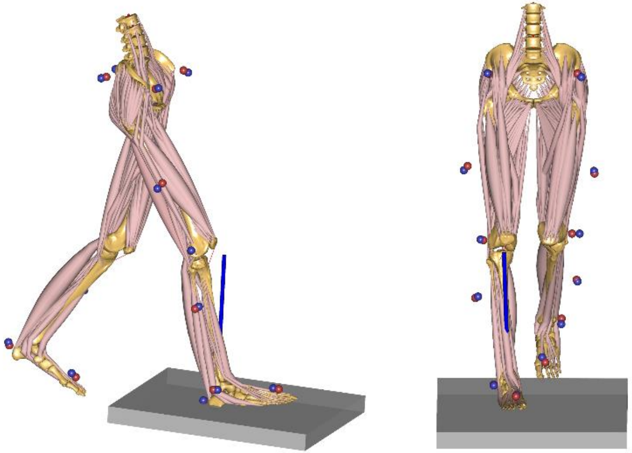
<u>FDRO</u>:

distal, external fixator:	20
proximal, locking plate:	5
surgical correction:	28.1°± 5.3°

Methods







De Pieri et al., 2021, Front. Bioeng. Biotechnol 9:551

Methods

Statistics

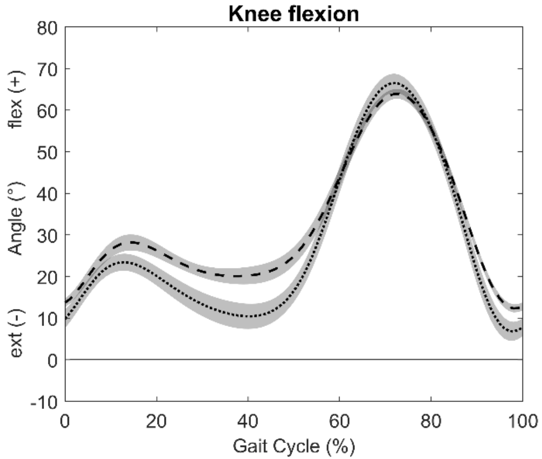
- Kinematics
- Joint moments
- Joint forces
- Muscle forces

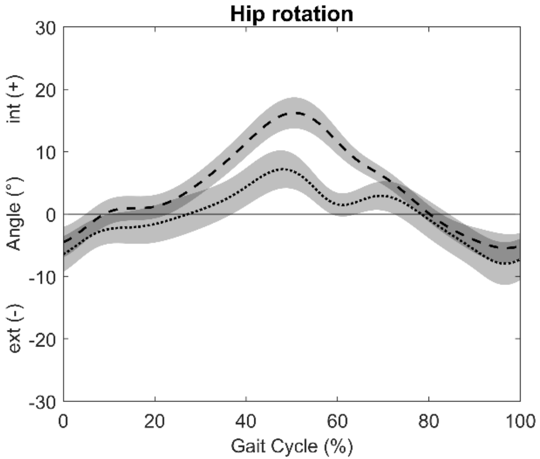
$\alpha = 0.05$

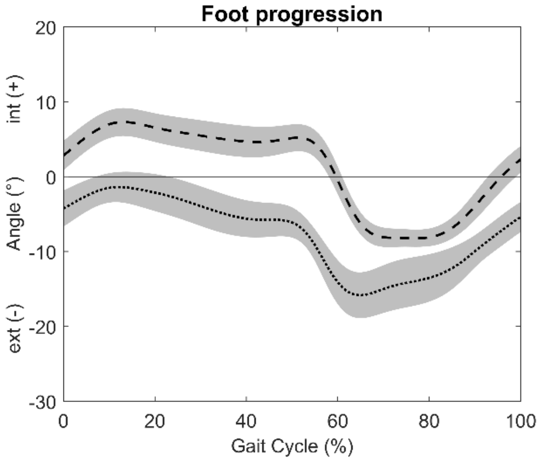
Pataky, 2012, Comput Methods Biomech Biomed Engin, 15(3):295-301.

Results & Discussion

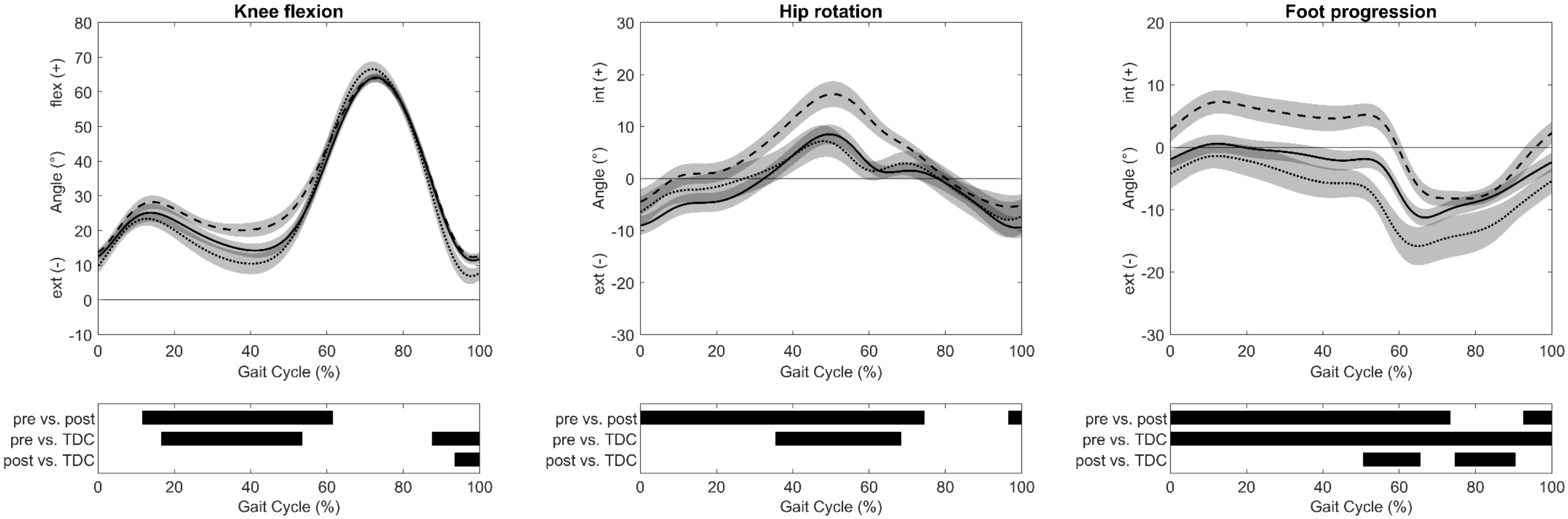
- - - - pre .... TDC





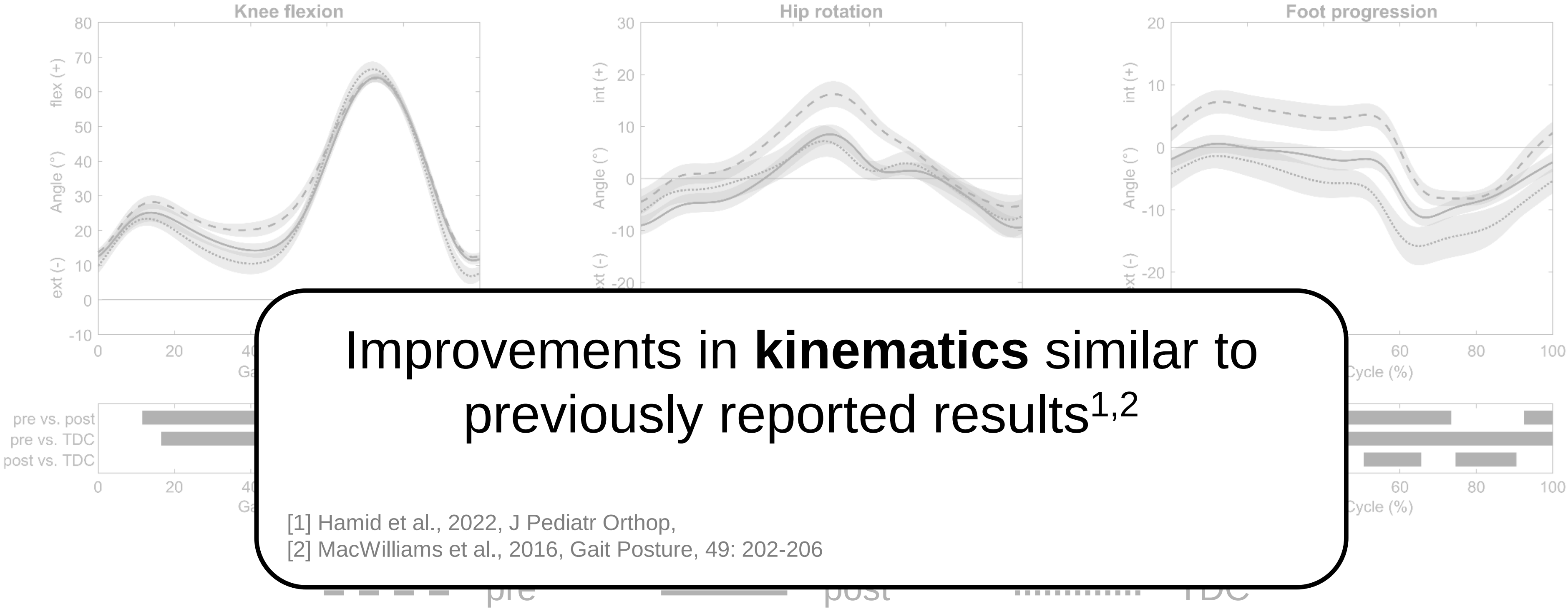


Results & Discussion



pre — post — TDC

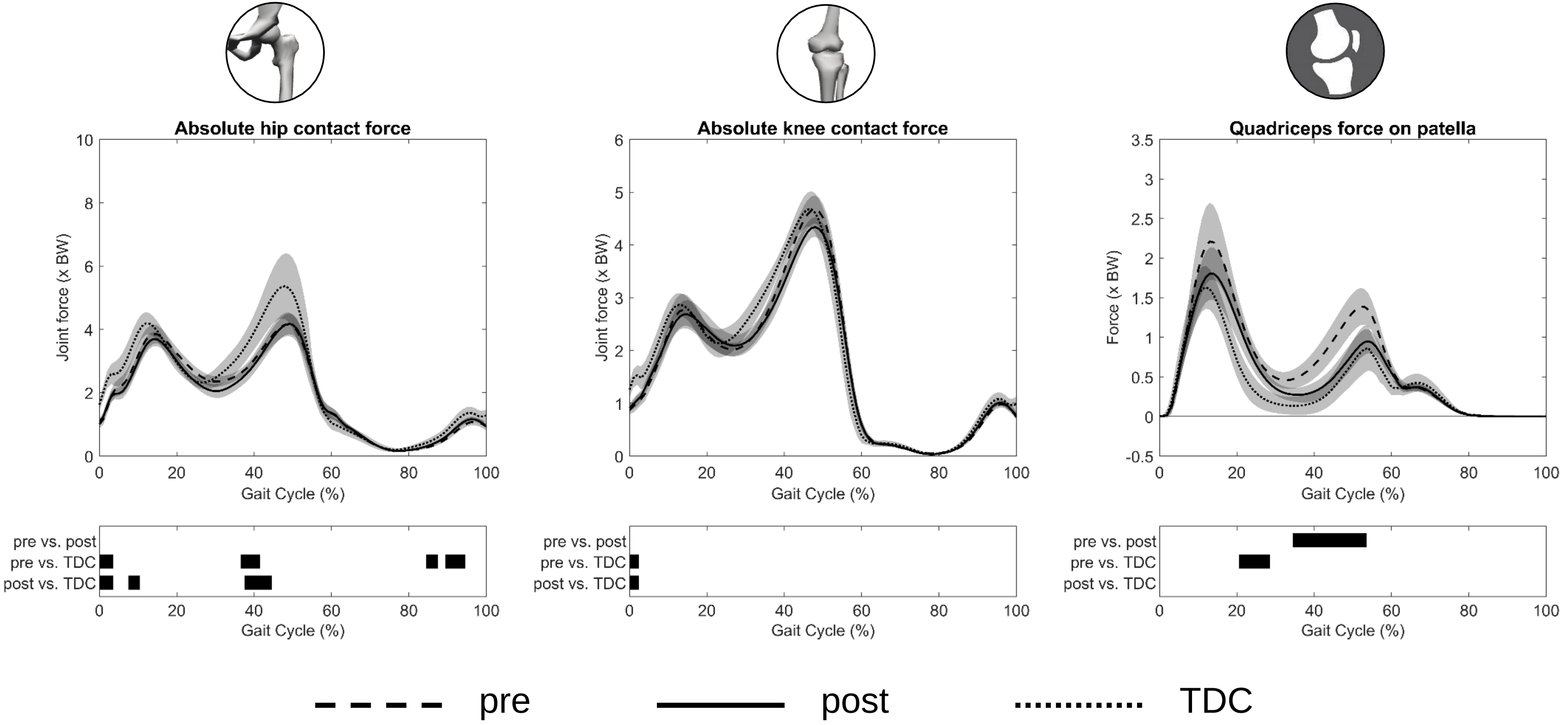
Results & Discussion



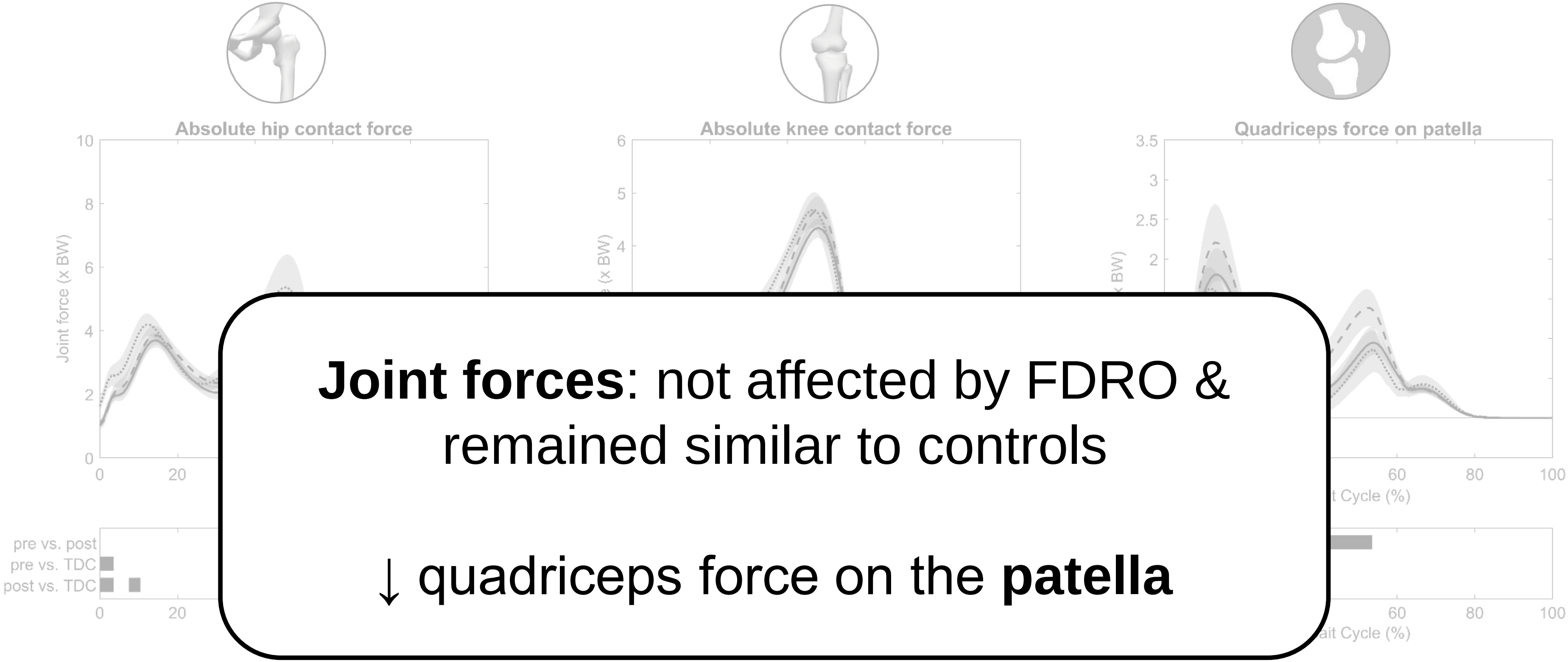
Improvements in **kinematics** similar to previously reported results[1,2]

[1] Hamid et al., 2022, J Pediatr Orthop,
[2] MacWilliams et al., 2016, Gait Posture, 49: 202-206

Results & Discussion



Results & Discussion

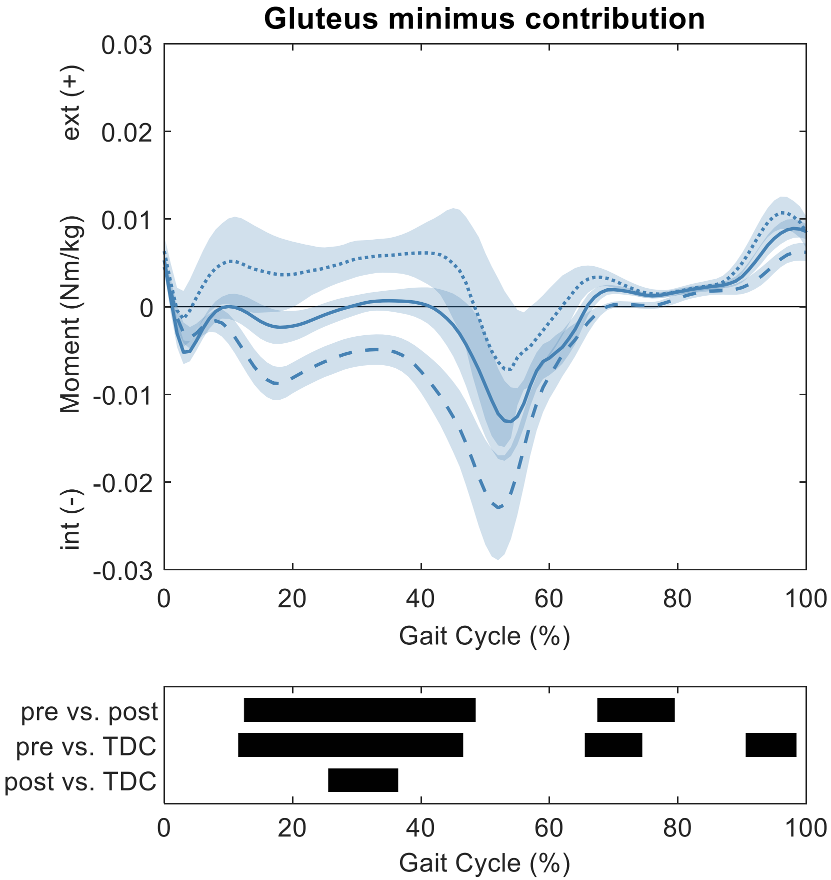


Joint forces: not affected by FDRO & remained similar to controls

↓ quadriceps force on the **patella**

pre post TDC

Results & Discussion

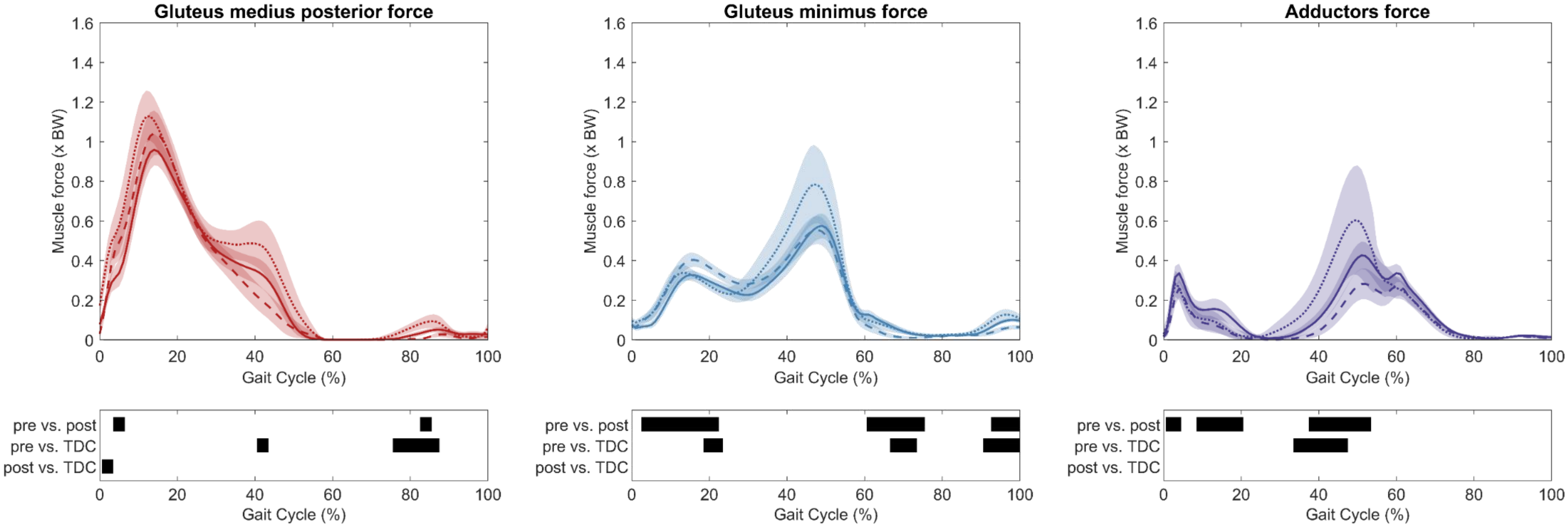


Gluteus minimus contribution to transversal hip moment

- Different directionality between patients and controls
- Improved after FDRO

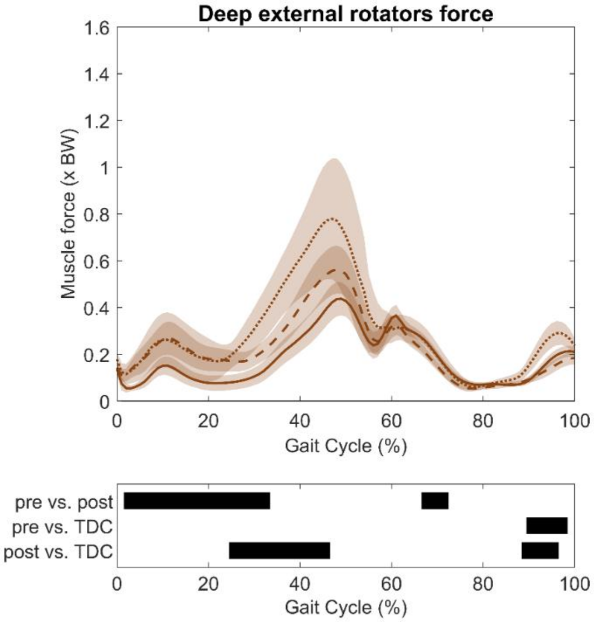
- - - - pre
—— post
.... TDC

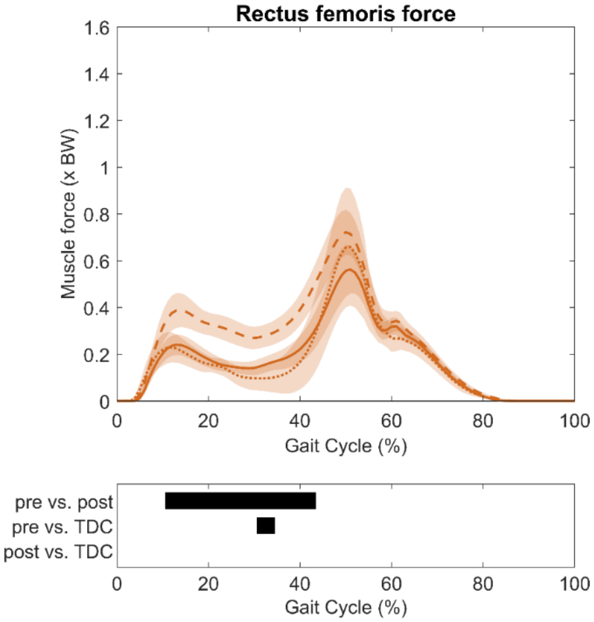
Results & Discussion



pre post TDC

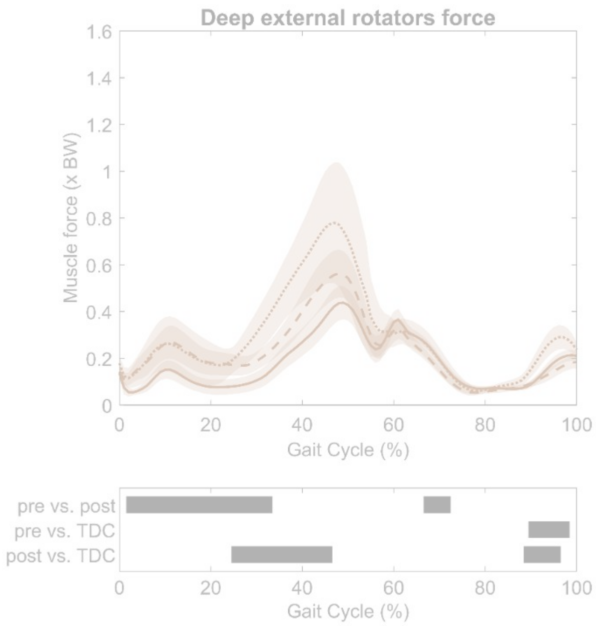
Results & Discussion





pre post TDC

Results & Discussion



Muscle function:

- improved after FDRO
- except deep external rotators → lingering compensation mechanism?

pre post TDC

Discussion

improved knee extension → ↓ quadriceps force on patella
↓ rectus femoris muscle force

- ↑ knee flexion is associated with ↑ tibio- and patellofemoral joint forces[1,2]
- reason for the reported improvements in knee pain[3] after FDRO?

[1] Alexander & Schwameder, 2016, Gait Posture, 45: 137-142.
[2] Steele et al., 2021, Gait Posture, 35(4): 556-60.
[3] Stambough et al., 2018, J Pediatr Orthop, 38:503-9.

Take Home

Improved **kinematics**

Joint forces unaltered and still comparable to controls

Improved **muscle forces**
(except deep external rotators)

If indicated, **FDRO seems like a good option for reducing gait pathologies**

Conclusion

- Increased femoral anteversion associated with:
  - Pain
  - Risk of joint overloading and secondary orthopaedic complications
  - Altered kinematics
  - Functional issues

Conclusion

- Patients present generally lower joint loads during gait
  - Long-term risk of joint overloading?
  - But higher loads for KneeFlex$_{tSt}$ gait pattern

- Interplay between morphology and kinematics
  - Patient-specific assessment required

Conclusion

- Confimed abductors' lever-arm dysfunction
  - «straight» walking less efficient, not impossible
- Muscles are 3-dimensional actuators
  - Transversal plane kinetics should be considered
- Interplay between morphology and kinematics

Conclusion

- Analysis of muscle function during motion(s) might lead to better conservative treatments
  - Targeted muscle strengthening / gait retraining might be effective in patients with mild symptoms

Conclusion

- For severe symptoms, surgical intervention (FDRO) is an effective option for restoring normal gait kinematics and muscle functionality

Outlook

- MSK modelling not yet a diagnostic tool for individual cases
- Final decision depends on overall clinical picture

- Retrospective MSK modelling studies provide a more comprehensive understanding of the pathology
- More evidence is needed for clinical translation

Thank you!

If you have questions, please do not hesitate to contact us!

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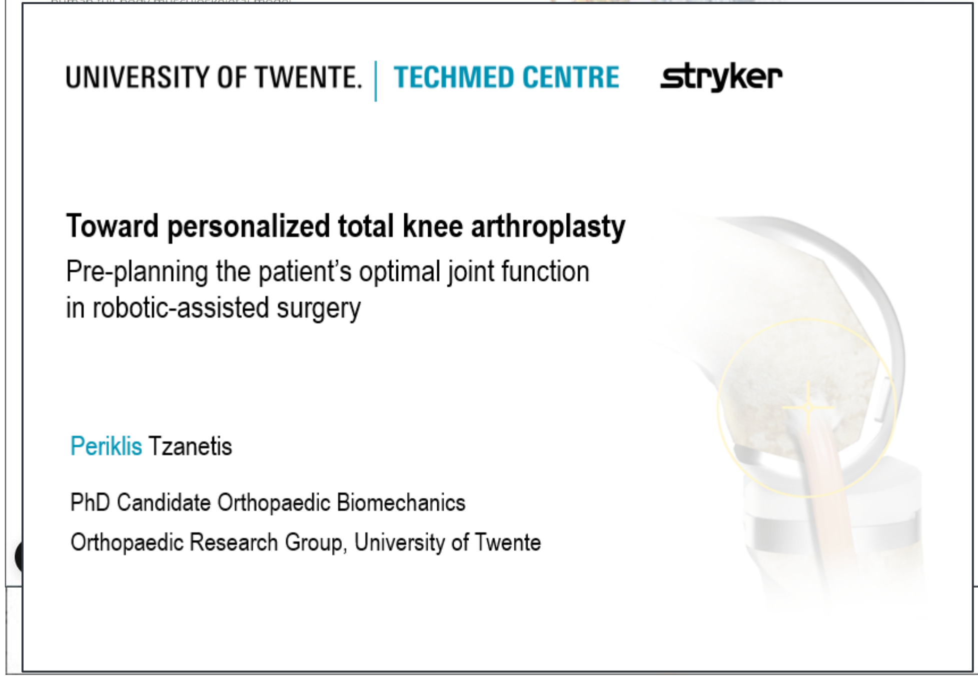
Events

- **ISTA - September 27th – 30th, 2023**
- **Webcast - 12 October 2023**
  - Toward personalized total knee arthroplasty: Pre-planning the patient’s optimal joint function in robotic-assisted surgery
    - Periklis Tzanetis, PhD candidate, University of Twente

Meet us? Send email to sales@anybodytech.com

Want to present? Send email to ki@anybodytech.com

Find us:



Thank you for your attention
- Time for questions